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FOREWORD

Presented number of Silesian University of Technology. Scientific Papers. Organization and Management Series. Presented papers contain result of researches conducted by various universities. The number consists of 37 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: economics business resilience; public management; logistics; sustainability; leadership; production management; technology management; design thinking; artificial intelligence in management; human resource management; supply chain management; project management; business models; knowledge management; Corporate Social Responsibility; lean gamification; creativity; human resource management; green transformation; circular economy and innovation management.

Bożena Skotnicka-Zasadzień

Radosław Wolniak

COMPARISON OF THE RESULTS OF THE ASSESSMENT OF THE ECONOMIC EFFECTIVENESS OF BANK BRANCHES USING STOCHASTIC FRONTIER FUNCTIONS

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Purpose: The main aim of the research was to assess the level of economic effectiveness of bank branches and then compare these results.

Design/methodology/approach: The research used stochastic frontier functions of costs, revenues and profits (both their standard and alternative formulas), assuming two market structures, conditions of perfect and imperfect competition.

Findings: The research confirmed the hypothesis that the results of the economic efficiency assessment of the studied branches differ significantly depending on the frontier function formula used (costs, revenues, and profits) and the assumptions made about the market structure.

Research limitations/implications: Difficult access to relevant data.

Practical implications: When assessing effectiveness, particular attention should be paid to selecting the appropriate evaluation method. Analysis using the appropriate method should contribute to improved effectiveness.

Originality/value: The obtained results constitute a significant contribution to the approach to assessing the economic efficiency of financial institutions, especially banks, from the point of view of selecting appropriate research methods.

Keywords: economic efficiency of banks, stochastic cost frontier function, stochastic revenue frontier function, stochastic profit frontier function.

Category of the paper: research paper.

1. Introduction

The issue of measuring management efficiency of financial institutions, especially banks, continues to be valid. This is due not only to the highly significant macroeconomic functions that financial institutions play in a country's economy, the dynamic changes in the financial markets and growing competition, but also to the fact that the numerous efficiency measuring methods developed continue to this day to produce differing results.

In accordance with the principle of rational management, broadly understood economic efficiency should constitute the basic assessment criterion of business activity. This rule requires that the best results i.e. the highest economic efficiency be achieved with the relatively smallest input. The higher this efficiency is, the fewer production factors must be used to generate a given production volume, or the higher output can be derived from the same quantity of production factors. Thus, improvement of management efficiency can be both a source of growth in production and a means of economising on production inputs.

Pertinent literature recognises different approaches to determining economic efficiency and various methods of its measurement. Most often economic efficiency means the relationship of a certain effect to an underlying production factor or a set of such factors. It is stressed that both economic theory and economic practice may use various measures of economic efficiency and that these depend on what is taken as an effect (output) and what as input, which in turn yields different efficiency relationships.

The concept based on the microeconomic theory of economics came into use thanks to Sealey and Lindley's (1977) development of a model approach to the financial institution and parametric methods have become one of the methodological tools used to assess the efficiency of banking institutions. Derived by Sealey and Lindley, the model of a financial institution, in contrast to other proposed models, is based on the assumption that a financial institution acting within certain bounds imposed by the environment (competitors, customers, legal – organizational regulations etc.) and technology pursues one major goal – maximisation of profit.

Studies of financial institutions' economic efficiency initially relied on deterministic models, which due to their assumptions ignoring random factors (lack of a purely random factor in the specification of a frontier model) proved to be of little use. More convincing results were produced by stochastic frontier models whose basis in the currently widely used methodology (and not just in banking) for efficiency testing was created in 1977 by two independent research teams: Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). According to this methodology, the issue of efficiency is captured by a single equation model consisting of a suitably specified microeconomic production or cost function (for logarithms of economic variables) and two random elements, one of which (symmetrical relative to zero) reflects the effects of the random factors and measurement errors, and the other (asymmetric and consistently negative or positive) models the potential inefficiency (Osiewalski, Marzec, 1996-1997). This methodology, propounded mostly by the "Journal of Econometrics" was further developed by e.g. Stevenson (1980), Pitt and Lee (1981), Jondrow, Lovell, Materov and Schmidt (1982), Schmidt and Sickles (1984), Beckers and Hammond (1987), Greene (1990), van den Broeck, Koop, Osiewalski and Steel (1994) and Koop, Osiewalski and Steel (1994, 1997).

Polish research into banks' cost efficiency and other economic entities was initiated by Osiewalski and Marzec as early as in 1996 and continued in next years (Fernandez, Osiewalski, 1997; Marzec, Osiewalski, 1996-1997, 2001, 2003, 2008; Osiewalski, 2001; Osiewalski, Marzec, 1998a, 1998b, 1998c; Marzec, 1998, 1999).

In studies on effectiveness of banks, the following standard (costs, revenues and profits) and alternate (revenues and profits) stochastic frontier functions are used. Furthermore, these models assume specific conditions in which a given enterprise operates, such as conditions of perfect competition or conditions of imperfect competition. The paper presents a concept for economic effectiveness measurements using the above-mentioned stochastic frontier functions (models).

The article also presents the results of economic effectiveness measurements of branches of a selected commercial bank in Poland, based on standard and alternative stochastic frontier functions of costs, revenues and profits. An important element of research is also the comparison of the obtained results. The Pearson and the Spearman correlation coefficients were used in comparisons.

The research hypothesis is as follows: the economic efficiency of the studied branches may differ significantly depending on the applied stochastic frontier function (costs, revenues and profits) and the adopted assumptions for the market structure (conditions of perfect and imperfect competition).

2. The Frontier Cost Function

The theory of economics distinguishes several types of market structures, starting with monopoly, and ending with ideal competition. However, in real life, a clear classification is difficult, due to their complexity and dynamics. Also each classification will always be relative (arbitrary), requiring some simplifications. Using such simplification, and assuming the enterprise influence on input (factors of production), products or services as a classification criterion, the market can be divided into two basic structures: an ideal competition and an imperfect competition markets. The first structure is often simply called competitive conditions, while the other is called non-competitive conditions. The market in which producers accept prices as independent (beyond their control) values is called a competitive market, with its special variant being the ideal competition. On the other hand, in a situation where producers influence price levels, we talk about conditions of imperfect competition, with its special variant of monopoly.

The above simplification and division is often very useful, convenient, and even necessary for various analyses and studies, including an analysis and measurements of economic effectiveness using stochastic frontier functions.

When a microeconomic model describing operations of a given company is constructed, determining objectives of its operations and conditions limiting those operations is of fundamental significance. Amongst usually many objectives pursued by every company, the fundamental one is to maximise its profit. To achieve that objective, an enterprise determines parameters such as an output size and its structure, and selects factors of production, while it has to face numerous limitations to its operations related to its environment (including the nature, available production technologies, etc.). The enterprises also operate in various market environments. Therefore, the company's microeconomic model is based on specific assumptions with which the company pursues its objective, being usually the profit maximisation.

The company solves a problem of selecting a number of factors technically indispensable for producing an output, Q , of a given quantity and yet guaranteeing costs are kept to minimum, by using a formula for costs minimising, which for a general case can be specified as:

$$\min_{x_1, \dots, x_n} (w_1 \cdot x_1 + w_2 \cdot x_2 + \dots + w_n \cdot x_n) \quad \text{with a condition: } f(x_1, \dots, x_n) = Q \quad (1)$$

where:

- $x_1, \dots, x_n$ – factors of production,
- $w_1, \dots, w_n$ – factors of production prices,
- Q – relevant (given) output level.

Finding a solution to the cost minimising issue, i.e., finding minimum costs necessary to produce the specified output level, will depend on prices $w_1, \dots, w_n$ and Q ; therefore, it can be expressed as $c(w_1, \dots, w_n, Q)$. In microeconomics, the $c(w_1, \dots, w_n, Q)$ function is described as the costs function, and it describes a minimum production cost for a given output level (quantity), Q , when factors of production prices are specified and equal to $(w_1, \dots, w_n)$. When interpreted geometrically, the issue of costs minimisation is solved by determining the point on an isoquant (an area of a homogenous output) to which the lowest possible isocost (a hyperplane of the same cost) corresponds (Varian, 1999).

For a general function, a solution for an optimal amount of inputs (factors of production) is obtained as a function of input prices, w , and an output quantity, y , using the method of Lagrange multipliers. A cost frontier is determined by estimation of the cost function, reflecting an observed cost in relation to an output quantity and prices of input, and including a random error and a variable representing ineffectiveness. This frontier can be expressed in the following way (see: Rogers, 1998):

$$C = C(y, w, u_c, v_c), \quad (2)$$

where:

- C is an actual incurred cost,
- y is a vector of the output quantity,

- w is a vector of input (factors of production) prices,
- u_c is a variable representing cost ineffectiveness,
- v_c is a random factor.

For cross-sectional data, the simplest one-equation model of a stochastic frontier cost function (long-term) can be expressed as (Marzec, Osiewalski, 1996-1997):

$$C = C(y, w, u_c, v_c), \quad (3)$$

where:

- $i = 1, \dots, N$ – number of companies,
- TC_i (Total Cost) – observed total cost for a company i ,
- Q_i - $G \times 1$ output vector for a company i ,
- W_i - $H \times 1$ factors of production prices vector for a company i ,
- $f(Q_i, W_i)$ – frontier cost function.

It is assumed that $\varepsilon_i = u_i + v_i$, and that u_i and v_i are independent random variables, where:

- u_i - represents components expressing ineffectiveness of analysed companies, characterized by independent distributions and assuming only nonnegative values ($u_i \geq 0$, thus $E(u_i) > 0$);
- v_i - are symmetrical random components reflecting the influence of random factors or errors in cost measurements; it is assumed they have independent identical distributions with an expected value equal to zero, e.g., $v_i \sim N(0, \sigma^2)$.

Both a short-term and a long-term cost function can be used in the analyses. The microeconomic short-term cost function¹ represents a minimum cost necessary to achieve a specified output quantity, with specified prices of variable factors of production and an input of a fixed factor (usually, a real capital). For the long-term cost function it is assumed that all factors of production are variable. The cost function expresses a deterministic relationship, which in fact is subject to various disturbances. Usually, for a relevant output quantity the production cost incurred by a company is higher than the microeconomic cost function indicates. The reasons of higher costs include: purely random disturbances (including errors in cost measurements) and solely positive deviations, originating within a company and caused, generally speaking, by suboptimal engagement and use of the factors of production. These deviations were adapted as a measure of cost inefficiency of a given entity (Farrell, 1957), and indicate a degree to which a company incurs production cost for a given output, Q , that is higher than implied by the available technology and rates of factors prices.

Applying the intermediation approach to the specification of a bank's products and factors as proposed by Sealey and Lindley (1977), the author resolved to build a model by deploying two variable production factors – the total value of acquired deposits and other financial resources expressed in the form of cash (financial capital) and the value of gross wages (human

¹ For a long-term function, principles for measuring the costs effectiveness are the same.

capital), as well as one constant factor constituted of office space (physical capital) and one product expressed by means of the value of loans granted. In the case of cross-sectional data, the short-term frontier model of a variable cost function takes the following form:

$$\begin{aligned} \ln VC_i = & \beta_0 + \beta_1 \ln w_{i,D} + \beta_2 \ln w_{i,L} + \beta_3 \ln Q_i + \beta_4 \ln K_i + \beta_5 \ln w_{i,D} \ln w_{i,L} + \\ & \beta_6 \ln w_{i,D} \ln Q_i + \beta_7 \ln w_{i,D} \ln K_i + \beta_8 \ln w_{i,L} \ln Q_i + \beta_9 \ln w_{i,L} \ln K_i + \\ & \beta_{10} \ln Q_i \ln K_i + \beta_{11} (\ln w_{i,D})^2 + \beta_{12} (\ln w_{i,L})^2 + \beta_{13} (\ln Q_i)^2 + \beta_{14} (\ln K_i)^2 + v_i + z_i \end{aligned} \quad (4)$$

where:

- $\ln VC_i$ – observable level of variable cost (human capital costs in the form of gross wages including other charges (social security and related charges), cost of financial capital such as interest on deposits and other obtained resources and cost of physical (tangible) capital excluding property of i branch,
- $w_{i,D}$ – financial factor price (deposits and other funding),
- $w_{i,L}$ – labour price (average gross wage per employee),
- Q_i – observable output expressed by means of the volume of loans granted,
- K_i – use of constant factor (physical capital) measured in terms of surface in square metres of proprietary and rented office space,
- v_i – symmetrically distributed random element,
- z_i – variable representing cost inefficiency.

Having calculated the frontier cost function, a given object's - CE_i – cost efficiency can be calculated as a quotient.

Having estimated the frontier cost function, the cost efficiency indicator (RE_i) for object i is calculated based on the formula:

$$CE_i = \frac{\hat{C}^{\min}}{\hat{C}^i}, \quad (5)$$

where:

- $\hat{C}^{\min}$ - minimum cost necessary to generate a given output,
- $\hat{C}^i$ - actually incurred cost.

In the above relationship the actual cost incurred to produce a specific bundle of products is compared with the minimum cost necessary to produce the same range of services (products). Cost efficiency is measured as the ratio of the minimum cost necessary to produce a given production volume (with given factor cost) and the cost actually incurred by the bank (branch). Thus, cost efficiency analysis can examine whether the company incurs a minimum total cost of producing a certain output level at certain prices (Osiewalski, Marzec, 1996-97). The level of inefficiency for a given object is calculated (ignoring the random element) as the difference: $1 - CE_i$.

The estimate of economic efficiency calculated on the basis of so-defined a cost function takes into account both the technical inefficiency (excessive consumption of inputs to produce a given volume of production) and allocative inefficiency (using inadequate proportions of each type of inputs and products at current market prices).

3. The Standard Frontier Revenue Function

In theory and practice, there are two different revenue frontier functions: standard and alternative. The standard revenue function assumes that a company operates in a perfectly competitive market. Prices are therefore taken to be exogenous data whose shape is beyond the bank's power. With this assumption, banks maximise their revenue for given input prices and product prices (Rogers, 1998) by optimising product quantity. In this case, the actual revenue from the sale of a specific quantity of products is compared to the maximum revenue realisable from the same quantity of products. A given bank's inefficiency is then the result of a wrong choice (determination) of the quantity of inputs or products.

Assuming that the presented model will be an equilibrium model (demand volume (d) is then equal to supply volume (s)), the following general functional dependencies are assumed:

- $d = d(p)$ - products demand function,
- $x = x(w)$ - production factors demand function,
- $y = y(x)$ - transformation of an x quantity of inputs into an y quantity of products,

where:

- p - vector of product prices,
- w - vector of production factors prices,
- x - vector of inputs quantities,

In that case the issue the company has to solve (maximising revenues) is modelled as:

$$\max_y R = p'y ; \text{ on condition that } g(y, p, w) = 0, \quad (6)$$

where:

- g is a function of three variables: s, p, w taking into account the external environment and technology.

The Lagrange multipliers method permits deriving the optimum quantity of products that maximises revenue as a function of $y(p, w)$. By definition, the revenue is $R = p'y$. Thus given the above condition the revenue function will be expressed by the following formula:

$$R = p'y = p'y(p, w) = R(p, w). \quad (7)$$

As in the case of the cost function, to approximate an unknown revenue function one can apply a translog function utilising the possibility of its approximation by expanding it into a Taylor series adjacent to any point. Assuming two production factors (the financial factor and work) and one product (number of loans granted) and making the appropriate transformations one obtains a stochastic frontier model of a standard translog function of revenue (for cross-sectional data) expressed by the following formula:

$$\begin{aligned} \ln R_i = & \beta_0 + \beta_1 \ln w_{i,D} + \beta_2 \ln w_{i,L} + \beta_3 \ln p_i + \beta_4 \ln w_{i,D} \ln w_{i,L} + \\ & + \beta_5 \ln w_{i,D} \ln p_i + \beta_6 \ln w_{i,L} \ln p_i + \beta_7 (\ln w_{i,D})^2 + \beta_8 (\ln w_{i,L})^2 + \\ & + \beta_9 (\ln p_i)^2 + v_i + z_i, \end{aligned} \quad (8)$$

where:

- $\ln R_i$ - observable revenue level,
- $w_{i,D}$ - financial factor price (deposits and other borrowed funds),
- $w_{i,L}$ - price of labour (average gross wage per employee),
- p_i - product price (loans and other receivables).

While cost efficiency measures how cheaply a bank makes its products, revenue efficiency determines how effectively a bank sells its products (what size revenue it generates). For example, two banks boasting the same level of costs may have different revenues. Higher revenues in one may result from effective marketing strategies or higher quality products. Such aspects of the assessment of the bank's business are not covered by the frontier cost function (Rogers, 1998).

Having estimated the frontier revenue function, the revenue efficiency indicator (RE_i) for object i is calculated based on the formula:

$$RE_i = \frac{\hat{R}^i}{\hat{R}^{\max}}, \quad (9)$$

where:

- $\hat{R}^i$ - actual realised revenue,
- $\hat{R}^{\max}$ - maximum available revenue of the most efficient object in a sample.

The above indicator compares actual revenue realised by object i (company) to hypothetical maximum revenue which it could realise in the same period if it were as efficient as the best object in the researched sample.

4. The Alternative Frontier Revenue Function

In the alternative revenue function, in comparison with standard formula, it is assumed that banks have greater flexibility in respect of product prices than of production (output) levels, hence they treat production volume as a principally exogenous factor at the time when they are making their decisions. On the other hand, product prices may vary and so affect revenue. This assumption allows testing revenue economies of scope, which constitutes its main asset.

As regards these assumptions, maximum revenue growth occurs as a result of solving the following problem (cf.: Berger, Humphrey, Pulley, 1996):

$$\max_p R = p'y; \quad \text{on condition that } g(y, p, w) = 0, \quad (10)$$

where:

- y – output quantity vector,
- p – products price vector,
- w – vector of production factors prices,
- g – function of three variables: y, p, w reflecting external conditions and technology.

Having applied Lagrange multipliers, we obtain the optimum product prices $p(y, w)$, which maximise revenue. By definition, revenue is $R = p'y$, hence with the above condition, the revenue function will have the following formula:

$$R = p'y = p(y, w)'y = R(y, w). \quad (11)$$

Assuming two factors of production (financial factor and labour) and one product (volume of extended loans) and approximating the unknown alternative revenue function by expanding it into a Taylor series, we obtain a stochastic frontier model of a translog alternative revenue function (for cross-sectional data) of the following formula:

$$\ln R_i = \beta_0 + \beta_1 \ln w_{i,D} + \beta_2 \ln w_{i,L} + \beta_3 \ln y_i + \beta_4 \ln w_{i,D} \ln w_{i,L} + \beta_5 \ln w_{i,D} \ln y_i + \beta_6 \ln w_{i,L} \ln y_i + \beta_7 (\ln w_{i,D})^2 + \beta_8 (\ln w_{i,L})^2 + \beta_9 (\ln y_i)^2 + v_i + z_i, \quad (12)$$

where:

- $\ln R_i$ - ascertained (actual) revenue level,
- $w_{i,D}$ – financial factor price (deposits and other acquired resources),
- $w_{i,L}$ – price of labour (level of average gross wage per employee),
- y_i - output volume (volume of loans and other receivables),
- v_i – symmetric random components,
- z_i – components expressing inefficiency of researched companies (technical or allocative) with independent distributions and solely negative values.

It is to be noted that an alternative revenue function contains the same set of exogenous variables as a cost function, the only difference being that revenue replaces costs as the dependent variable.

The revenue efficiency ratio (REi) calculated on the basis of an alternative function for the i object is calculated in the same way as in the standard revenue function and its interpretation is analogous.

5. The Standard Frontier Profit Function

In addition to the frontier cost and revenue function, empirical analysis of enterprises' economic efficiency also uses a frontier profit function. The main advantage of the profit function is that it allows measuring inefficiency on both the revenue and cost sides. What that means is that the profit function combines revenue effects arising from manufacturing at an incorrect level or manufacturing inadequate products with cost effects associated with excessive incurred expenses or an improper combinations thereof. The possibility to reduce problems associated with incorrect specification of products and inputs is an important characteristic of the profit function. In banking, it is not always clear which of the balance sheet items should be recognised as inputs and which as outputs. The profit function also allows one to better identify the sources of inefficiency. One can determine estimated technical and allocative inefficiency on the inputs and outputs sides, as well as the effects of their interaction. It should be emphasised that the cost function ignores the revenue side, while the revenue function does the same to the cost side.

Standard profit efficiency can also take better account of cost inefficiency because it incorporates deviations of the scale of operations (production) from the optimum level. Cost efficiency assesses activities for a constant level of products at the current level, which is not always the optimum level. A company that is relatively efficient in terms of cost for the current level of the products may not be efficient to the same extent at the optimum product level in terms of profit maximisation (see: Berger, Mester, 1997).

Profit maximisation is one of the key objectives of any company. By definition, profit is the differential between revenues from sales and costs incurred. If a company produces m products ($y_1, \dots, y_m$) and uses n inputs ($x_1, \dots, x_n$), its profit can be expressed as follows (cf. Berger, Mester, 1997):

$$\pi = \sum_{i=1}^n p_i \cdot y_i - \sum_{i=1}^m w_i \cdot x_i \quad (13)$$

where:

- $p_i = p_1, \dots, p_m$ – products prices,
- $w_i = w_1, \dots, w_n$ – production factors prices.

Denoting products and inputs vectors as x and y respectively, and further assuming that $Q \equiv (y, -x)' = (y_1, \dots, y_m, -x_1, \dots, -x_n)'$ will be a vector of results (with a negative sign on the inputs side) and $P \equiv (p, w)' = (p_1, \dots, p_m, w_1, \dots, w_n)'$ will be the prices vector, where p is the products price and w denotes inputs prices, profits are calculated according to the formula:

$$\pi = P'Q \quad (14)$$

In a competitive environment companies take prices to be an exogenous factor, and therefore their profits are maximised when the following equation is solved:

$$\max_Q \pi = P'Q \quad \text{on condition that: } h(y, x) = 0, \quad (15)$$

where:

- $h(y, x)$ is a transformation of inputs quantity into quantity of products².

In the case of a general function, use of the Lagrange multipliers method offers a solution to the issue of the optimum quantity of inputs and outputs which is a function of the prices of inputs and outputs: $Q = Q(P)$, and since the total profit by definition is $\pi = P'Q$, hence the profit function can be written as:

$$\pi = P'Q(P) = \pi(P). \quad (16)$$

Thus, assuming that the company operates in a competitive market, its profit can be expressed as a function of inputs prices and outputs prices.

Using the intermediation approach in a manner similar to that in the cost and revenue functions and adopting two variable production factors (value of acquired deposits and value of wages), one constant/fixed input (physical capital measured by surface in square meters) and one product (value of loans granted) the stochastic model of the translog frontier profit function can be written in the following way:

$$\begin{aligned} \ln \pi_i = & \alpha_0 + \alpha_1 \ln w_{i,D} + \alpha_2 \ln w_{i,L} + \alpha_3 \ln p_i + \alpha_4 \ln K_i + \alpha_5 \ln w_{i,D} \ln w_{i,L} + \\ & \alpha_6 \ln w_{i,D} \ln p_i + \alpha_7 \ln w_{i,D} \ln K_i + \alpha_8 \ln w_{i,L} \ln p_i + \alpha_9 \ln w_{i,L} \ln K_i + \alpha_{10} \ln \quad (17) \\ & p_i \ln K_i + \alpha_{11} (\ln w_{i,D})^2 + \alpha_{12} (\ln w_{i,L})^2 + \alpha_{13} (\ln p_i)^2 + \alpha_{14} (\ln K_i)^2 + v_{it} + z_{it} \end{aligned}$$

where:

- $\ln \pi_i$ - observable level of variable profit of an i - branch of the bank,
- $w_{i,D}$ - financial factor price (deposits and other borrowed funds),
- $w_{i,L}$ - price of labour (the average gross wage per employee),
- p_i - product price (loans and other funds granted),
- K_i - involvement of a constant factor (physical capital) as measured by the surface of proprietary and rented office space in square meters.

² In this non-specific case under consideration (multiple products and inputs) the dependence of products cannot be explicitly derived from inputs. Thus, the $h(x,y)$ formula represents the relationship in the form of implicit functions and is a generalisation of the production function.

Having assessed the above frontier profit function, one can compute the profit efficiency indicator as follows:

$$\pi E_i = \frac{\hat{\pi}^i}{\hat{\pi}^{\max}}, \quad (18)$$

where:

- $\hat{\pi}^i$ - actual realised profit,
- $\hat{\pi}^{\max}$ - maximum value of profit that can be realised by the most efficient object in the sample.

The above indicator reveals the relation between profit actually realised by object i (company) and a hypothetical maximum profit which it could generate over the same time period if it were as efficient as the best object in the researched sample.

6. The Alternative Frontier Profit Function

The profit function has an alternative formula in very much the same manner as the revenue function, and the same may be used when the conditions underlying the standard function are not satisfied.

When the conditions of perfect competition are satisfied, in order to assess efficiency it is necessary to assume a standard formula of the profit function, which is (cf.: Rogers, 1998):

$$\pi = \pi(p, w, u_c, v_c), \quad (19)$$

where:

- π is the actual realised profit,
- p is a products price vector,
- w is a vector of production factor prices,
- u_c is a variable representing inefficiency of profit,
- v_c signifies a random element.

Yet in most cases (economies of individual countries) the assumptions of perfect competition are not satisfied. These cases are best served by an alternative formula of the profit function, which assumes that banks maximise profit for given output y and inputs prices w , by selecting the prices of products p at the same time determining the size of variable inputs (at given inputs, z) x . Considering the above assumptions, an alternative profit function is derived by resolving the following problem (cf.: Humphrey, Pulley, 1997):

$$\max_{p,x} \pi = P'Q = (p, w) \cdot (y, -x)'; \text{ on condition that: } g(p, y, w, z) = 0; h(y, x) = 0, \quad (20)$$

where:

- $g(p, y, w, z)$ stands for a set of possibilities for a bank to fix prices by way of transforming the size of y, w and z into prices of products p . This reflects the bank's assessment of its own competitive position and assessment of customers' willingness to pay prices asked by the bank. Inputs prices w are included in function $g(\cdot)$, as higher inputs prices may signal customers' willingness to accept higher prices.

The use of Lagrange multipliers allows finding the best level of product prices, as function $p = p(y, w, z)$ and optimum size of inputs $x = x(y, z)$. After solving this problem and substituting the acquired optimum size to the profit formula, the following alternative profit function is obtained:

$$\pi = P'Q = [p(y, w, z), w]/[y, -x(y, z)]' = \pi(y, w, z) \quad (21)$$

The main benefit afforded by the alternative profit function is that it captures more appropriate specifications when the forces of the market come to play. Moreover, the prices of products p , which appear in the standard profit function are measured less accurately than in the alternative approach as certain significant elements of lenders' and borrowers' prices are not accounted for in the information which is available.

By using of an *intermediation approach* recommended by Sealey and Lindlay (1977) and assuming two variable production factors (value of deposits taken and value of salaries), one fixed netput (physical capital measured in terms of surface in square metres) and one product (value of loans granted), a stochastic frontier model of a translog alternative revenue function may be written as follows:

$$\begin{aligned} \ln \pi_i = & \alpha_0 + \alpha_1 \ln w_{i,D} + \alpha_2 \ln w_{i,L} + \alpha_3 \ln y_i + \alpha_4 \ln K_i + \alpha_5 \ln w_{i,D} \ln w_{i,L} + \alpha_6 \ln w_{i,D} \ln y_i + \\ & \alpha_7 \ln w_{i,D} \ln K_i + \alpha_8 \ln w_{i,L} \ln y_i + \alpha_9 \ln w_{i,L} \ln K_i + \alpha_{10} \ln y_i \ln K_i + \alpha_{11} (\ln w_{i,D})^2 + \\ & + \alpha_{12} (\ln w_{i,L})^2 + \alpha_{13} (\ln y_i)^2 + \alpha_{14} (\ln K_i)^2 + v_{it} + z_{it}, \end{aligned} \quad (22)$$

where:

- $\ln \pi_i$ – ascertained level of variable revenue of i branch of the bank,
- $w_{i,D}$ – price of financial factor (deposits and other acquired resources),
- $w_{i,L}$ – price of labour (level of average gross wage per employee),
- y_i – volume of output (loans and other offered resources),
- K_i – fixed netputs (physical capital) engaged measured in terms of surface in square metres of proprietary and rented office space,
- z_i – components expressing inefficiency of researched companies (technical or allocative) with independent distributions and solely negative values.

The profit efficiency ratio (πEi) is calculated on the basis of an alternative function for the i object and is calculated in the same way as in the standard profit function and its interpretation is analogous.

7. Economic effectiveness assessment for Polish bank branches on a basis of stochastic frontier functions of costs, revenues and profits

The main problem underlying econometric analysis of efficiency involves estimating the parameters of a given frontier function and indicators of efficiency (inefficiency) levels. In order to model frontier functions one can use classic econometric methods as well as linear and square programming methods. The latter are prone to a number of serious flaws, the most important being their high sensitivity to atypical observations and a failure to accommodate information on the distribution of the inefficiency variable.

The econometric analysis of branches' economic efficiency relied on the following stochastic frontier models: stochastic frontier cost function model, stochastic frontier model of standard and alternative revenue function and stochastic frontier model of standard and alternative profits functions. In the case of the profit function, the number of branches was narrowed to 54. Actually, four of the analysed branches reported a negative operating profit, which, in the case of a translog function posed a problem which enforced their exclusion from the analysis. In order to estimate the structural parameters of these models and further to measure efficiency, the author used the Corrected Least Squares Method (CLSM). The results of the measurement of branch efficiency using various econometric models are presented in Table 1-3 (based on the calculated efficiency measures, efficiency rankings can also be prepared).

In order to facilitate the description of efficiency ratios corresponding to the various frontier functions, the author used the following symbols:

- a) CE – cost efficiency indicators,
- b) SRE – standard revenue efficiency indicators,
- c) ARE – alternative revenue efficiency indicators,
- d) SPE – standard profit efficiency indicators,
- e) APE – alternative profit efficiency indicators.

The best fit of empirical data to theoretical values for each of the periods was revealed by the cost function (coefficients of determination in each quarter standing at 0.996), and the alternate profit function (coefficients of determination for the quarters standing at 0.962; 0.957; 0.958 for the respective quarters). By contrast, the poorest fit occurred in the case of the standard profit function (0.347, 0.338, 0.350 respectively). The remaining functions revealed a coefficient of determination ranging from 0.654 to 0.779 (cf. Table 1-3).

However, because of the simplified assessment method and measurement of efficiency itself which was used (which assumes, among others, lack of pure random deviations) the estimated individual inefficiency levels should be considered as rather inaccurate.

Table 1.

Economic efficiency indicators for bank branches computed on the basis of the stochastic frontier functions (1 Quarter)

Number of branch	1. SCE	2. SRE	3. ARE	4. SPE	5. APE
1	0,951	0,940	0,714	xxx	xxx
2	0,928	0,925	0,738	0,387	0,465
3	0,902	0,707	0,737	0,502	0,436
4	0,934	0,804	0,852	0,707	0,633
5	0,905	0,557	0,758	0,391	0,362
6	0,872	0,455	0,683	0,128	0,133
7	0,947	0,722	0,894	0,554	0,671
8	0,874	0,602	0,808	0,391	0,477
9	0,890	0,667	0,887	1,000	0,529
10	0,881	0,954	0,927	0,419	0,752
11	0,909	0,542	0,745	0,487	0,478
12	0,942	0,323	0,678	0,155	0,256
13	0,854	1,000	0,938	0,879	0,771
14	0,844	0,567	0,836	0,225	0,511
15	0,883	0,552	0,867	0,614	0,690
16	0,887	0,495	0,791	0,313	0,499
17	0,857	0,326	0,623	xxx	xxx
18	0,913	0,740	1,000	0,884	0,852
19	0,875	0,303	0,721	0,246	0,268
20	0,937	0,622	0,716	0,297	0,418
21	0,934	0,328	0,812	0,584	0,400
22	0,899	0,482	0,826	0,688	0,601
23	0,918	0,432	0,761	0,240	0,332
24	0,943	0,511	0,847	0,429	0,715
25	0,959	0,418	0,798	0,146	0,609
26	0,905	0,351	0,828	0,318	0,579
27	0,846	0,297	0,769	0,323	0,379
28	0,970	0,296	0,777	0,342	0,547
29	0,869	0,420	0,899	0,382	0,673
30	0,889	0,370	0,843	0,849	0,534
31	0,848	0,372	0,798	0,200	0,509
32	0,823	0,350	0,837	0,165	0,409
33	0,989	0,391	0,863	0,496	0,811
34	0,925	0,198	0,707	0,134	0,381
35	0,862	0,241	0,734	0,023	0,396
36	0,991	0,291	0,746	0,315	0,552
37	0,872	0,206	0,719	0,113	0,333
38	0,925	0,216	0,375	0,141	0,253
39	0,915	0,354	0,911	0,244	0,930
40	0,901	0,242	0,719	0,134	0,310
41	1,000	0,203	0,677	0,141	0,384
42	0,914	0,159	0,812	xxx	xxx
43	0,921	0,404	0,845	0,321	0,614
44	0,868	0,480	0,940	0,292	0,770
45	0,894	0,177	0,713	0,158	0,363
46	0,948	0,357	0,894	0,267	0,770
47	0,983	0,133	0,701	0,151	0,409
48	0,977	0,148	0,730	0,117	0,420
49	0,923	0,275	0,955	0,229	1,000
50	0,877	0,556	0,892	0,498	0,613
51	0,918	0,190	0,818	0,225	0,580
52	0,827	0,150	0,825	0,076	0,270
53	0,953	0,156	0,755	0,131	0,484
54	0,976	0,106	0,724	0,068	0,459
55	0,923	0,164	0,755	0,099	0,442
56	0,919	0,188	0,806	0,086	0,487
57	0,931	0,044	0,709	xxx	xxx
58	0,851	0,085	0,907	0,026	0,552
Minimum value	0,823	0,044	0,375	0,023	0,133
Average value	0,910	0,406	0,792	0,328	0,520
Determination Coefficient R ²	0,996	0,779	0,962	0,347	0,768

Source: author's own calculations.

Table 2.

Economic efficiency indicators for bank branches computed on the basis of the stochastic frontier functions (II Quarter)

Number of branch	1. SCE	2. SRE	3. ARE	4. SPE	5. APE
1	0,906	0,422	0,610	xxx	xxx
2	0,937	1,000	0,681	1,000	0,161
3	0,909	0,749	0,810	0,463	0,247
4	0,881	0,645	0,881	0,757	0,334
5	0,913	0,587	0,764	0,483	0,215
6	0,891	0,361	0,769	0,493	0,141
7	0,898	0,442	0,852	0,263	0,296
8	0,866	0,657	0,819	0,397	0,251
9	0,890	0,468	0,914	0,476	0,849
10	0,880	0,700	0,966	0,280	0,845
11	0,880	0,452	0,714	0,307	0,190
12	0,910	0,189	0,707	0,033	0,015
13	0,838	0,596	0,927	0,420	0,376
14	0,847	0,537	0,827	0,238	0,300
15	0,909	0,575	0,890	0,323	0,791
16	0,867	0,418	0,782	0,185	0,254
17	0,882	0,634	0,605	xxx	xxx
18	0,905	0,401	1,000	0,367	1,000
19	0,840	0,333	0,806	0,194	0,219
20	0,879	0,188	0,746	0,078	0,207
21	0,896	0,229	0,774	0,392	0,318
22	0,852	0,270	0,850	0,213	0,395
23	0,932	0,279	0,773	0,248	0,219
24	0,896	0,369	0,864	0,208	0,388
25	0,974	0,277	0,814	0,069	0,355
26	0,874	0,465	0,780	0,237	0,275
27	0,875	0,290	0,700	0,186	0,181
28	0,929	0,253	0,788	0,183	0,338
29	0,828	0,291	0,860	0,218	0,280
30	0,866	0,262	0,779	0,200	0,296
31	0,849	0,206	0,707	0,074	0,145
32	0,810	0,300	0,877	0,099	0,361
33	0,948	0,340	0,912	0,258	0,462
34	0,939	0,150	0,622	0,071	0,142
35	1,000	0,140	0,693	0,042	0,276
36	0,949	0,238	0,736	0,181	0,257
37	0,851	0,161	0,705	0,054	0,137
38	0,874	0,122	0,430	xxx	xxx
39	0,882	0,212	0,872	0,183	0,319
40	0,888	0,278	0,759	0,192	0,174
41	0,941	0,276	0,678	0,343	0,139
42	0,891	0,143	0,787	0,080	0,157
43	0,892	0,273	0,872	0,178	0,334
44	0,878	0,220	0,883	0,139	0,329
45	0,896	0,116	0,667	0,041	0,168
46	0,918	0,243	0,841	0,201	0,371
47	0,976	0,126	0,614	0,077	0,223
48	0,968	0,132	0,749	0,061	0,232
49	0,877	0,161	0,947	0,088	0,364
50	0,925	0,303	0,789	0,323	0,375
51	0,871	0,133	0,991	0,141	0,487
52	0,823	0,189	0,897	0,061	0,191
53	0,914	0,149	0,786	0,093	0,180
54	0,915	0,084	0,738	0,030	0,143
55	0,921	0,138	0,757	0,062	0,185
56	0,927	0,091	0,827	0,057	0,361
57	0,905	0,044	0,609	xxx	xxx
58	0,847	0,112	0,913	0,035	0,271
Minimum value	0,810	0,044	0,430	0,030	0,015
Average value	0,895	0,317	0,788	0,224	0,306
Determination Coefficient R ²	0,996	0,773	0,957	0,338	0,654

Source: author's own calculations.

Table 3.

Economic efficiency indicators for bank branches computed on the basis of the stochastic frontier functions (III Quarter)

Number of branch	1. SCE	2. SRE	3. ARE	4. SPE	5. APE
1	0,771	0,669	0,653	xxx	xxx
2	0,795	1,000	0,613	0,620	0,278
3	0,765	0,974	0,812	0,517	0,245
4	0,776	0,674	0,769	0,712	0,616
5	0,779	0,607	0,666	0,384	0,282
6	1,000	0,268	0,664	0,835	0,025
7	0,774	0,479	0,755	0,282	0,368
8	0,746	0,592	0,707	0,411	0,248
9	0,812	0,335	0,698	0,156	0,229
10	0,759	0,524	0,812	0,209	0,337
11	0,752	0,621	0,708	0,557	0,310
12	0,763	0,325	0,718	0,055	0,092
13	0,720	0,836	1,000	0,516	0,625
14	0,701	0,500	0,797	0,225	0,328
15	0,721	0,549	0,825	0,660	0,378
16	0,706	0,527	0,775	0,391	0,454
17	0,709	0,200	0,551	xxx	xxx
18	0,822	0,312	0,833	0,413	0,565
19	0,703	0,392	0,766	0,330	0,308
20	0,781	0,329	0,754	0,102	0,300
21	0,808	0,289	0,727	0,381	0,407
22	0,755	0,226	0,782	0,253	0,384
23	0,793	0,251	0,676	0,314	0,229
24	0,769	0,633	0,932	1,000	1,000
25	0,826	0,393	0,730	0,169	0,577
26	0,750	0,345	0,826	0,318	0,449
27	0,751	0,251	0,659	0,424	0,238
28	0,797	0,486	0,856	0,946	0,952
29	0,702	0,316	0,850	0,274	0,520
30	0,743	0,241	0,728	0,492	0,451
31	0,729	0,258	0,629	0,100	0,186
32	0,730	0,254	0,629	0,096	0,137
33	0,796	0,313	0,861	0,326	0,600
34	0,806	0,171	0,574	0,178	0,192
35	0,847	0,198	0,715	0,057	0,261
36	0,826	0,366	0,723	0,396	0,354
37	0,719	0,245	0,703	0,149	0,240
38	0,759	0,142	0,447	xxx	xxx
39	0,755	0,230	0,848	0,188	0,622
40	0,782	0,270	0,677	0,216	0,267
41	0,848	0,294	0,640	0,243	0,216
42	0,761	0,283	0,785	0,132	0,276
43	0,769	0,268	0,852	0,357	0,659
44	0,742	0,178	0,781	0,141	0,409
45	0,768	0,137	0,605	0,154	0,226
46	0,776	0,148	0,760	0,142	0,397
47	0,849	0,160	0,610	0,151	0,260
48	0,827	0,182	0,675	0,149	0,306
49	0,736	0,149	0,818	0,121	0,572
50	0,786	0,161	0,645	0,114	0,216
51	0,732	0,154	0,853	0,136	0,963
52	0,737	0,414	0,957	0,205	0,285
53	0,768	0,154	0,737	0,138	0,402
54	0,762	0,075	0,726	0,038	0,247
55	0,754	0,087	0,605	0,042	0,151
56	0,753	0,109	0,749	0,077	0,276
57	0,802	0,131	0,539	xxx	xxx
58	0,752	0,066	0,819	0,023	0,448
Minimum value	0,701	0,066	0,447	0,023	0,025
Average value	0,771	0,340	0,735	0,297	0,377
Determination Coefficient R ²	0,996	0,737	0,958	0,350	0,660

Source: author's own calculations.

It should be noted that the highest levels of effectiveness are observed for economic costs effectiveness, followed by alternate revenue effectiveness. This indicates that the objective function realised by bank branches to the highest extent is the cost minimisation.

In the case of the cost function, the results show that in Q1 on average 9% of variable cost incurred by all the branches was an unjustified expense, unwarranted by either the volume of production or the prices of the production factors, or even the size of the fixed factor (in Q2 and Q3: 11% and 23% respectively). On the other hand, based on efficiency ratios derived using an alternative revenue function, it can be stated that the branches could have made a 21% higher profit on average in Q1 and Q2 and 27% in Q3 if they had sold more of their production or paid lower prices for the use of production factors. However, due to the deployment of a simplified method to estimate structural parameters of the models and measure efficiency itself (they assume, among others, lack of purely random deviation) the efficiency levels estimated individually should be considered undervalued (inaccurate). For this reason, further analysis and assessment should, in this case, be based on prepared rankings, which should be accepted as reliable.

As the results show, the effectiveness ratios obtained with the standard and the alternate profit functions are, generally, lower than cost- and revenue-effectiveness ratios, and this conforms to the definition and assumptions of the revenue function, which combines (contains) both cost and revenue effects.

Depending on the assumed assessment criterion (costs, revenues and profits functions) branches occupy a different place in the rankings. In order to identify the most or the least efficient branches use should be made of the place occupied by a given branch in the rankings. An overall assessment of the efficiency is best reflected by the results obtained from the alternative profit function, which, on the one hand, reveals both the of cost effects and revenue effects of activities and, on the other, is based on assumptions of imperfect competition occurring in the economic activity of the analysed branches. Based on the alternative profit function, the highest efficiency was revealed for the following units:

- a) in Q1 - branches no: 49, 39, 18, 33, 13,
- b) in Q2 - branches no: 18, 9, 10, 15, 51,
- c) in Q3 - branches no: 24, 51, 28, 43, 13.

On the other hand, the following are the least efficient branches:

- a) in Q1 - branches no: 6, 42, 12, 19, 52,
- b) in Q2 - branches no: 12, 37, 41, 6, 34,
- c) in Q3 - branches no: 6, 12, 32, 55, 31.

Also worth noting is another very important aspect of the analysis. The economic effectiveness ratios obtained for the bank branches are significantly higher for the alternate revenue and cost functions than for the analogous standard functions. This means that the assumptions are fulfilled to a higher extent for the alternate functions than for the standard

functions. The calculations results for the standard and the alternate functions can form a basis for indirect conclusions about an existing market structure.

The final stage of the research was to compare the obtained results by analyzing the correlation of the economic efficiency assessments of the bank branches. Correlation results (the C. Spearman's rank correlation coefficients and the Pearson's coefficients) for each quarter are shown in the Tables 4-6.

Table 4.
Correlation between econometric efficiency indicators (I Quarter)

<i>Correlation coefficients</i>		<i>SCE</i>	<i>SRE</i>	<i>ARE</i>	<i>SPE</i>	<i>APE</i>
Spearmana	<i>SCE</i>		-0,228	-0,180	-0,123	0,008
Pearsona			-0,136	-0,220	-0,060	0,110
Spearmana	<i>SRE</i>	-0,228		0,397	0,755	0,377
Pearsona		-0,136		0,353	0,707	0,368
Spearmana	<i>ARE</i>	-0,180	0,397		0,515	0,813
Pearsona		-0,220	0,353		0,480	0,822
Spearmana	<i>SPE</i>	-0,123	0,755	0,515		0,513
Pearsona		-0,060	0,707	0,480		0,435
Spearmana	<i>APE</i>	0,008	0,377	0,813	0,513	
Pearsona		0,110	0,368	0,822	0,435	

Source: author's own calculations.

Table 5.
Correlation between econometric efficiency indicators (II Quarter)

<i>Correlation coefficients</i>		<i>SCE</i>	<i>SRE</i>	<i>ARE</i>	<i>SPE</i>	<i>APE</i>
Spearmana	<i>SCE</i>		-0,147	-0,307	-0,179	-0,208
Pearsona			-0,119	-0,301	0,003	-0,030
Spearmana	<i>SRE</i>	-0,147		0,271	0,848	0,227
Pearsona		-0,119		0,188	0,847	0,293
Spearmana	<i>ARE</i>	-0,307	0,271		0,257	0,747
Pearsona		-0,301	0,188		0,120	0,714
Spearmana	<i>SPE</i>	-0,179	0,848	0,257		0,313
Pearsona		0,003	0,847	0,120		0,216
Spearmana	<i>APE</i>	-0,208	0,227	0,747	0,313	
Pearsona		-0,030	0,293	0,714	0,216	

Source: author's own calculations.

Table 6.
Correlation between econometric efficiency indicators (III Quarter)

<i>Correlation coefficients</i>		<i>SCE</i>	<i>SRE</i>	<i>ARE</i>	<i>SPE</i>	<i>APE</i>
Spearmana	<i>SCE</i>		-0,061	-0,335	-0,005	-0,261
Pearsona			-0,105	-0,263	0,200	-0,205
Spearmana	<i>SRE</i>	-0,061		0,322	0,699	0,161
Pearsona		-0,105		0,307	0,645	0,161
Spearmana	<i>ARE</i>	-0,335	0,322		0,227	0,763
Pearsona		-0,263	0,307		0,280	0,700
Spearmana	<i>SPE</i>	-0,005	0,699	0,227		0,346
Pearsona		0,200	0,645	0,280		0,406
Spearmana	<i>APE</i>	-0,261	0,161	0,763	0,346	
Pearsona		-0,205	0,161	0,700	0,406	

Source: author's own calculations.

The obtained calculation results (correlation coefficients range from ca. 0.7 to ca. 0.8, on average) indicate similarities in methods for effectiveness assessment only in two cases: standard revenue and profit functions, and alternate revenue and profit functions. On the other hand, in most cases coefficients of correlation between the effectiveness measured with the cost function and with the revenue function are values oscillating around zero. Thus, the obtained results indicate a relatively high correlation between the profit effectiveness and the revenue effectiveness (branches with the high revenue effectiveness are also effective in terms of profits). On the other hand, cost-effective branches usually do not achieve the high profit effectiveness.

8. Conclusions

In the text, the Harvard referencing citation style should be used (Smith, 2017) or (Smith, Bradley, 2017). In the case of more than three authors, write the surname of the first of them and add the abbreviation “et al.” (Bradley et al., 2017).

This paper presents stochastic frontier models of costs, revenues, and profits. These models can be used to measure efficiency by developing appropriate theoretical (microeconomic) foundations.

Unlike other assessment methods, parametric methods have solid micro-economic and statistical foundations and their efficiency measurement is based on solving the corresponding optimisation problems. Individual frontier costs, revenue and profit functions are derived by solving problems involving cost reductions and revenue and profit maximisation respectively. Given certain limiting conditions, they therefore represent the optimum amount of costs, revenues and profits obtainable. After estimating the appropriate frontier function, measurement of the efficiency of a given object occurs through its comparison with a reference object. According to this assumption, an object with the highest efficiency level is set to 1.0 level, while the remaining objects assume values within the range of $(0, 1)$. As a result, it is also possible to measure the level of inefficiency, i.e. it is possible to determine the amount of loss incurred by a given object (e.g. did it make excessive outlays or suffer from insufficient effects) as a result of irrational activities. Econometric methods also allow one to identify sources of inefficiency, including incurring an excessive amount of effort, use of inappropriate proportions of production factors, or production set at the wrong level.

By comparing efficiency ratios based on stochastic frontier functions, the author managed to achieve high correlation in the case of standard revenue and profit functions and alternative revenue and profit functions. By contrast, there is no correlation between effectiveness indicators (and branch rankings) drawn up on the basis of cost and revenue efficiency and cost

and profit efficiency. This means that profit efficiency was more significantly influenced (more dependent) by revenue efficiency than cost efficiency.

In the case of alternative revenue and profit functions, the indicator values obtained are significantly higher than the corresponding values produced by standard functions. This means that in the case of the analysed entities, the assumptions underlying alternative functions (imperfect competition) are satisfied better than the assumptions of standard functions (perfect competition). Thus, the econometric methods used and the results produced by these methods allow indirect inference about the existing market structure. In this case, it must be concluded that the analysed branches operated under conditions of imperfect competition.

One defect of the studies, as already mentioned attributable to the use of a simplified estimation method, is that the individual efficiency levels of the tested objects are too low. The characteristics of the production process and the efficiency of individual companies can be comprehensively arrived at only on the basis of the Bayesian analysis combining in the estimation process both pre-knowledge of the analysed phenomenon (e.g. resulting from economic theory) and the information contained in the sample, which is proposed and presented by van den Broeck, Koop, Osiewalski and Steel (1994). Thus, the use of more advanced estimation methods capable of producing more accurate measurement results is an open issue available for further research.

To sum up, the conducted research confirmed differences in the levels of economic effectiveness of the examined branches depending on the adopted assessment criterion (cost, revenue, profit) and depending on the assumptions for the market structure (conditions of perfect or imperfect competition), which was the research hypothesis.

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FINANCIAL AND OPERATIONAL ANALYSIS OF MUNICIPALITIES IN THE UPPER SILESIAN–ZAGŁĘBIE METROPOLIS (GZM) IN 2020-2024 – A COST-EFFICIENCY APPROACH

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Purpose: The paper presents an analysis of the financial and operational dynamics of the public transport system within the Górnośląsko-Zagłębiowska Metropolis (GZM) during the period 2020-2024. The study focuses on the structure of costs, revenues, and the efficiency of financing mechanisms among municipalities participating in the metropolitan system. The analysis uses aggregated datasets from the Metropolitan Transport Authority (ZTM GZM) and covers both planned and executed values. An original analytical tool based on Visual Basic and Power Query was used for the study. The presented analysis focuses on the assessment of total transport-related costs and additional expenditures. The study also includes a comprehensive calculation of the so-called variable contribution, financed by the individual municipalities of the Metropolis.

Design/methodology/approach: The research presented in the article was based on statistical methods complemented by economic analysis techniques, in particular using a set of financial indicators determining the variable contribution.

Since one of the constraints during the implementation of the study was the requirement to use only those tools that are already in use and for which the GZM holds valid licenses, the analytical scope was therefore limited to the functionalities available within the Microsoft Office 365 suite.

Findings: In the course of the work, it was found:

- dispersion of data between different cost-controlling units,
- lack of uniform data structures between units,
- inconsistency of dictionaries over time.

Practical implications: The data model developed during the work was used to build the analytical platform used within the GZM.

Social implications: The developed model was used for presentation to the mayors of the municipalities that make up the GZM. It is an analytical tool used by the management of the GZM to present and optimize the scope of communication in the designated area.

Originality/value: Authorial model for processing data from heterogeneous sources into a coherent and unified data structure has been developed.

Keywords: GZM, public transport, cost analysis, efficiency, financial structure, sustainable mobility.

Category of the paper: Practical implementation of data processing system and data model construction.

1. The Nature and Importance of Financial-Operational Analysis in Public Transport

Financial-operational analysis in metropolitan transport is the process of assessing the economic and operational efficiency of the transport system in both financial and technical-organizational terms. It covers the relationships between operating costs, revenues from transport activity, and the quality and reliability of the services provided (Szołtysek, 2018).

The aim of this analysis is to ensure the sustainable development of public transport while making optimal use of financial and operational resources (Burnewicz, 2021).

The literature emphasizes that financial-operational analysis in urban transport makes it possible to assess whether financial resources are used efficiently and whether transport undertakings achieve the desired level of operational efficiency. In metropolitan transport-where maximizing profit is not always the goal-balancing operating costs with service availability and quality plays a crucial role (Tundys, 2020).

In urban conditions, financial-operational analysis serves four basic functions:

- Diagnostic - enables identification of inefficiencies in the operation of the transport system, e.g., excessive fleet maintenance costs, energy losses, or declining profitability on lines with low passenger flows (Cieśla, 2022).
- Forecasting - allows the prediction of the financial effects of changes in operations (e.g., introducing electric rolling stock, ticket tariff changes) (Wojewódzki, Puzio; 2023).
- Decision-making - supports strategic decisions on infrastructure investment, fleet modernization, and shaping the route network (European Commission, 2020).
- Control - enables monitoring the degree to which operational goals are achieved by operators and transport-managing authorities (e.g., Metropolitan Transport Authorities).

In public transport, financial-operational analysis faces several constraints (Gajewski, 2020):

- The nature of public services - transport activity is not profit-oriented but aimed at fulfilling social functions, which makes efficiency assessment in classical financial terms more difficult (Pucher, Buechler, 2021).
- Variability of operating conditions - seasonality of passenger traffic, changes in road infrastructure or fare policy can affect results.
- Dependence on grants and subsidies - a large part of operators' revenues comes from local-government budgets, which distorts the picture of the system's financial self-sufficiency (OECD, 2023).

- Data imperfections - operational data (e.g., fuel consumption, mileage, failures) are often dispersed across different IT systems, hampering analytical integration (GZM Metropolia, 2023).

Modern metropolitan transport systems, such as the GZM Metropolis, use financial-operational analyses as tools for planning and cost optimization. Using these analyses makes it possible, among others, to (Grzelec, 2021):

- plan budgets and subsidies for operators,
- define efficient transport lines,
- assess the impact of rolling-stock modernization on operating costs and CO₂ emissions,
- improve the efficiency of transport infrastructure utilization.

The integration of financial and operational data is becoming a key element of modern public transport management, particularly in the context of sustainable development and reducing the operating costs of urban systems.

2. Genesis and the Metropolitan Context

The organization of public transport within the Upper Silesian–Zagłębie Metropolis (GZM) constitutes one of the largest integrated systems in Poland, both in terms of operational scope and financial complexity. The GZM, as a union of 56 municipalities, coordinates and co-finances collective transport through the Metropolitan Transport Authority (Zarząd Transportu Metropolitalnego, ZTM), ensuring uniform service standards and tariff integration (GZM Metropolia, 2024).

The implementation of the common metropolitan fare system, the development of integrated lines, and the increasing digitalization of operational data have significantly enhanced the capacity for evidence-based policy and analytical evaluation.

The key objective of the study is to assess the dynamics of transport costs and revenues in the years 2020-2024 and to evaluate their implications for the financial sustainability of the metropolitan system. Particular emphasis is placed on identifying the relationship between the variable part of the municipal contribution (GZM Metropolia, 2024) (składka zmienna), ticket income, and total operational costs (GZM Metropolia, 2020, 2021).

The analysis also considers spatial diversity within the metropolis - distinguishing between central cities (e.g., Katowice, Gliwice, Sosnowiec), medium-sized municipalities (e.g., Ruda Śląska, Tychy, Zabrze), and peripheral communities. This differentiation allows for a more comprehensive understanding of financial and operational efficiency in the metropolitan transport system.

The study aligns with the strategic goals of the GZM and the Sustainable Urban Mobility Policy, aiming to improve environmental performance and economic efficiency while ensuring equitable access to transport across all municipalities.

The introduction of the metropolitan model of transport settlements constitutes an element of implementing the Sustainable Urban Mobility Strategy, consistent with the European Union's transport policy and the National Strategy for Sustainable Transport Development 2030 (Gov.pl, accessed 2025).

3. Characteristics of Source Data

The empirical foundation of the analysis is based on datasets developed by the Metropolitan Transport Authority (ZTM GZM), specifically derived from the spreadsheet "*DaneZbiorczo*" (Aggregate Data). This dataset contains comprehensive financial and operational information for the years 2020-2024, divided into two categories: *Plan* (planned values) and *Execution* (actual results). The data structure enables the comparison of assumptions with real financial outcomes at the level of individual municipalities and the entire metropolitan system.

The dataset includes the following key categories:

- Costs of transport services financed by municipalities, broken down into main operators and service types.
- Ticket revenues, representing the share of self-financing in total operational costs.
- Variable part of the municipal contribution (ZCzS), determining the scale of local financial engagement in the GZM system.
- Lost revenues due to statutory exemptions (e.g., children and youth, rail integration, socially entitled groups).
- Organizational costs and additional compensations, such as infrastructure amortization and subsidies to specific lines.

Each observation in the dataset represents an annual record, which makes it possible to analyze changes over time and to calculate dynamic indicators. The range of data - covering five years - captures the pandemic and post-pandemic periods, showing the impact of COVID-19 on operational costs, revenues, and municipal contributions.

The analytical process involved several stages:

1. Data cleaning and normalization – inconsistent or missing values were verified using internal reports from ZTM GZM and corrected for coherence.
2. Aggregation – data from multiple operators were consolidated into a single analytical structure.

3. Computation of efficiency indicators – including:

- *Cost per kilometer* (PLN/km),
- *Revenue per kilometer* (PLN/km),
- *Ticket income ratio* (ticket revenue to total cost),
- *Unit cost of operation per vehicle kilometer*.

These indicators were calculated for each municipality and then compared across functional subgroups:

- Core municipalities – Katowice, Gliwice, Sosnowiec, constituting the metropolitan core with the highest operational and financial input.
- Intermediate municipalities – Zabrze, Tychy, Ruda Śląska, Dąbrowa Górnicza, representing a balanced structure of costs and revenues.
- Peripheral municipalities – smaller urban and rural areas with lower passenger density and limited service frequency.

All computations were conducted using Microsoft Excel, Power Query, and Power BI, allowing the visualization of trends and the preparation of comparative dashboards for further interpretation.

This methodology ensures data comparability across years and municipalities and forms the basis for quantitative analysis of cost efficiency and financial dynamics in the GZM public transport system.

The data were collected in a standardized tabular format comprising 15,904 records described by 144 columns, representing individual data categories. The key categories of data are presented in Table 1.

Table 1.
Key Data Categories

Category	Example columns	Meaning
Identification	Typ_danych, Przynależność, Typ_Operatora, Typ_Linii, Gmina, Podregion, Rok, Nr_linii, Opreator, Umowa	Define the source and context of the data (e.g., route, operator, municipality, year).
Operational work (transport)	M km, A km, B km, C km, Razem km, TB km, Praca_ekspl_Oblicz	Route lengths, transport work (vehicle-km/passenger-km).
Operating costs	M koszt netto, A koszt netto, B koszt netto, C koszt netto, MABC koszt netto, Suma Kosztów, Koszt przewozu razem z kosztami dodatkowymi (netto)	Main operating costs of transport.
Additional costs and investments	KLIMA koszt netto, MONITORING koszt netto, WIFI koszt netto, SDIP koszt netto, PPK koszt netto, Płaca_min koszt netto	Additional expenditures on equipment and system operations.
Revenues and financing	Dochody z biletów, Utracone dochody (kolej/ONZ/dzieci), Składka_Zmienna_Oblicz	Revenues and compensations.
ZTM investments	ZTM/... columns (e.g., ZTM/ORG/B/P, ZTM/P3/B/WPF)	Expenditures and projects financed by ZTM or GZM.
Taxes and fees	Oplaty przystankowe, Podatek od nieruchomości, Użytkowanie wieczyste gruntów	Costs of maintaining infrastructure.
Audit and projects	Audyt Świerklaniec, Audyt Tychy, Zielony Transport GZM, HYDROGEN GZM	Control or project-related data.
Auxiliary indicators	Praca_ekspl_Oblicz, Składka_Zmienna_Oblicz, Wyswietlanie	Computed fields and visibility flags.

Source: Author's own elaboration based on GZM data.

4. Transport Costs Financed by Municipalities in 2020-2024

The direct costs that constitute the transport costs financed by municipalities comprise two groups.

The first group consists of the net cost of transport, with the following cost types distinguished:

- M net cost - costs of bus transport operated by M-type vehicles,
- A net cost - costs of bus transport operated by A-type vehicles,
- B net cost - costs of bus transport operated by B-type vehicles,
- C net cost - costs of bus transport operated by C-type vehicles,
- TB net cost - costs of trolleybus transport,
- T net cost - costs of tram transport.

The second group contains additional costs charged to the bus and trolleybus fleet, including:

- KLIMA - air-conditioning costs,
- MONITORING - costs of on-board monitoring,
- WIFI - costs of on-board wireless Internet access,
- SDIP - costs of operating the Passenger Dynamic Information System (SDIP) (sprint.pl, accessed 2025),
- PPK - costs of operating the Employee Capital Plans (PPK),
- Placa_min - costs of aligning wages with the statutory minimum wage,
- INNE - other previously unclassified costs.

Aggregate values for both groups are shown in Table 2, while their structure is presented in Figure 1.

Table 2.

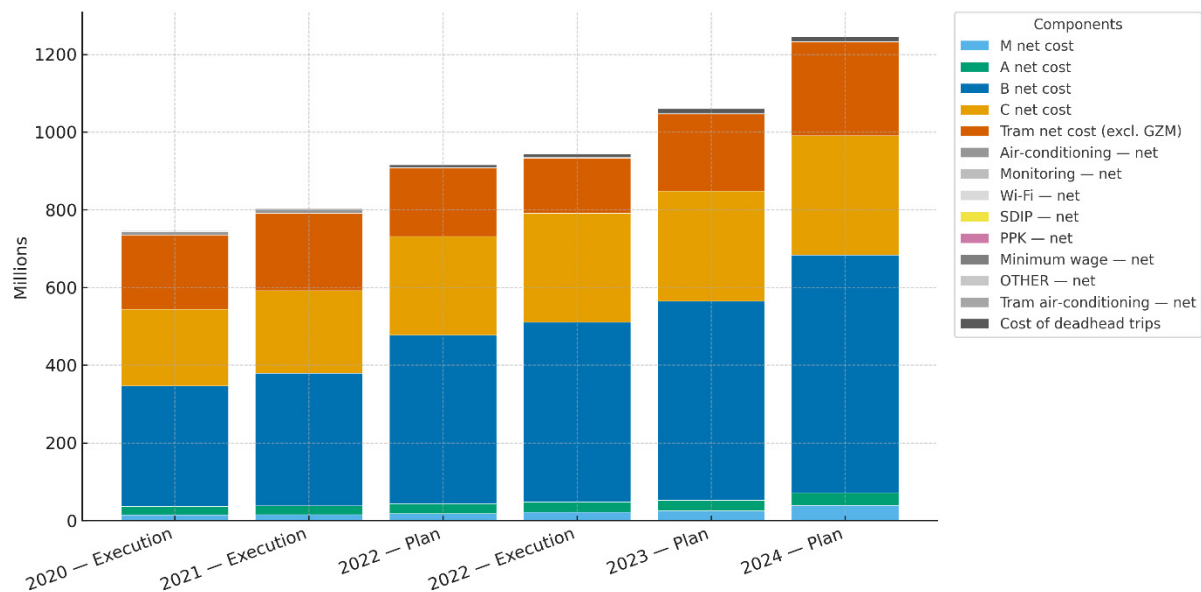
Transport costs financed by municipalities in 2020-2024

Years	2020	2021	2022	2022	2023	2024
	Execution	Execution	Plan	Execution	Plan	Plan
M net cost	15,03	15,68	18,24	21,41	25,23	39,71
A net cost	21,24	22,45	25,20	26,77	27,44	31,97
B net cost	310,55	340,99	433,76	462,36	512,19	611,99
C net cost	197,27	212,82	254,81	280,71	283,45	307,76
T net cost	191,22	199,63	175,33	142,15	198,87	240,57
KLIMA net cost	8,48	9,08	0,00	0,00	0,00	0,00
MONITORING net cost	2,56	2,81	0,00	0,00	0,00	0,00
WIFI net cost	0,49	0,53	0,00	0,00	0,00	0,00
SDIP net cost	0,20	0,19	0,00	0,00	0,00	0,00
PPK net cost	0,61	0,68	0,05	0,10	0,00	0,00
Minimum wage - net	0,14	0,24	0,00	0,37	0,22	0,00
OTHER - net	0,32	0,00	0,00	0,05	0,00	0,00

Cont. table 2.

Tair-conditioning - net	0,00	0,00	1,04	1,02	1,20	1,25
Cost of deadhead trips	0,00	0,00	7,21	9,12	11,99	12,86
Transport costs financed by municipalities	748,11	805,10	915,63	944,06	1 060,61	1 246,11

Source: Author's own elaboration based on GZM data.

**Figure 1.** Structure of transport costs.

Source: author's own elaboration.

Based on the analysis of the data presented in Table 1, the main cost trends are summarized in.

Table 3.

Main trends in net costs (PLN million)

Year	Data type	Total costs (PLN m)	y/y change	Notes
2020	Execution	748,1	–	first year of the pandemic; service reductions
2021	Execution	805,1	7,60%	recovery of transport work
2022	Plan	915,6	13,70%	indexation of fuel and wages
2022	Execution	944,1	3,10%	execution close to plan
2023	Plan	1 060,60	12,40%	expansion of service offer
2024	Plan	1 246,10	17,50%	inclusion of new standards and services

Source: Author's own elaboration based on GZM data.

Net costs are growing by an average of 10-12% per year, in line with rising operating and inflationary trends in public transport. In 2021, a rebound was recorded after the declines in 2020. The 2023-2024 plans already include new cost components (e.g., minimum wage, SDIP, PPK). The combined share of the three largest components (B, C, T) exceeds 93% of net costs. Other elements (monitoring, WIFI, SDIP, PPK, etc.) are marginal. The trend line shows a persistent increase in operating costs after 2020.

The increase in costs results from two groups of factors:

- macroeconomic (operator rate indexation, rising minimum wage, fuel inflation),
- systemic (expanded service offer and more metropolitan lines).

The dominance of B and C indicates these are the main bus-service categories. The stability of plan vs. execution confirms the quality of ZTM GZM's financial planning. The T net-cost component declines from 25% (2021) to 19% (2023 plan). In 2020-2024, net costs show systematic growth: the pace slows in actual execution but accelerates in financial plans for 2023-2024. In real terms (after CPI), the increase was approx. 6% annually, indicating moderate effective growth; the small plan-execution gap in 2022 supports the robustness of the planning mechanism.

5. Annual Municipal Contribution - Comparative Analysis

The variable part of the annual contribution for municipalities is determined in accordance with the resolution of the Management Board of the Upper Silesian-Zagłębie Metropolis on adopting the document "Principles for calculating the variable part of the annual contribution for GZM municipalities and subsidies for non-GZM municipalities". Both the above-mentioned costs and the following elements are used in the calculation:

- Ticket revenues.
- Organizational costs.
- Lost revenues (free travel for children and youth).
- Lost revenues (rail).
- Lost revenues (other).
- Shelters (W).
- Other settlements (I).

Aggregate values for the elements constituting the variable contribution are shown in Table 4.

Table 4.

Variable part of the annual municipal contribution (PLN million)

	2020	2021	2022	2022	2023	2024
Values	Execution	Execution	Plan	Execution	Plan	Plan
Transport costs financed by municipalities	748,11	805,10	915,63	944,06	1 060,61	1 246,11
Ticket revenues	126,46	145,75	260,75	189,11	283,00	232,00
Organizational costs	21,92	13,52	19,66	13,89	20,00	21,51
Lost revenues (free travel-children & youth)	15,42	15,70	16,42	18,19	15,70	19,44
Lost revenues (rail)	1,15	1,54	1,13	3,08	2,56	2,71
Lost revenues (other)	0,00	0,06	0,00	2,64	0,00	0,00

Cont. table 4.

Variable part of the annual municipal contribution (ZCzS)	627,00	655,57	657,00	744,92	779,35	1 013,47

Source: Author's own elaboration based on GZM data.

The dynamics of costs financed by municipalities rose from PLN 748 million in 2020 to PLN 944 million in 2022 (+26% in two years). In the 2024 plans, the amount increases to PLN 1.25 billion (+66% vs. 2020), driven by a more intensive service offer and higher unit operating costs. Ticket revenues grow but irregularly: 2020-2021 saw +15.3% (post-pandemic demand recovery). The 2022 plan assumed a jump to PLN 260.8 million, but actual 2022 execution reached only PLN 189.1 million (27% below plan). The 2023-2024 plan of PLN 283-232 million indicates stabilization at a higher level, tempered by realistic revenue potential.

Organizational costs fluctuate around PLN 13-22 million annually (~2% of total costs). They were lowest in 2021 (PLN 13.5 million) during post-pandemic restructuring. From 2022, they rise again to over PLN 21 million in the 2024 plan, likely reflecting added planning and accounting functions within ZTM.

Total lost revenues due to concessions, free travel for children/youth, and rail:

- 2020: 16.6 million PLN,
- 2021: 17.3 million PLN,
- 2022: ~23.9 million PLN,
- 2023: 17.3 million PLN,
- 2024: Plan: 22.1 million PLN.

The largest increase concerns rail lost revenues between 2021 and 2022. Rising lost-revenue items (especially rail) call for balancing through GZM budget subsidies/compensation. Ticket revenues cover no more than one-fifth of costs, so municipal co-funding must be maintained. While plans foresee further cost growth in 2023–2024, there is also potential to improve farebox income. Correlation analysis suggests that greater service work does not directly translate into higher revenue-evidence of low demand elasticity relative to supply.

6. Variable Part of the Annual Municipal Contribution Including Additional Settlements

Final settlement also requires additional items. An example is extra costs charged to tram operations. Over the years, these have been allocated differently among partners: up to 2021 they were fully financed by individual municipalities; from 2022, part of these costs was separated and financed directly by GZM. Additional tram-related cost elements include: air-conditioning in trams, cost of deadhead trips (depot to terminal stops), stop charges, property tax, perpetual usufruct fees, amortization of other assets, maintenance of tracks, catenary and

substations, infrastructure amortization, rolling-stock amortization, bond redemption, and financial costs.

Table 5.

Additional settlements for municipalities (PLN million)

	2020	2021	2022	2022	2023	2024
Values	Execution	Execution	Plan	Execution	Plan	Plan
Variable municipal contribution (ZCzS)	627,00	655,57	657,00	744,92	779,35	1 013,47
Additional remuneration of Tramways - current part (TrBi)	9,17	11,16	68,63	70,04	81,31	97,58
• <i>Stop charges</i>	0,45	0,41	0,50	0,41	0,50	0,50
• <i>Property tax</i>	8,72	10,75	22,75	20,42	25,41	33,79
• <i>Perpetual usufruct of land</i>	0,00	0,00	0,39	0,40	0,45	0,43
• <i>Amortization of other assets</i>	0,00	0,00	11,39	12,65	12,43	14,40
• <i>Maintenance of tracks, catenary, substations</i>	0,00	0,00	33,59	36,16	42,51	48,46
Additional remuneration of Tramways - investment part (TrIn)	23,03	27,67	48,52	49,37	101,57	112,86
• <i>Infrastructure amortization</i>	7,87	10,00	15,50	12,73	19,84	25,11
• <i>Rolling-stock amortization</i>	5,58	8,90	11,42	10,92	11,81	11,32
• <i>Bond redemption</i>	4,61	2,52	6,22	0,00	0,00	4,51
• <i>Financial costs</i>	4,97	6,26	15,38	25,72	69,92	71,91
Shelter settlement (R1)	0,23	0,00	2,30	2,96	1,08	1,53
Audit settlement - PKM Świerklaniec (R2)	0,00	0,00	0,00	0,01	0,00	0,00
Audit settlement - PKM Tychy (R3)	0,00	0,00	0,00	-0,99	0,00	0,00
Audit settlement - Tychy Trolleybus Lines (R4)	0,00	0,00	0,00	0,93	0,00	0,00
Top-up for line 69 in Żory (R5)	0,00	0,03	0,00	0,04	0,00	0,00
Variable municipal contribution incl. additional settlements (ZCzS + TrBi + TrIn + R1 + R2 + R3 + R4 + R5)	659,41	694,43	776,44	867,27	963,31	1 225,43

Source: Author's own elaboration based on GZM data.

A rise is evident from PLN 627 million in 2020 to PLN 867 million in 2022 (+38% in two years). In the 2024 plans it reaches PLN 1.23 billion-an +85% increase vs. 2020-equivalent to an average annual growth (2020-2024) of +16.6%. The rise reflects growing operating costs and the mechanism adding new investment and amortization components. An increasing share of municipal financing goes to tram infrastructure upkeep and development. From 2022, previously absent items appear (amortization of other assets; maintenance of tracks, catenary, substations; bond redemption; financial costs). Together, these generate over PLN 60 million

in 2024 (~5% of the entire contribution). Other settlements have a minimal share (below PLN 1 million combined). In 2020-2022, municipalities financed 85-92% of operating costs-standard for public systems. Continued growth of the municipal contribution reflects GZM's expanding competences and rising service costs; tram funding, especially infrastructure investment (TrIn), is particularly dynamic. Further growth to 2025 is likely but will require parallel improvements in cost efficiency by operators and ZTM.

7. Comparative Analysis of Municipalities (Top 10)

To illustrate the increased burden of the variable part of the annual contribution, a detailed analysis was carried out for ten selected municipalities, presented in Table 6.

The comparative analysis of municipalities provides an insight into the spatial differentiation of transport financing within the Upper Silesian-Zagłębie Metropolis. The assessment of the ten largest municipalities (by total contribution) reveals both structural diversity and functional specialization within the GZM transport system.

The year 2022 was selected as the reference period for the comparison because it represents the first full post-pandemic year with stabilized transport demand and restored service supply.

Table 6.

Top 10 municipalities by total transport costs in 2022 (Execution)

Rank	Municipality	Total contribution (PLN m)	Share of total (%)	Change vs 2021 (%)	Notes
1	Katowice	103,7	13,40%	8,6	Largest share in financing metropolitan transport.
2	Gliwice	82,1	10,60%	7,2	Strong increase due to metropolitan route network and TŚ services.
3	Sosnowiec	65,4	8,40%	6,9	Stable share; bus and tram lines dominate.
4	Tychy	58,9	7,60%	9,1	Significant share of electric and trolleybus fleet costs.
5	Zabrze	52,7	6,80%	8,2	Higher spending on tram lines and stop shelters.
6	Bytom	46,3	6,00%	7,9	High costs of track network maintenance.
7	Ruda Śląska	43,2	5,60%	6,4	Increased organizational costs after new routes added.
8	Dąbrowa Górnicza	41,0	5,30%	6,0	Greater share in metropolitan M-type lines.
9	Chorzów	37,8	4,90%	5,5	Stable share; higher tram-infrastructure amortization costs.
10	Jaworzno	29,5	3,80%	4,9	High costs of electric fleet and SDIP.

Source: Author's own elaboration based on GZM data.

The data clearly show the dominance of core municipalities, particularly Katowice, which alone accounts for over 14% of all transport costs in the GZM system. Together with Gliwice and Sosnowiec, these three cities generate approximately 32% of the total municipal financing.

This concentration reflects the polycentric nature of the Metropolis, where the largest urban centers provide the backbone of transport demand and financial contribution. Nevertheless, medium-sized cities - such as Ruda Śląska, Zabrze, and Tychy - maintain a stable and proportionate level of participation, confirming their growing functional role in the metropolitan transport network.

The differences in per capita contributions are driven primarily by the extent of service coverage and the frequency of metropolitan lines. For example, Katowice and Gliwice maintain dense urban networks and a higher number of metropolitan routes, whereas peripheral municipalities (e.g., Jaworzno and Bytom) show smaller scale and fewer high-frequency services.

When comparing cost dynamics, the average annual increase in municipal contributions between 2020 and 2022 amounted to approximately 11%, with the highest relative growth recorded in Tychy (+14%) and Ruda Śląska (+12%). These results correspond to network extensions, new rolling stock acquisitions, and the expansion of the common fare system.

The results confirm a positive correlation between operational work (in vehicle-kilometers) and the level of municipal contribution, which supports the conclusion that local financing mechanisms are aligned with the actual intensity of transport services.

8. Conclusions and Recommendations

The conducted analysis of the financial and operational data of the Upper Silesian-Zagłębie Metropolis (GZM) for the years 2020-2024 allows for several key conclusions concerning the functioning, efficiency, and sustainability of the metropolitan public transport system:

1. Systematic cost increase: Total transport costs financed by municipalities increased by approximately 66% during the analyzed period - from PLN 748 million in 2020 to PLN 1.25 billion in 2024. This dynamic was mainly driven by macroeconomic factors, including inflation, energy prices, and wage growth, as well as structural changes in the service offer.
2. Stable share of ticket revenues: Ticket revenues accounted for 18-22% of total costs, which confirms the social nature of the GZM transport model. Despite the introduction of the metropolitan fare system, the degree of self-financing remained stable, reflecting a balance between economic and social policy objectives.

3. Dominance of bus transport: Bus services continue to generate over 90% of total expenditure, although tram and trolleybus components have shown faster growth, linked to investment and modernization projects.
4. Increasing role of investment expenditures: The rising share of amortization and infrastructure maintenance costs (particularly tram-related) indicates a shift towards an investment-oriented financing model - consistent with sustainable mobility and decarbonization objectives.
5. Spatial differentiation of efficiency: Core cities (Katowice, Gliwice, Sosnowiec) exhibit the highest operational efficiency, while peripheral municipalities show lower ratios due to longer routes and reduced passenger density. The correlation between population density and cost efficiency confirms the spatial-economic logic of the GZM transport system.

The conducted research forms the basis for the following strategic recommendations:

1. Introduce performance-based monitoring: Develop a comprehensive set of cost-efficiency indicators (PLN/km, revenue/km, cost per passenger) to enable ongoing monitoring of system performance and inter-municipal comparisons.
2. Implement predictive modeling of financial needs: Utilize data-driven forecasting tools (e.g., Power BI, regression models) to anticipate financial requirements for the upcoming fiscal years and optimize the municipal contribution formula.
3. Strengthen cost control and transparency: Increase data integration between ZTM and municipalities, ensuring full transparency of operational costs, subsidies, and the distribution of the variable contribution (*składka zmienna*).
4. Enhance fare and revenue policy: Consider adaptive pricing mechanisms (e.g., zonal or time-based fares) to improve cost recovery while maintaining accessibility and social inclusion.
5. Promote zero-emission and energy-efficient transport: Prioritize projects that reduce operational costs in the long term - such as the expansion of electric bus fleets and tram modernization - aligning financial sustainability with environmental goals.

The research confirms that the GZM transport system demonstrates high organizational maturity and resilience to external shocks (e.g., the COVID-19 pandemic and inflationary fluctuations). At the same time, it underscores the need for continuous adaptation of financial mechanisms to ensure sustainable growth.

The proposed analytical framework - based on data integration, indicator monitoring, and predictive modeling - can serve as a foundation for the development of a metropolitan cost-efficiency management system, supporting decision-making at both the local and regional levels.

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RESILIENCE STRATEGIES – DEFINITION, CATEGORIZATION AND LITERATURE REVIEW

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Purpose: The purpose of this text is to identify and categorize various types of corporate resilience strategies based on a literature review.

Design/methodology/approach: The study was conducted in a mixed convention. The methodology was developed pursuant to the rigour of a literature review, taking into account the recommendations of PRISMA. On the basis of the adopted strategy for searching for scientific texts in the EBSCO database, 252 texts were returned, with 50 texts being approved for the final analysis after the implementation of the elimination criteria. The study used the qualitative typology method. In addition, a selection of bibliometric analysis, keyword analysis and content analysis tools were also used in the literature review.

Findings: The main outcome of the conducted analyses is the formulation of a definition of corporate resilience strategies and the development of their typology based on the results of the literature review of texts addressing this research issue, published between 2020 and 2025.

Originality/value: The added value arising from this literature review is primarily the identification of the currently used types of corporate resilience strategies and their categorization in the form of a typology based on the criterion of the various guiding objectives pursued by enterprises in developing and strengthening resilience mechanisms. Another original element of the study findings is the presentation of the main thematic currents currently emerging in strategic management focused on organisational resilience.

Keywords: resilience, strategy, enterprise, strategic management.

Category of the paper: Literature review.

1. Introduction

Given the recent history of global crises and the resultant conditions in which business organizations conduct their activities, it is important to recognize that organizational resilience is now an extremely important research topic, requiring constant exploration in search of the best practices for building and strengthening resilience mechanisms, which, unfortunately, often prove too weak to respond to the challenges of today's risk-prone economic environment.

Previous research texts on the topic of resilience tend to focus on threads such as: building a resilient enterprise; enterprise resilience in the face of global crises, pandemic and natural disasters; concepts and attributes of enterprise resilience; or management tools for adaptation, survival and renewal during crisis situations. By contrast, researchers much less often focus their attention on the topic of strategies supporting enterprise resilience (Bąk, 2025). And it is the strategic, long-term and plan-based approach to resilience that can guarantee the real effectiveness of resilience mechanisms in confrontation with a crisis situation.

Furthermore, existing review texts on the topic of organizational resilience often concentrate on the integration of resilience issues with other aspects conditioning dynamic abilities to cope with crisis situations, such as leadership (Gichuhi, 2021; Istiqaroh et al., 2022), business continuity (Ostadi et al., 2023) or sustainability (Abdullahi et al., 2023; Ciasullo et al., 2024; Florez-Jimenez et al., 2024).

However, in the academic literature there is a clear deficit of studies presenting catalogues of resilience strategies and their typologies aimed at helping enterprises to select resilience strategies tailored to their individual needs. In view of this research gap, the purpose of this text is to identify and categorize various types of corporate resilience strategies based on a literature review.

2. Theoretical background

2.1. The role of strategic management in the shaping of enterprise resilience

As it turns out, an incidental, non-cyclical approach to organizational resilience does not work in the conditions of most crises, even less so in crises with a high potential for development and a global character. The academic and business worlds more and more often express the conviction that only a cyclical, long-term, strategic approach to building resilience, tested and refined also in non-crisis conditions, can actually be effective in a real crisis. This purpose can be served by conceptual approaches based on strategic management as a basis for creating resilience mechanisms.

Concepts of this type are increasingly reflected in the treatment of resilience itself as a strategic attribute which should find its place in the strategic management process and should determine the main strategies of enterprises. Consistent with this approach seems to be the concept that defines strategic resilience as the capability to turn threats into opportunities (Colberg, 2022). The goal is to maximize an organization's potential for variability in order to adapt it as much as possible to the conditions caused by a crisis and even to turn a crisis into growth opportunities, which was the case in various business sectors during the COVID-19 pandemic.

Another concept that coincides with the necessity to take resilience into account in the strategic management process is that of a “robust company” (Gleißner, 2023). It indicates the need to integrate risk management, strategic management and corporate ratings in order to ensure the robustness of an enterprise, understood as the ability to survive crises while maintaining a level of performance that ensures success in the long term, thus directly influencing the level of resilience.

It seems, therefore, that the role of strategic management in shaping resilience is indisputable. A holistic approach to this issue, such as that presented in the SMOR (Strategic Management of Organisational Resilience) concept (de Moura, Tomei, 2021) clearly confirms this thesis, further indicating which specific areas of strategic management should be prioritized in building resilience mechanisms. These areas include systematic analysis of scenarios, partnerships with stakeholders, systematic sharing of information, decision-making ability, financial management, rapid response and learning ability.

2.2. Understanding and objectives of resilience strategies

A resilience strategy can be understood in different ways, depending on the context in which and in relation to which actors it is considered. With regard to management, particularly risk management in organizations, the understanding of resilience strategies is quite well structured.

The most general definition of a resilience strategy, which can apply to individuals, businesses, communities or countries, is as follows: “A resilience strategy refers to a set of actions, plans, and measures put in place to enhance the resilience of individuals, organizations, communities, or systems in the face of challenges, disruptions, or adverse events. It involves proactive efforts to build adaptive capacity, mitigate risks, and effectively respond and recover from shocks or stresses” (Bhat et al., 2023).

There are a number of guidelines, drawn from the best practices of enterprises grappling with crises and implementing different types of resilience strategies, which can provide guidance for supplementing an approach to resilience with a strong strategic dimension and formulating a resilience strategy tailored to the needs of a particular business environment. These guidelines include (Deloitte, 2025):

- treating crises as catalysts for strategic transformation,
- accelerating towards the future on the basis of learning from crisis experiences,
- responding to uncertainty,
- taking actions (in response to the uncertainty of events) as a key to maintaining stability and business continuity,
- scenario planning,
- reshaping business architecture,
- defining core and edge (activities of primary importance to resilience include both those that serve the core objectives of an organisation and new business activities resulting from collaboration with external stakeholders).

A resilience strategy should not be confused with strategic resilience, which denotes the capacity of organisations to proactively transform and renew through innovation to minimize the effects of unknown future crises (Dieterle, Ducheck, 2023). It is therefore one of an enterprise's levels of maturity in terms of resilience (arguably the highest), rather than its leading operational idea (i.e. a strategy).

Some conceptual approaches related to relationships between a strategy and resilience treat the development and maintenance of resilience itself as a long-term strategy. Resilience can then be defined as a strategy that not only helps to survive change, challenges and crises, but also provides an opportunity to reexamine the organization's identity (Nelson, 2021).

Based on the reviewed concepts of strategic approaches to resilience, it is possible to identify the main objectives that guide actors building resilience strategies. These objectives can include: transforming business to reshape it for the future while sustaining operations and maintaining trust (EY, 2025), anticipating material changes to the operating environment, systemically developing and testing strategic plans in the context of changes, allocating resources and creating value in ways that enable success in multiple potential futures (Cramer, Diamante, 2025).

3. Methodology

The main objective of this study was to identify and categorize organisational resilience strategies based on a literature review. In order to identify the resilience strategies currently followed by enterprises, we searched for scientific texts in the EBSCO database, which is an integrated database of academic texts within the discipline of management science. We performed text searches using keywords such as organizational resilience, organizational resiliency, resilient organization, enterprise resilience, resilient enterprise, strategy, strategies and strategic. The aforementioned keywords were supposed to be used in the titles of texts. The search was conducted on 15 June 2025.

To ensure the integrity of the intended study, we followed the methodological rigour of a literature review (Xiao, Watson, 2019) by developing an EBSCO database text search strategy and inclusion criteria. We applied the following inclusion criteria: 1) only peer reviewed articles or conference proceedings, 2) only texts in English, 3) texts published between 2020 and 2025, 4) only texts available in Open Access.

The texts retrieved on the basis of the strategy outlined above underwent an elementary bibliometric analysis based on such bibliometric indexes as the number of publications, the date of issue and keywords (Khan et al., 2020). An extension of the keyword analysis was to collate them with regard to the criterion of frequency of occurrence in the texts approved for the review and the criterion of chronology. The keywords were also analysed in terms of thematic links

among them. We also used exclusion criteria in the keyword analysis, rejecting from the analyses those keywords that did not directly reflect the subject matter of the texts reviewed (e.g. names of research methods, countries, etc.). We used the keyword network analysis tools available in the VoSViewer software.

In the next step, we became familiar with the abstracts and full texts of the retrieved texts in order to identify resilience strategies mentioned in them. For this purpose, we used elements of content analysis.

Conducting a thorough analysis of the identified resilience strategies, we followed the methodology of exploratory research (Saunders et al., 2009). This constituted the first stage of the substantive analysis of the identified strategies and, at the same time, the starting point for the second stage, which was the categorization of the identified strategies. In order to categorize them, we used the methodology of qualitative typology, which, as intended, allows the researcher to group the objects of analysis with an arbitrary catalogue of criteria for assessing their similarity (Babbie, 2003; Rzepiński, 2016).

The detailed search strategy that was applied in this study is presented in Figure 1.

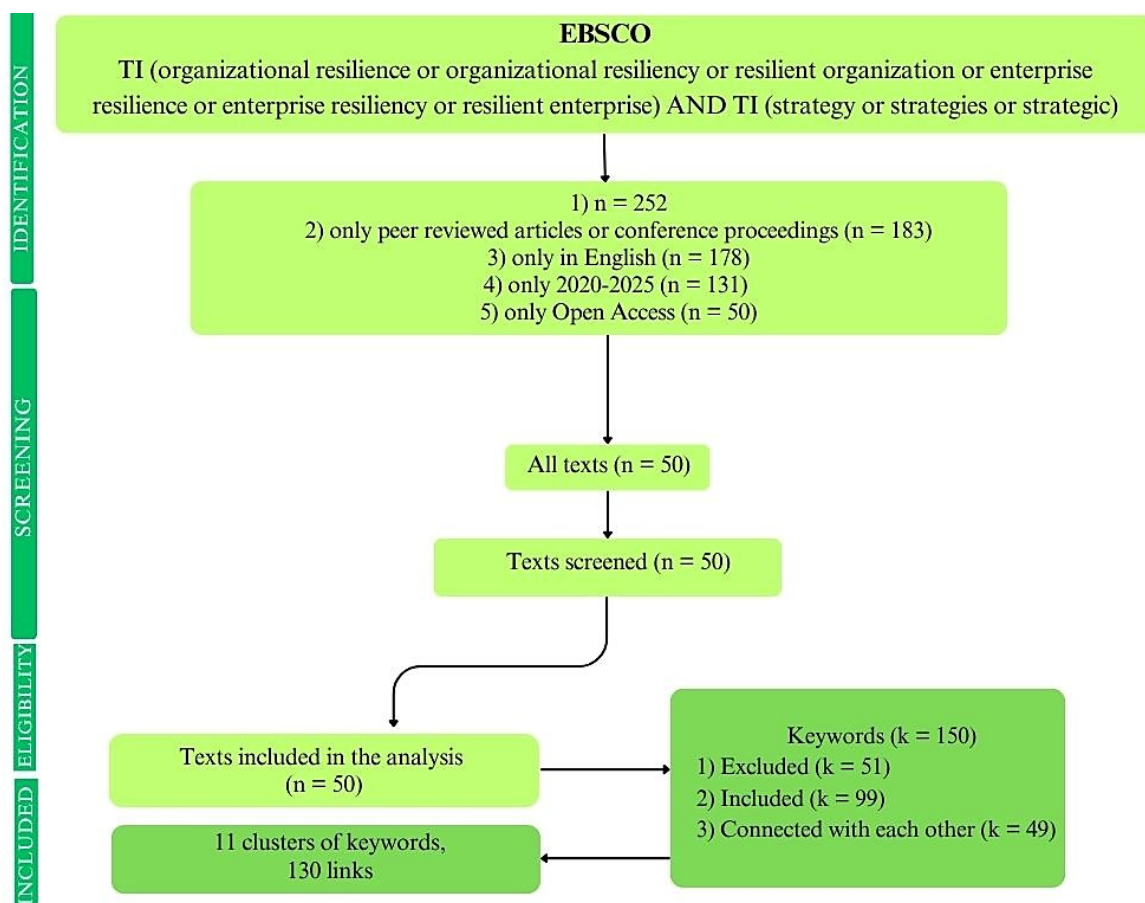


Figure 1. Search strategy based on the PRISMA guidelines.

Source: own work.

4. Results

4.1. Search results and elements of bibliometric analysis

The application of the search strategy shown in Figure 1 resulted in the identification of 252 scientific texts. After adopting the detailed inclusion criteria, this number was reduced to 50 texts, which were approved for further analysis. Having reviewed the abstracts of the texts, we concluded that they fulfilled the inclusion criteria and none of them needed to be eliminated due to a mismatch in content. Within the time range covered by the study (2020-2025), we found that the largest number of texts qualified for analysis had been published in 2024 (16), followed by 2023 (15), and then 2025 (7). In interpreting these trends, however, it should be taken into account that we conducted our review in mid-2025, so the general upward trend observed from the beginning of the period covered by the study can be expected to continue. The increase in the number of texts on enterprise resilience itself, or on strategic approaches to its development, is justified by the crisis-ridden global situation in which enterprises have been operating essentially continuously since 2020: first under conditions marked by the pandemic, then by the armed conflict in Ukraine, the energy crisis, inflationary problems, etc. The quantitative distribution of the texts selected for the review is presented in Figure 2.

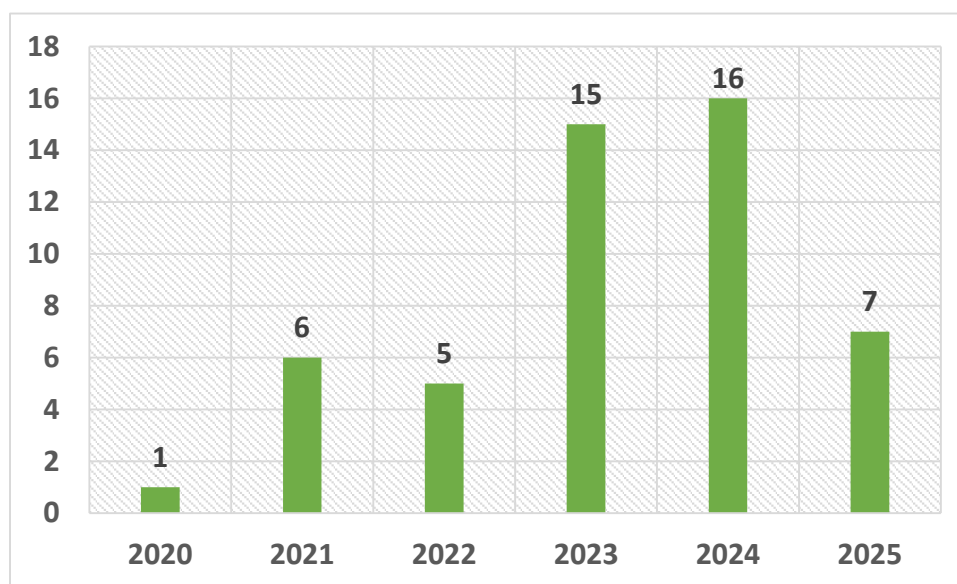


Figure 2. Chronological distribution of the texts analysed.

Source: own work.

4.2. Keywords analysis

An extremely valuable step in the first part of the literature review was a keyword analysis, with particular emphasis on a keyword network analysis. We first analysed the frequency of occurrence of the keywords identified in the texts included in the study. We identified a total of 150 keywords, which were reduced to 99 after content-based verification. Of these 99 keywords, 49 showed substantive links with each other, so we qualified these keywords for final analysis. They formed 11 thematic clusters, while also showing 130 links with each other.

It turned out that the most frequently recurring keyword, and at the same time the one showing the most thematic links to other keywords, was the term “organizational resilience”. Interestingly, the second most frequently used word was “Covid-19”. The distribution of the keywords with regard to the occurrence frequency criterion is shown in Figure 3.

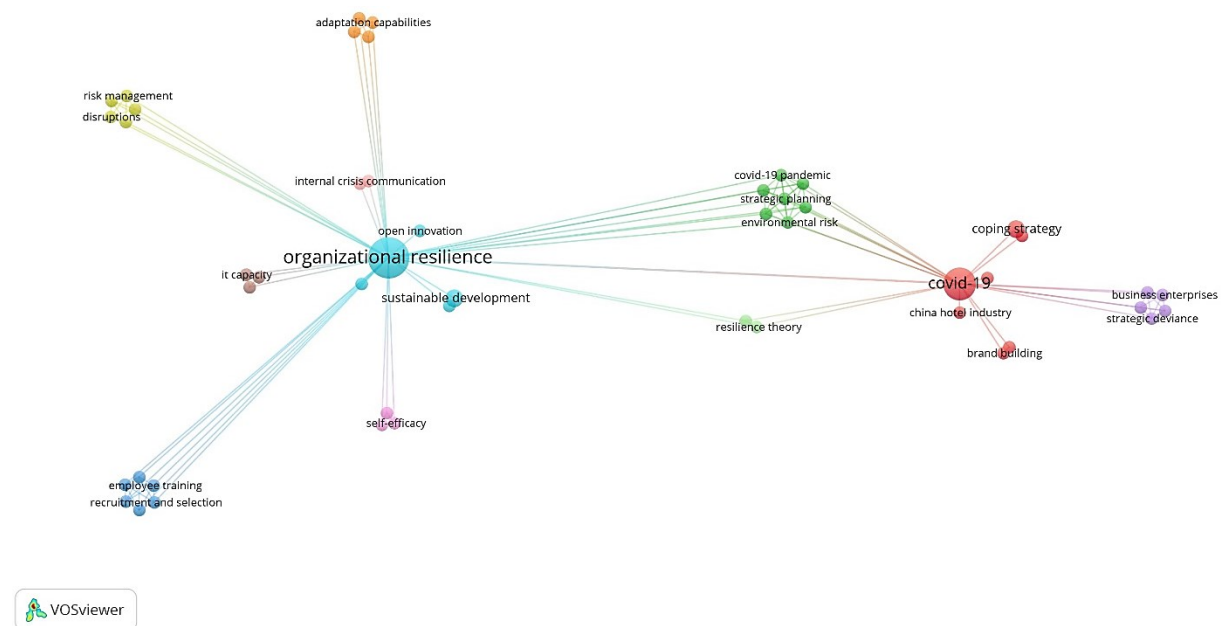


Figure 3. Keywords analysis – the occurrence frequency criterion.

Source: own work based on VOSviewer.

In the next step, the keywords were analysed against the criterion of chronology. It turned out that the latest to start appearing in the texts were keywords such as “sustainable development”, “employee training”, “recruitment and selection” and “coping strategy”. The chronological distribution of the keywords is shown in Figure 4.

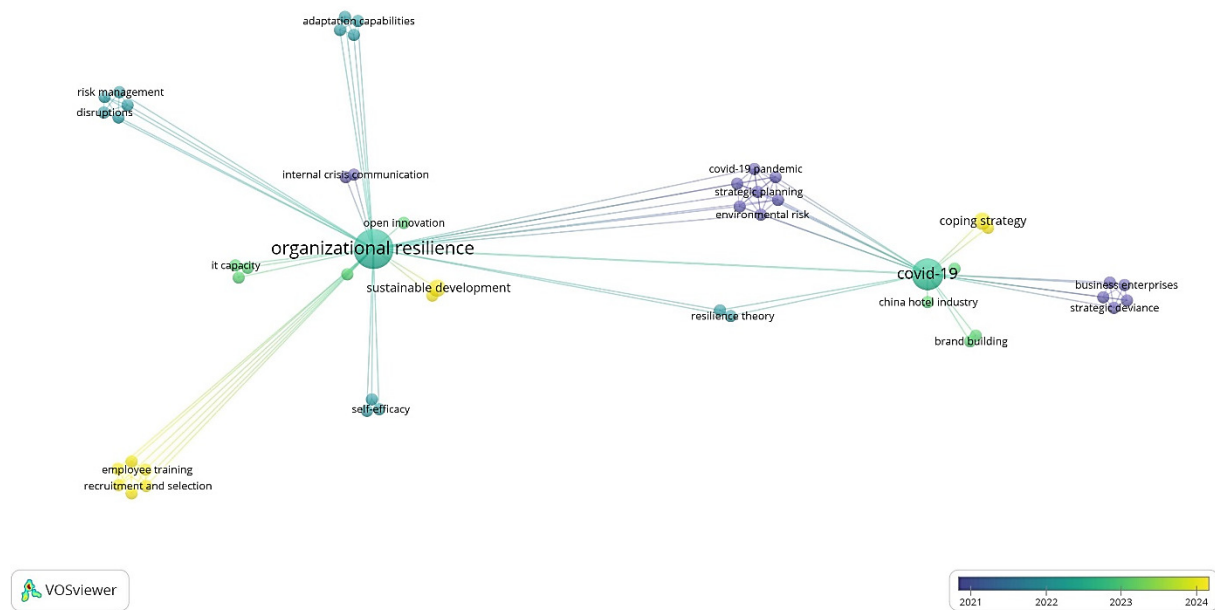


Figure 4. Keywords analysis – the chronology criterion.

Source: own work based on VOSviewer.

4.3. Typology of resilience strategies

The review of the selected texts allowed us to identify the types of resilience strategies with an indication of the sectors to which each strategy was dedicated. A summary of these types of resilience strategies is presented in Table 1.

Table 1.
Summary of types of resilience strategies

Author (year)	Type of resilience strategy	Dedicated sector
(Melvani et al., 2020)	Livelihood strategy	Farming enterprises
(Fathi et al., 2021)	Foresight strategy	Pharmaceutical enterprises
(Kodis et al., 2021)	Retreat strategy	Conservation enterprises
(Utami et al., 2021)	Mitigation strategy	MSMEs
(Kim, 2021)	Internal crisis communication strategy	All enterprises
(Kong et al., 2021)	Diversification strategy	Capital market enterprises
(de Moura et al., 2021)	Holistic SMOR strategy	All enterprises
(Cordes, 2022)	Individual workforce strategy	Healthcare enterprises
(Yu et al., 2022)	Human resource strategy	All enterprises
(Heredia et al., 2022)	“Strategy tripod”	All enterprises
(Ahmić, 2022)	Strategic sustainability orientation	All enterprises
(Baghersad, Zobel, 2022)	Operational strategy	All enterprises
(Žak, 2023)	ESG strategy	All enterprises
(Verreynne et al., 2023)	Resilience measurement strategy	SMEs
(Erdiaw-Kwasie et al., 2023)	Coping strategy	SMEs
(Mirghaderi et al., 2023)	“Blue ocean strategy”	Startups
(Pertheban et al., 2023)	Ambidextrous and dynamic capabilities strategy	SMEs
(Jiang et al., 2023)	Non-market strategy	All enterprises
(Trejo-Arista et al., 2023)	Environmental resilience strategy	Livestock enterprises
(Ho et al., 2023)	Leadership strategy	Hospitality and tourism enterprises
(Cekuls, 2023)	Competitive intelligence and AI strategy	All enterprises

Cont. table 1.

(Gu et al., 2023)	Recovery strategy	Hotels
(Muluh, Lekgau, 2023)	Adaptive strategy	SMEs
(Barbhuiya, Chatterjee, 2023)	Innovative strategy	Hospitality enterprises
(Mawonde et al., 2023)	Supply chain resilient strategy	Humanitarian organizations
(Forliano et al., 2023)	Digital maturity strategy	All enterprises
(Wided, 2023)	Flexibility strategy	SMEs
(Liang et al., 2024)	Change strategy	Manufacturing enterprises
(Takroui, 2024)	Strategic sustainability	Service sector
(Zapłata et al., 2024)	Circular strategy	Manufacturing enterprises
(Adamu et al., 2024)	Internal crisis management strategy	All enterprises
(Chen, He, 2024)	Resilience measurement and enhancement strategy	Bay Port Enterprises
(Endaryono et al., 2024)	Leadership strategy	Healthcare enterprises
(Xia et al., 2024)	Enhancing corporate innovation strategy	All enterprises
(Direction, 2024)	Non-market strategy	All enterprises
(Mushtaq, Akhtar, 2024)	Sustainable HRM strategy	Hotels and restaurants
(Wided, 2024)	Flexibility strategy	SMEs
(Park, Seo, 2024)	Bricolage strategy	SMEs
(Engelen et al., 2024)	Pre-shock emphasis on innovation strategy	All enterprises
(Candrasa et al., 2024)	Change management strategy	All enterprises
(Georgescu et al., 2024)	Human resource management strategy	Public institutions
(Stanojević, 2024)	Thriving strategy	Telecommunications enterprises
(Abuzaid, 2024)	Corporate diversification strategy	Telecommunications enterprises
(Charisma et al., 2025)	Strategic entrepreneurship	Micro-enterprises
(Zacky, Zacky-Eze, 2025)	Communication strategy	All enterprises
(Chumpanya & Panpakdee, 2025)	Coping strategy	Agricultural enterprises
(Alkema et al., 2025)	Economic and social security strategy	All enterprises
(Plaček et al., 2025)	Offensive and defensive strategies	Public organizations and social enterprises
(Raza, Anwar, 2025)	Performance strategy	SMEs in tourism industry
(Nohong et al., 2025)	Financial and risk management strategy	SMEs

Source: own work.

The next stage of the study was to categorize the types of resilience selected mentioned in the texts included in the review. Based on this, we developed their typology (Figure 5). The identified strategy types were assigned to the following five categories: 1) resources strategies, 2) adaptability strategies, 3) development strategies, 4) relational strategies, 5) security strategies.

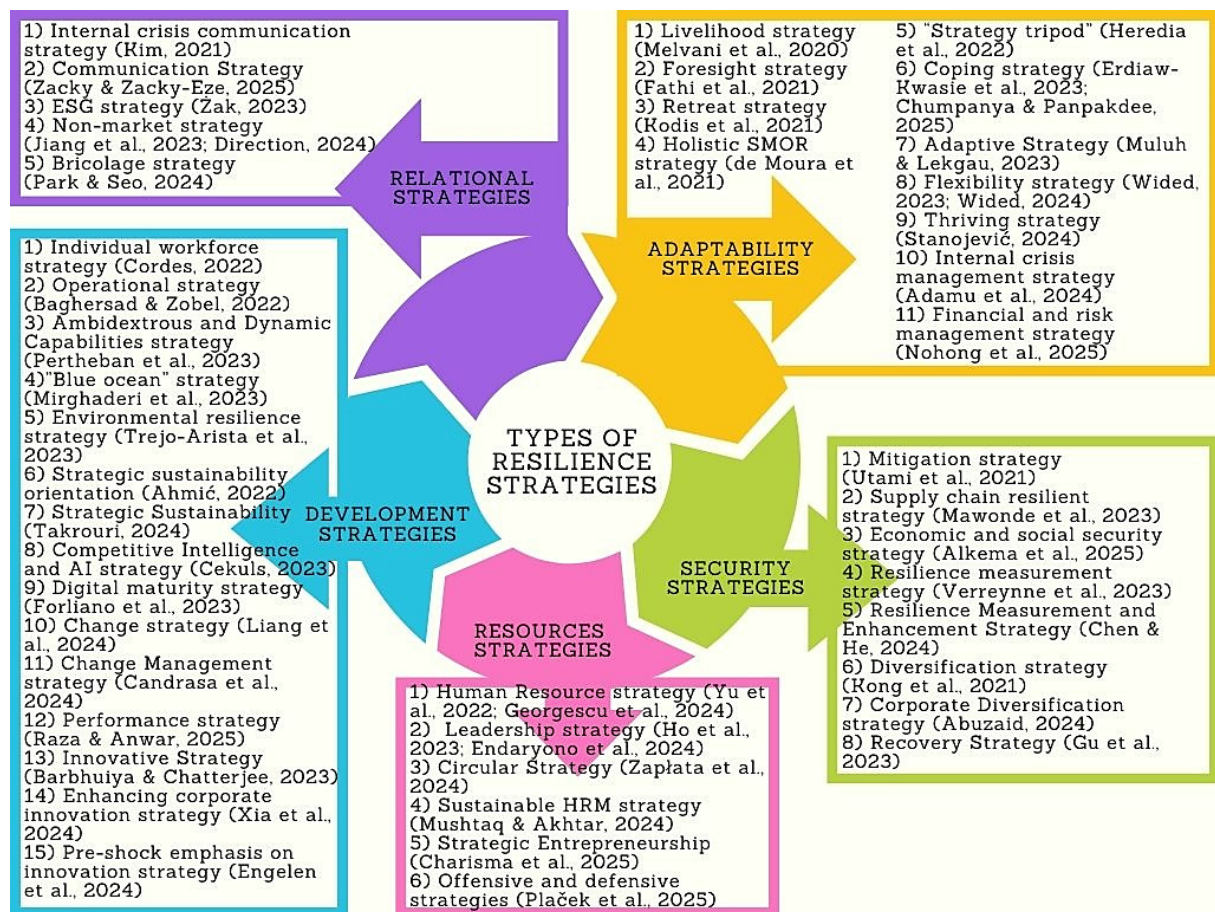


Figure 5. Typology of resilience strategies.

Source: own work.

It turned out that the highest proportion of resilience strategies identified fell into the category of development strategies (15 strategies), followed by adaptability strategies (11 strategies), security strategies (8 strategies), resources strategies (6 strategies) and relational strategies (5 strategies). As for the groups of enterprises to which the identified strategies are dedicated, 34% of the strategies are not dedicated to any specific business sector, but are presented as applicable to any enterprise, regardless of its business profile. However, the remaining 66% of the strategies are specifically adjusted to different sectors or groups of enterprises. Strategies dedicated to SMEs, hospitality and tourism enterprises, manufacturing enterprises, healthcare institutions or other groups of entities often appear.

5. Discussion

Our study shows that the largest number of resilience strategies identified in the literature on the subject are those that fall into the category of development strategies, based on building resilience through an enterprise's position and performance. Strategies in this category assume

that the stronger the position when entering a crisis, the greater the possibility of surviving it and minimizing its negative effects. Enabling the uninterrupted growth of an enterprise despite the occurrence of a crisis situation, including growth that keeps pace with the evolution of digital transformation, seems to be the highest level on the scale of resilience. This category comprises the following strategies: the “blue ocean strategy” (Mirghaderi et al., 2023), innovative strategy (Barbhuiya, Chatterjee, 2023), competitive intelligence and AI strategy (Cekuls, 2023), digital maturity strategy (Forliano et al., 2023), change strategy (Liang et al., 2024), change management strategy (Candrasa et al., 2024), performance strategy (Raza, Anwar, 2025).

Adaptability is a distinguishing factor of another broad category of resilience strategies. Adaptability strategies constitute the most default category when it comes to shaping mechanisms for resilience to various types of crises, as they are based on flexible adaptation to changing conditions. A significant proportion of the identified strategies in this category were implemented during the most prominent global crisis of recent years, namely the COVID-19 pandemic. These strategies are very often based on two aspects: creating resilience mechanisms while getting ready for crisis situations and strengthening resilience once the crisis has been contained. Strategies specific to the stage of creating resilience mechanisms include, for example, the foresight strategy (Fathi et al., 2021), coping strategy (Erdiaw-Kwasie et al., 2023; Chumpanya, Panpakdee, 2025) and flexibility strategy (Wided, 2023; Wided, 2024). On the other hand, the livelihood strategy (Melvani et al., 2020), retreat strategy (Kodis et al., 2021) or thriving strategy (Stanojević, 2024) represent the adaptability category and are specific to the stage of strengthening and improving resilience.

Another group of resilience strategies identified during the course of our study are security strategies, i.e. those that base their ability to counter crises on ensuring security for both business continuity and employees, systems, supply chains, contracts, etc. Strategies in this category include, for example, the mitigation strategy (Utami et al., 2021), supply chain resilient strategy (Mawonde et al., 2023), recovery strategy (Gu et al., 2023) as well as economic and social security strategy (Alkema et al., 2025).

Several of the resilience strategies identified referred directly to concepts based on the availability and optimal use of resources to build resilience to crises, including those of an unpredictable nature. The circular strategy (Zapata et al., 2024) and strategic entrepreneurship (Charisma et al., 2025) are examples of resource strategies. Interestingly, within this group of strategies, there were also those that consider human resources (knowledge, competence, effective management under pressure, leadership, attitudes to risk, etc.) as key to building and maintaining resilience. Such resource strategies are represented by the leadership strategy (Ho et al., 2023; Endaryono et al., 2024), sustainable HRM strategy (Mushtaq, Akhtar, 2024) and human resource management strategy (Yu et al., 2022; Georgescu et al., 2024).

The last and least numerous category of strategies comprises relational strategies, based on the concept of relationship building as a key factor in strengthening defence mechanisms against crises. In this category, we can distinguish the internal crisis communication strategy (Kim, 2021), communication strategy (Zacky, Zacky-Eze, 2025), ESG strategy (Zak, 2023) or non-market strategy (Jiang et al., 2023; Direction, 2024).

6. Conclusions

The conducted study and its results presented in this text fill the identified research gap concerning, firstly, the lack of a typology of enterprise resilience strategies in the academic literature and, secondly, the lack of a compilation of resilience strategies whose effectiveness has been proven in the face of the crises of recent years.

The proposed typology of resilience strategies could give rise to important practical implications. For many enterprises from various business sectors, they can serve as a source of knowledge of what strategies are currently proving effective in creating and strengthening resilience mechanisms in the face of global crises. Furthermore, the sectoral diversification of the strategies analysed can also assist enterprises in selecting a resilience strategy appropriate to their business profile, size and individual circumstances.

The conducted study also has some limitations. The focus on reviewing scientific texts from only one base can be considered as one of them. However, the choice of the EBSCO database is justified because it also integrates texts from other databases and accumulates scientific literature from the discipline of management science. The narrow time range covering the years 2020-2025 can be considered a further limitation. However, being aware of how rapidly approaches and methods to resilience management were evolving and how strongly they correlated with ongoing changes in the macroeconomic conditions of doing business, we wanted to focus only on the most up-to-date strategies.

We are aware that the presented catalogue of resilience strategies followed at present by various enterprises is not exhaustive. Consequently, this area of management studies needs further research focusing, firstly, on identifying newly emerging types of resilience strategies and, secondly, on analysing their effectiveness by means of appropriate measurement tools.

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THE IMPACT OF RFID TECHNOLOGY ON WAREHOUSE AND INVENTORY MANAGEMENT IN A MANUFACTURING COMPANY

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Purpose: The aim of the article is to analyze the impact of RFID technology on warehouse and inventory management on the example of a selected manufacturing company. The research problem took the form of a question: What role does the implementation of RFID technology play in warehouse management?

Design/methodology/approach: The study is based on a case study of the analyzed company, in which a diagnosis of warehouse problems was carried out using tools such as SWOT analysis and Ishikawa diagrams. Then, an RFID implementation model was proposed, taking into account technical infrastructure, system integration (WMS, ERP), staff training and data analysis. The approach combines qualitative analysis and technological solution design in a logistics context.

Findings: The implementation of RFID allowed for the automation of warehouse processes, improved inventory accuracy, reduced number of errors and better management of warehouse space. Goods identification was improved, order fulfillment time was shortened and operational transparency was increased. Potential implementation limitations were also identified and discussed in detail.

Research limitations/implications: The study was conducted on the example of one enterprise, which may limit the possibility of full generalization of the results. Technological, financial and organizational barriers related to the implementation of RFID were also pointed out. Future research is suggested to be extended to other industries and to analyze the impact of RFID in the broader supply chain context.

Practical implications: The research results have direct application in warehouse management practice. The use of RFID can contribute to increasing operational efficiency, reducing logistics costs, improving the quality of customer service and reducing human errors. The proposed model can be used by other companies as a model for implementing the technology.

Social implications: Implementing RFID can improve working conditions by reducing errors and increasing automation. It indirectly affects the quality of services for end customers and can also support the development of modern, sustainable supply chains, having a positive impact on the environment and social responsibility of companies.

Originality/value: The paper adds value by presenting a comprehensive RFID implementation model in the operational context of a manufacturing enterprise. A unique element is the combination of the analysis of logistic problems with the proposal of a practical technological

solution. The recipients are logistics managers, warehouse management practitioners and RFID technology researchers.

Keywords: RFID, warehouse management, process.

Category of the paper: Research paper.

1. Introduction

RFID (Radio Frequency Identification) technology is playing an increasingly important role in modern warehouse and inventory management, introducing significant improvements to everyday logistics operations (Attaran, 2020; Sarac et al., 2010). Manufacturing companies that operate in a dynamic business environment are constantly looking for solutions that will allow them to increase the efficiency, precision and security of resource management (Bottani, Rizzi, 2008; Chowaniec, Pamuła, 2018). In this context, RFID, as a technology enabling wireless identification of objects and remote reading of information, offers a new quality in warehouse management (Ngai et al., 2012; Dlodlo, Mafini, 2013).

One of the key advantages of RFID is the automation of processes, which significantly reduces the time needed for inventory control, inventory and tracking the flow of goods (Lee, Özer, 2007; Gaukler et al., 2007). The ability to read data without the need for manual scanning allows for faster and more precise inventory management, which in turn minimizes human errors, reduces operational costs and increases the smoothness of logistics activities (Jones et al., 2005; Szozda, 2012). In addition, RFID provides greater control over the security of goods, so that companies can better protect their assets against theft or unauthorized access (Tajima, 2007; Garfinkel, Rosenberg, 2005).

Modern manufacturing companies that operate in increasingly complex and global supply chains must constantly adapt their logistics strategies to changing market conditions and growing customer expectations (Harisson, Van Hoek, 2008; Turoń, 2021). The implementation of RFID technology is the answer to these challenges, enabling enterprises to better integrate warehouse processes with the entire supply chain and providing access to accurate data in real time (Montanari, Rinaldi, 2004; Pruska, 2015). For this reason, RFID is becoming one of the key tools used by companies that strive to improve their efficiency and competitiveness on the market (Kłos, Patalas-Maliszewska, 2014; Liu, Liu, 2011).

2. Literature review

The process of implementing RFID technology in a company is a multi-stage undertaking that requires appropriate preparation and coordination (Gubi, Strom, 2005; Krzyżanowski, 2019). The first step is to thoroughly understand the company's needs and define the goals of RFID implementation. This includes analyzing areas where RFID technology can bring the greatest benefits, such as warehousing, production, transportation and sales support (Chappell, 2004; Karppinen, 2010). At this stage, specific problems that RFID can solve are also identified, e.g. improving inventory management or accelerating the order picking process (Witkowski, 2010; Pujawan, Geraldin, 2009). RFID comes in various forms, such as passive, semi-passive and active tags, which differ in range, data capacity and cost (Bhuptani, Moradpour, 2005; Rogers, Tibben-Lembke, 2006).

The next step is to prepare the infrastructure needed to implement RFID. This includes installing RFID readers in key locations, such as entry and exit points to warehouses, production stations, and transportation lines (Gunther, Kletti, 2007; Łaguna, 2017). You also need to provide appropriate software for integration with existing company management systems (ERP, WMS). Before fully implementing RFID technology, it is important to test it on a smaller scale, e.g. on a selected production line or in one warehouse (Haberman, 2004; Waller, Fawcett, 2013). Piloting allows you to assess the operation of the system, identify potential problems and collect information needed to optimize the entire process (Szozda, 2012; Ngai et al., 2012).

The success of RFID implementation largely depends on the preparation of staff. Employees responsible for operating the RFID system, both in production and warehousing, must undergo appropriate training to understand how the system works, how to read data from tags, and how to use the information in everyday operations (Attaran, 2020; Dlodlo, Mafini, 2013). After successful completion of the pilot phase, the company can proceed to full implementation of RFID on all production lines, warehouses and distribution points. It is important at this stage to monitor system performance and respond to possible problems (Liu, Liu, 2011; Pujawan, Geraldin, 2009).

Once fully implemented, it is crucial to continuously monitor the performance of the RFID system. The effectiveness, costs and benefits of technology should be analyzed and processes should be continuously optimized (Turoń, 2021; Waller, Fawcett, 2013). This may include infrastructure improvements, software updates or employee training. RFID can be combined with other technologies such as GPS, IoT or data analysis systems to increase the efficiency of the entire supply chain (Witkowski, 2010; Sarac et al., 2010). This integration allows for even better product tracking and optimization of operations.

The implementation of RFID technology is a long-term process that requires careful planning and coordination, but in return offers many benefits, such as greater supply chain transparency, better inventory control, and optimization of logistics processes (Ngai et al., 2012; Harrisson, Van Hoek, 2008).

3. Research Methodology

The structure of key processes in Enterprise includes five blocks of operations. The first is obtaining orders from customers, which includes not only distribution and production orders, but also those related to projects. After receiving the order, you proceed to the stage of purchasing individual elements necessary to meet the customer's requirements. The nature of your purchases may vary significantly depending on the type of order. Then, once the purchasing process is complete, the actions vary depending on the type of order. In the case of design orders, the project preparation phase begins, while for distribution and production orders, the production phase begins, closely related to the process of cooperation between many organizational units of the company. After completing production or project preparation, the sales phase began. It is worth noting that at each point of implementation of the company's main processes, complaint actions may occur related to a given stage of order fulfillment. Figure 1 shows a simplified diagram of the main processes in the analyzed company.

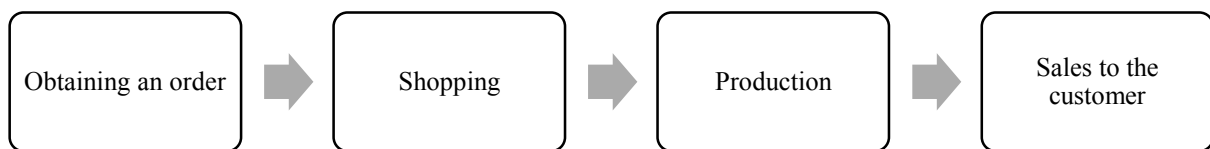


Figure 1. Main processes taking place in the analyzed company.

Source: Own study based on data from the surveyed company.

As part of the activities of company, the storage aspect is partially taken into account in processes such as purchasing, cooperation, production and sales. In the cooperation-production process in the analyzed company, storage is an activity that precedes the actual production of electronic modules. This is dictated by the frequent request of customers who require the use of their own components when carrying out production orders. Therefore, before production begins, the design department and the purchasing department must coordinate the introduction of a new product into the system and purchase the necessary materials. After the customer delivers the materials, warehouse employees accept the delivery, which allows the production process to begin. According to the discussed logistics process, the warehouses of Enterprise participate in three main processes: purchases, cooperation-production and sales. Furthermore, storage plays an important role in numerous more detailed procedures. The product sales process in the context of warehousing consists of three stages and is closely related to the activities of the sales department. This process involves the following activities:

- issuing sales documents by the sales department,
- issuing goods through the warehouse,
- sending goods to the final recipient.

In addition to the warehouse, the purchasing department and logistics department also participate in the process of purchasing elements for production. As part of this process, the tasks performed can be divided into the following three stages:

- placing an order for goods by the purchasing department,
- coordination of transport by the logistics department,
- receipt of goods by the warehouse.

In order to identify problems in warehousing logistics, a SWOT analysis was carried out, which can be used to observe the conditions for a new entity to enter the market and to identify areas requiring improvement. This is one of the most popular methods of strategic analysis, which can also be used in advisory activities - consulting as a form of organizational diagnosis. It can also be used in various areas of a company's operation - marketing, finance, production and sales. The name of the method is an acronym of the English words strengths, weaknesses, opportunities (potential or existing opportunities in the environment), threats (probable or existing threats in the environment) (Machaczka, 2001). All of the above-mentioned elements should be classified due to the fact that each of them is important in the final assessment of the company's situation. They can be classified as external to the organization and internal, which have a negative or positive impact on the organization. internal conditions and having a negative or positive impact on the organization. For this purpose, a scheme is used that divides the SWOT analysis factors into four categories:

- external positives (chances or opportunities) - these are factors that enable maintaining or increasing the market position,
- negative external (threats) - this is the identification of elements that have a negative impact on the development of the enterprise,
- internal positives (strengths) - identification of these elements is possible thanks to knowledge of the subject of the analysis, the more accurate it is, the more effective and reliable the result is,
- internal negatives (weaknesses) - their occurrence is most often caused by the lack of financial, human and other resources that block the company's development.

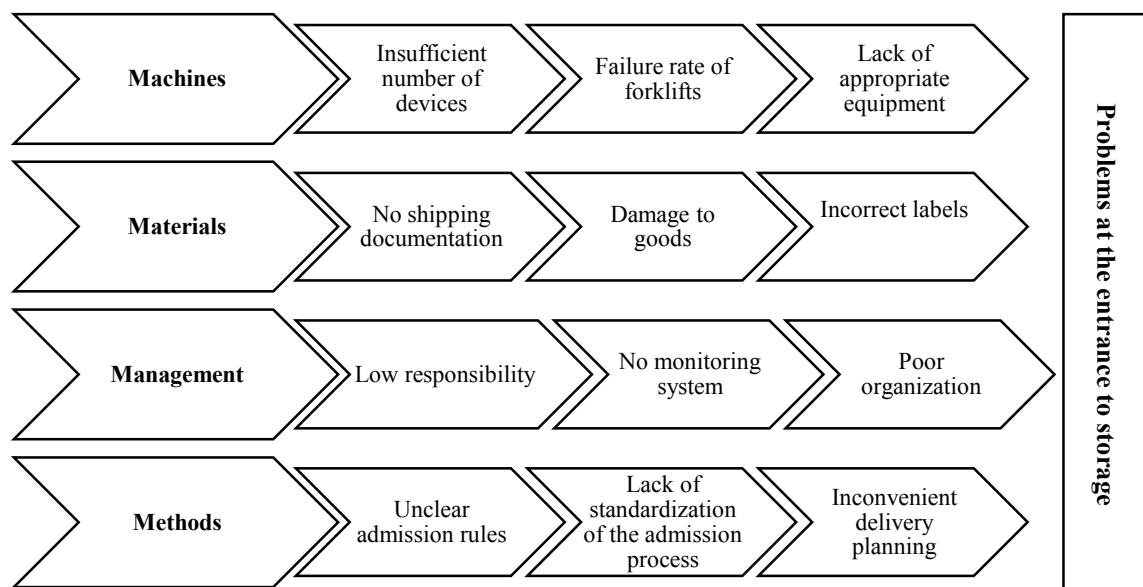
As a result of the analysis, strengths that need to be strengthened, weaknesses that need to be reduced, opportunities to be exploited and threats to be avoided can be identified. Table 1 contains the SWOT analysis for the examined the analyzed company.

Table 1.*SWOT analysis of the warehouse operation in the analyzed company*

STRENGTHS	WEAKNESSES
• systematic adaptation of the warehouse layout to the evolving turnover structure, • planning deliveries in a way that eliminates time conflicts.	• unsatisfactory inventory management, • errors in the area of identification and labeling of goods, • suboptimal organization of warehouse space, • inappropriate use of technology, • problems with handling complaints, • lack of training for staff, • lack of process performance monitoring, • low level of warehouse automation, • small number of forklifts, • lack of feedback from suppliers, • problems with product availability.
OPPORTUNITIES	THREATS
• growing availability of technology, including software and hardware, enabling more effective warehouse management, • increasing market share of warehouse networks.	• changes in the supply system, • warehouse resources lying on the shelves, • the aging process of both buildings and technologies, • evolution of market needs, • constant employee turnover and the related need to invest in training for new employees.

Source: Own study based on data from the surveyed company.

Problems in the area of warehouse receipt, storage process and exit are illustrated in Ishikawa diagrams (Figures 2, 3, 4).

**Figure 2.** Ishikawa diagram in the area of goods receipt into the warehouse.

Source: Own study based on data from the surveyed company.

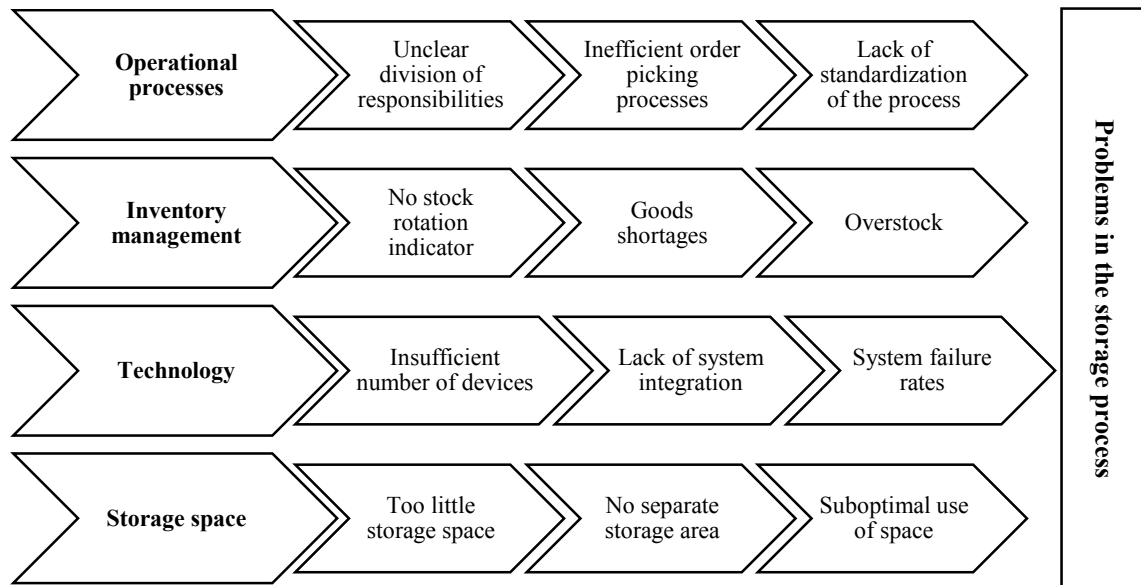


Figure 3. Ishikawa diagram in the area of the storage process.

Source: Own study based on data from the surveyed company.

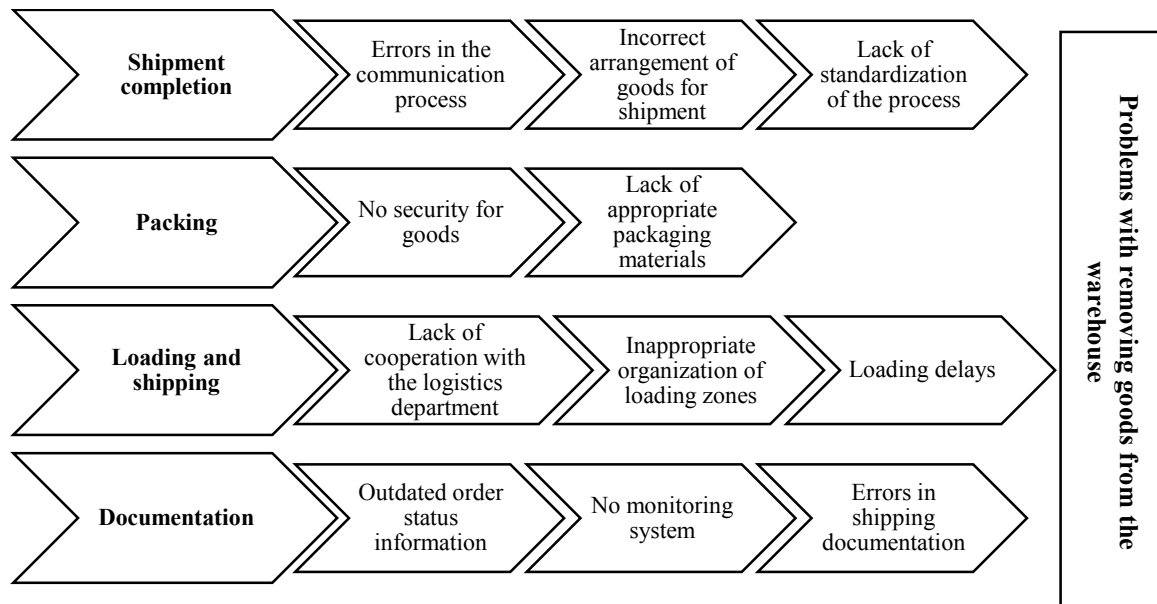


Figure 4. Ishikawa diagram in the warehouse goods release area.

Source: Own study based on data from the surveyed company.

Problems were identified in the area of warehouse receipt, storage process and output, which was presented in the above Ishikawa diagrams (Figures 4, 5, 6). To summarize these processes, a SWOT analysis was carried out (Table 2), which better illustrates the strengths, weaknesses, opportunities and threats related to these diagrams. In order to identify in detail the key conditions influencing the efficiency of warehouse processes in the analysis company, an in-depth SWOT analysis was conducted. This analysis allows for the assessment of both the internal resources and limitations of the organization, as well as external opportunities and threats that affect the way warehouse logistics functions. Compared to the classic approach, this version of SWOT has been expanded to include organizational, technological and strategic aspects, taking into account the specifics of implementing RFID technology.

Table 2.

SWOT analysis for the processes of receiving goods, storing and issuing goods in the analyzed enterprise

STRENGTHS	WEAKNESSES
• standardization of goods receipt processes, • organized storage areas in the warehouse, • effective order picking processes, • advanced inventory management systems, • clear loading and shipping procedures.	• lack of training in the identification of goods at reception, • ineffective organization of warehouse space, • delays in loading and shipping processes, • failure rate of warehouse equipment, • errors in shipment documentation
OPPORTUNITIES	THREATS
• automation of goods identification at reception, • expansion of warehouse space and better zone management, • integration of WMS technology with shipping processes, • implementation of new technologies for inventory management, • better training of warehouse staff.	• increasing requirements regarding the speed of receipt of goods, • increased risk of expired inventory in the warehouse, • problems with logistic synchronization in shipping processes, • growing competition in storage efficiency, • increased technology and infrastructure costs.

Source: Own study based on data from the surveyed company.

SWOT analysis of warehouse processes in the analyzed enterprise revealed both strengths that are worth developing, as well as significant weaknesses and threats that require urgent corrective actions. The main problems identified in the reception, storage and exit processes include: lack of staff training, ineffective organization of storage space, equipment failure rates and documentation errors. Additionally, threats such as growing customer requirements, increased competition and problems with logistic synchronization require the implementation of modern technological solutions. The response to the identified weaknesses and threats is the implementation of RFID technology, which will allow the analyzed company to significantly improve efficiency and eliminate key operational problems. RFID offers the possibility of automating the processes of identifying and monitoring goods, which will positively affect the speed, precision and inventory control throughout the entire warehouse cycle.

4. Results and Discussions

The implementation of RFID technology in the analyzed enterprise requires the development of a comprehensive model that will take into account all stages of the process, resources and benefits resulting from the implementation of this solution (Figure 5, 6, 7).

I MODEL INPUT DATA

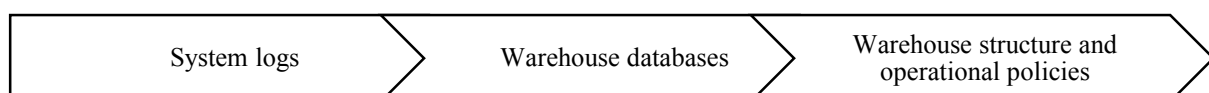


Figure 5. Model input data.

Source: Own study based on data from the surveyed company.

1. System logs:
 - Collecting information about activities in warehouse processes, such as registration of goods at the entrance, movement of goods between zones, goods leaving the warehouse.
 - These logs allow you to analyze process efficiency and identify errors in real time.
2. Warehouse databases:
 - Data on warehouse levels and goods rotation, excess and shortage of stocks, history of goods movements in the warehouse.
 - It allows you to optimize the use of space and prevent products from expiring.
3. Warehouse structure and operational policies:
 - Information on the location of reception, storage and exit areas, reception and loading policies.
 - Enables adaptation of RFID technology to existing infrastructure.
4. User interaction:
 - Intuitive interface enabling viewing data on warehouse stock, goods movements and generating reports.
 - Warehouse employees can monitor operations in real time and use recommendations generated based on RFID data.

II PROCESSES OF IMPLEMENTING RFID TECHNOLOGY

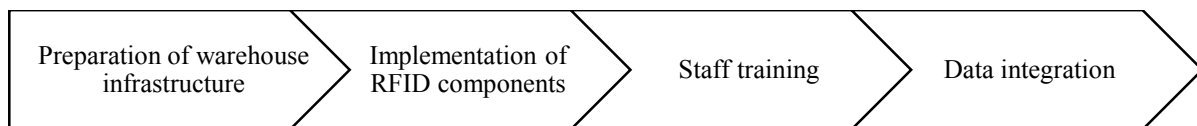


Figure 6. RFID technology implementation processes.

Source: Own study based on data from the surveyed company.

1. Preparation of warehouse infrastructure:
 - Installation of RFID antennas in receiving, storage and exit areas.
 - Implementation of RFID gates to record the flow of goods between zones.
 - Integration of RFID readers with the existing WMS system.
2. Implementation of RFID components:
 - RFID tags - placing tags on goods during reception, ensuring tags that are highly durable and adapted to the type of goods.
 - RFID readers - installation in key points of the warehouse, ensuring real-time data reading.
3. Staff training:
 - Training in the operation of RFID readers and the use of software.
 - Education on the interpretation of data generated by the RFID system.

4. Data integration:

- Combination of RFID technology with WMS and ERP systems to automatically update inventory levels, generate reports on goods movement and inventory rotation.

III OUTPUT DATA

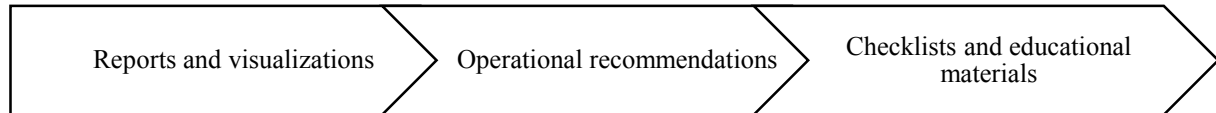


Figure 7. Model output data.

Source: Own study based on data from the surveyed company.

1. Reports and visualizations:

- PDF reports with detailed data on goods flows, inventory rotation and errors in operations, creating comprehensive analyzes of warehouse efficiency.
- Visualizations, diagrams of goods movement in the warehouse, statistics of errors, delays and product rotation.

2. Operational recommendations:

- Proposals for actions aimed at reducing excess inventory, optimizing the distribution of goods, increasing the efficiency of loading and picking.

3. Checklists and educational materials:

- Checklists, assessment of compliance of activities with warehouse policies.
- Infographics, presenting key information about the operational efficiency of the warehouse and ways to avoid errors.

The implementation of RFID technology in the analyzed enterprise will improve the operational efficiency of the warehouse and increase the quality of logistics processes. Automation of warehouse processes will eliminate the need to manually enter data, because information about the flow of goods will be recorded automatically and updated in real time. RFID systems precisely monitor inventory levels and the movement of goods, which will increase the accuracy of operations and reduce the occurrence of errors. Figure 8 shows a comparison of key operational indicators before and after the implementation of RFID technology. There is a significant improvement in the time of delivery and order completion, as well as a reduction in warehouse errors by over 80%.

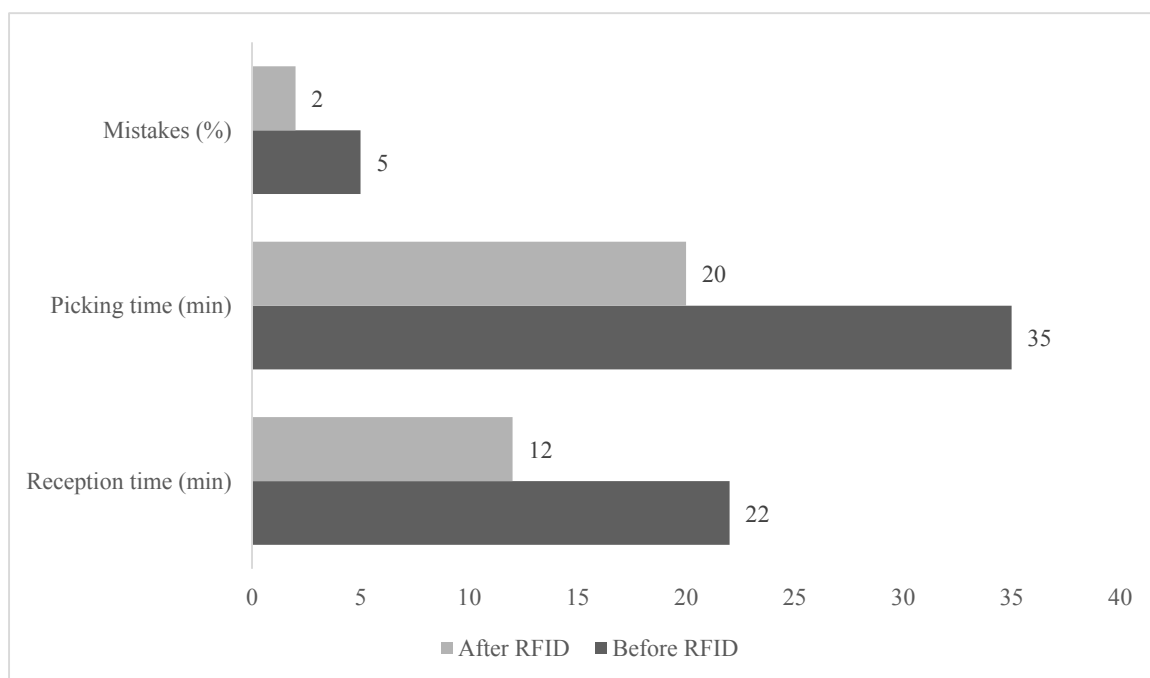


Figure 8. Comparison of key operational efficiency indicators of the warehouse before and after RFID implementation.

Source: Own study based on data from the surveyed company.

Moreover, RFID technology will significantly reduce the number of errors in warehouse processes. Precise tracking of goods at every stage, from receipt to loading, will help avoid errors in order picking and eliminate discrepancies in shipping documentation. Logistics processes will become more predictable and reliable, which will increase customer trust and satisfaction. Figure 9 illustrates the reduction in the number of documentation errors and complaints after RFID implementation. The reduction of errors from 73 to 9 cases and the decrease in complaints by 70% prove the greater precision of logistics processes.

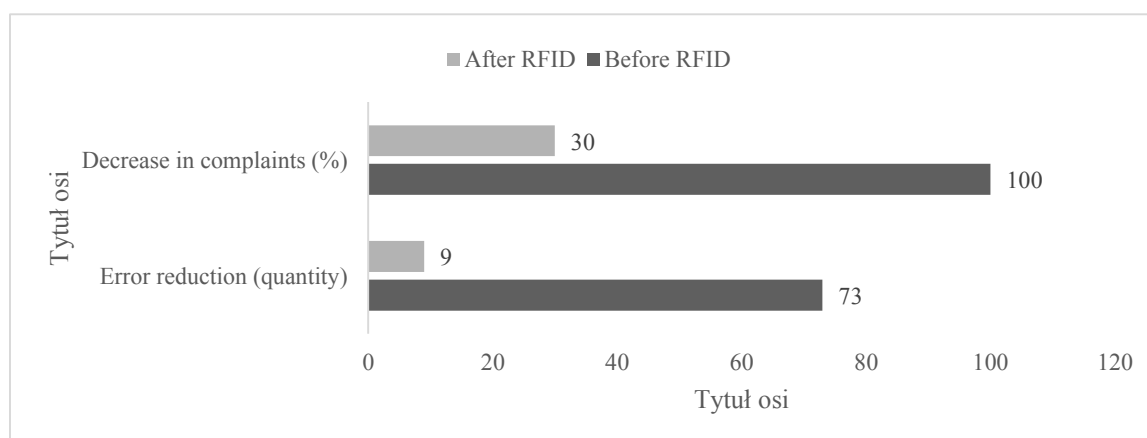


Figure 9. Reduction of documentation errors and complaints.

Source: Own study based on data from the surveyed company.

The ability to monitor the location and rotation of inventory will allow you to effectively use warehouse space, which will solve problems related to excess or shortage of goods. Figure 10 shows the level of warehouse losses before and after RFID implementation. The decrease from 2.4% to 0.5% indicates improved inventory control and reduced errors in merchandise records.

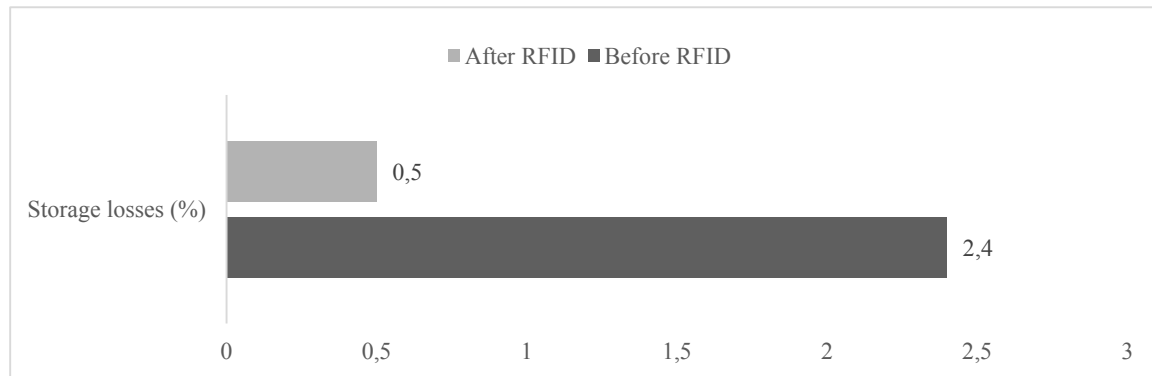


Figure 10. Decrease in the level of warehouse losses after the implementation of RFID technology.

Source: Own study based on data from the surveyed company.

RFID will also improve the organization of warehouse operations, introducing greater transparency and control over key processes. This solution will increase the company's ability to quickly adapt to changing market conditions and customer requirements. RFID systems will provide flexibility and expandability, which will support the development of the company in the long term. Higher quality of inventory management and timely execution of orders will contribute to improving the company's competitiveness and strengthen its position on the market.

The implementation of RFID technology in the analyzed enterprise may encounter certain barriers and limitations that will need to be taken into account in the implementation process. One of the main challenges is the high initial cost associated with purchasing equipment such as RFID tags, readers and the IT infrastructure necessary to operate the system. For many enterprises, such an investment may constitute a significant financial burden, especially if the technology will be implemented on a large scale. Another barrier may be the lack of appropriate knowledge and experience in RFID technology among employees. The implementation process requires training so that staff can use the new tools effectively. Lack of appropriate

Some industries may encounter difficulties related to the physical limitations of RFID, such as interference in reading tags in the case of metal goods or goods stored in specific conditions, e.g. in cold stores. These technical limitations may impact the effectiveness of the system and require equipment to be adapted to the specific needs of the enterprise.

Managing data generated by RFID is also a significant challenge. These systems produce huge amounts of information that must be properly processed and analyzed. The lack of efficient analytical tools or inadequate data management can limit the effectiveness of the entire solution.

Finally, resistance from employees who may be afraid of change or have difficulty adapting to new technologies may be a barrier. This attitude may impact the pace of implementation and require additional communication and education efforts about the benefits of RFID implementation.

Overcoming these barriers will require appropriate planning, technical support and education at every stage of implementation so that the technology can bring maximum benefits to the analyzed enterprise.

5. Summary

The analysis showed that RFID technology plays an important role in warehouse and inventory management in a manufacturing company. The implementation of this solution resulted in the automation of key warehouse processes, which significantly improved operational efficiency, reduced the number of errors in the identification and management of goods, and increased the transparency of operations. The use of RFID enabled monitoring the movement of goods in real time, which contributed to a faster response to changing customer needs and better management of inventory rotation.

The analysis confirmed that the implementation of RFID allowed the elimination of many problems identified before the technology implementation, such as errors in documentation, improper use of warehouse space or delays in order fulfillment. The RFID system also enabled optimization of the use of warehouse space and better inventory planning, which reduced the risk of excesses and shortages. The use of this technology also contributed to increased customer satisfaction thanks to timely execution of orders and improved quality of delivered products.

The analysis also identified barriers and limitations related to the implementation of RFID, such as high initial costs, the need to modernize IT infrastructure and the need to conduct staff training. Despite these challenges, the benefits of implementing this technology significantly outweighed the implementation difficulties, which proves the great potential of RFID in warehouse management.

The research results allow us to conclude that RFID technology can become a key tool supporting enterprises in achieving greater operational efficiency and flexibility. Based on the conducted analyses and identified limitations of RFID technology implementation, it seems reasonable to focus future research on several key areas. First, it is recommended to conduct comparative studies in various industries, which will allow for assessing the scalability and effectiveness of RFID implementations in different operating conditions. In particular, it is worth paying attention to the adaptability of the technology in small and medium-sized enterprises, which may have limited technological and financial resources.

Another important area of research is the integration of RFID with advanced analytical tools, such as predictive systems, big data or artificial intelligence, which can significantly increase the level of automation and precision in inventory management. In addition, future analyses should include the impact of RFID on relationships with partners in the supply chain, with particular emphasis on data synchronization and operational transparency.

It is also worth undertaking research on the impact of RFID implementations on sustainable development, including reducing material losses, better use of resources and improving working conditions. The above directions should be supplemented by the identification of success factors and the most common implementation barriers, which will enable the development of effective implementation strategies tailored to the specifics of a given.

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LABOUR MARKET CHARACTERISTICS AGAINST THE BACKDROP OF SOCIO-ECONOMIC PHENOMENA IN POLAND IN 2008-2023

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Purpose: The aim of this study is to identify and assess the diversity, strength and direction of relationships between key labour market characteristics and selected socio-economic areas.

Design/methodology/approach: The study was conducted on statistical data for 16 voivodeships of Poland from 2008 to 2023. Multi-criteria assessments for selected socio-economic areas were obtained using the TOPSIS method, followed by correlation analysis to determine the interdependence with the considered labour market characteristics.

Findings: The results indicate the existence of relationships between the dynamics of labour market characteristics and multi-criteria assessments for the analysed areas, as well as their regional diversity.

Research limitations/implications: The limitation of the study is the dependence of the results on the quality and availability of statistical data. The results obtained may serve as a starting point for further comparative studies and long-term analyses.

Practical implications: The study is the basis for designing activities to support the sustainable economic and social development of voivodeships.

Originality/value: The originality of the research lies in the combination of the TOPSIS method with correlation analysis in relation to Polish voivodeships, which allows for a comprehensive assessment of the relationships between key socio-economic phenomena and labour market characteristics.

Keywords: labour market, TOPSIS, multi-criteria analysis, socio-economic phenomena.

Category of the paper: Research paper.

1. Introduction

The labour market is a fundamental element of the economy, determining its efficient functioning and supporting stable and sustainable development. The literature on the subject contains numerous theories and approaches explaining the mechanisms and processes occurring in this market, pointing to its complex and multidimensional nature (Zieliński, 2023).

Demographic factors, including low birth rates, ageing populations and integration processes between countries, have a significant impact on the labour market. Social and economic migration and the impact of the COVID-19 pandemic are also important factors (Gajdos, Lewandowska-Gwarda, 2022; Mrugała, Kowalska, Kilichowski, 2024). The rapidly advancing processes of digitalisation and the popularisation of artificial intelligence applications in various spheres of social and economic life are also playing an increasingly important role (Górniak, Jelonek, 2023; Hollanders, 2023; Huseynov, 2023; World Economic Forum, 2023). These factors can both stimulate the development of the labour market and pose threats to its proper functioning. Mainly they are the result of civilisational and economic changes. This makes it necessary to conduct an in-depth analysis of the relationships between the labour market and important socio-economic areas.

The aim of this study is to identify and assess the diversity, strength and direction of correlations between labour market characteristics (average employment, unemployment rate, long-term unemployment, net number of workplaces) and selected socio-economic areas (Demographics, Economy, Innovations and R&D). The analysed areas are represented by multi-criteria assessments, determined using the TOPSIS method, considering the division into Polish voivodeships for data covering the years 2008-2023. The results of the research may serve as a basis for further comparative analyses and for formulating recommendations for labour market policy in the context of socio-economic phenomena, as well as for designing activities to support the sustainable development of voivodeships.

2. Research methodology

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is one of the multi-criteria decision support methods developed by Hwang and Yoon (Hwang, Yoon, 1981). It is used for the alternatives' evaluation when the simultaneous consideration of multiple criteria is required, often of a conflicting nature (Pośpiech, 2021; Roszkowska, Wachowicz, 2024). Its essence lies in the assumption that the best alternative should be both as close as possible to the positive ideal solution PIS (a hypothetical alternative with the best values for all criteria) and as far as possible from the negative ideal solution NIS (the alternative with the worst values). The procedure for determining multi-criteria rankings using the TOPSIS method has been extensively discussed in the literature (Hwang, Yoon, 1981; Lai, Liu, Hwang, 1994; Roszkowska, Wachowicz, 2013; Trzaskalik, 2014).

The TOPSIS procedure involves the following steps:

Step 1. Construct a decision matrix containing the values of criteria $C_1, C_2, \dots, C_n$ for the evaluated alternatives $A_1, A_2, \dots, A_m$:

$$\mathbf{X} = [x_{ik}] \quad (1)$$

where x_{ik} is the value of the k -th criterion for the i -th alternative for $i = 1, 2, \dots, m$ and $k = 1, 2, \dots, n$.

Step 2. Normalise data to enable comparison when criteria have different scales:

- for stimulants

$$z_{ik} = \frac{x_{ik} - \min_{1 \leq i \leq m} \{x_{ik}\}}{\max_{1 \leq i \leq m} \{x_{ik}\} - \min_{1 \leq i \leq m} \{x_{ik}\}} \quad (2)$$

- for destimulants

$$z_{ik} = \frac{\max_{1 \leq i \leq m} \{x_{ik}\} - x_{ik}}{\max_{1 \leq i \leq m} \{x_{ik}\} - \min_{1 \leq i \leq m} \{x_{ik}\}} \quad (3)$$

for $i = 1, 2, \dots, m$ and $k = 1, 2, \dots, n$.

Step 3. Determine the weights of criteria reflecting their importance:

$$w = [w_1, w_2, \dots, w_n] \quad (4)$$

where:

w_k denotes the weight of the k -th criterion for $k = 1, 2, \dots, n$ and $\sum_{k=1}^n w_k = 1$.

Step 4. Calculate the weighted normalised matrix:

$$V = [v_{ik}] \quad (5)$$

where $v_{ik} = w_k \cdot z_{ik}$ for $i = 1, 2, \dots, m$ and $k = 1, 2, \dots, n$.

Step 5. Construct the weighted reference points PIS (positive ideal solution) $v^+ = [v_1^+, v_2^+, \dots, v_m^+]$ and NIS (negative ideal solution) $v^- = [v_1^-, v_2^-, \dots, v_m^-]$ based on the formulas:

$$v_k^+ = \max_{1 \leq i \leq m} \{v_{ik}\} \quad (6)$$

and

$$v_k^- = \min_{1 \leq i \leq m} \{v_{ik}\} \quad (7)$$

for $k = 1, 2, \dots, n$.

Step 6. Calculate the distance of each alternative from the weighted reference points PIS and NIS (usually using the Euclidean metric):

$$d_i^+ = \sqrt{\sum_{k=1}^n (v_{ik} - v_k^+)^2} \quad (8)$$

and

$$d_i^- = \sqrt{\sum_{k=1}^n (v_{ik} - v_k^-)^2} \quad (9)$$

for $i = 1, 2, \dots, m$.

Step 7. Determine the value of multi-criteria measure:

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (10)$$

for $i = 1, 2, \dots, m$.

The values R_i obtained based on the procedure are the starting point for determining the final ranking of alternatives. This measure takes values from the range $[0, 1]$, with a higher value indicating a higher position in the ranking.

3. Results and Discussion

3.1. Selection of diagnostic variable

In this research the alternatives assessed are the voivodeships of Poland. Due to the purpose of the research, diagnostic variables that characterise the labour market and variables that represent various socio-economic categories were selected (Grajewska, 2013; Malina, 2020; Roszkowska, Karwowska, 2014; Sokołowska, Filipowicz-Chomko, 2015). The set of diagnostic variables are divided into the following four areas: Area I – Labour Market, Area II – Demographics, Area III – Economy, Area IV – Innovations and R&D.

Considering the availability of data, 40 diagnostic variables were considered, of which, for substantive, formal and statistical reasons – universality, comparability, appropriate variation¹ (Młodak, 2006; Gdakowicz, Hozer-Koćmiel, Markowicz, 2023), a set of 23 characteristics was ultimately selected (Table 1).

Table 1.
Set of diagnostic variables

Areas	Diagnostic variables	
Area I – Labour Market	1.1	Average employment per 1000 inhabitants
	1.2	Registered unemployment rate
	1.3	Registered unemployed persons out of job for longer than 1 year per 1000 inhabitants
	1.4	Net number of workplaces per 10,000 inhabitants
Area II – Demographics	2.1	Natural increase per 1000 inhabitants
	2.2	Working-age registrations for permanent residence per 1000 inhabitants
	2.3	Working-age registrations of departure per 1000 inhabitants
Area III – Economy	3.1	Average monthly gross wages
	3.2	Sold production of industry per capita (entities with >9 employees)
	3.3	Investment outlays in enterprises per capita
	3.4	Investment outlays per capita
	3.5	GDP per capita
	3.6	State budget revenue from personal income tax (PIT) per capita
	3.7	State budget revenue from corporate income tax (CIT) per capita
	3.8	Entities entered in the REGON register per 10,000 inhabitants
	3.9	New-registered entities in the REGON register per 10,000 inhabitants
	3.10	Entities unregistered from the REGON register per 10,000 inhabitants
Area IV – Innovations and R&D	4.1	Intramural expenditure on R&D per capita
	4.2	Intramural expenditure on R&D as a percentage of GPD (current prices)
	4.3	Average employment in section J of the NACE rev2 classification per 1000 inhabitants
	4.4	Share of net income from the sale of products in entities classified to high and medium-high technology in net income from the sale of products in entities classified in the Manufacturing section
	4.5	Entities engaged in R&D per 100,000 inhabitants
	4.6	Entities engaged in R&D per 100,000 entities of the national economy

Source: Own research.

¹ Variables for which the coefficient of variation did not exceed 10% were eliminated (for variable 3.1, in 2019-2023, this coefficient ranged between 9-10%, but for substantive reasons, this variable was included in the study).

The variables included in the first area (Labour Market) were treated as separate characteristics against which the multi-criteria assessments obtained for the other three areas were compared. The multi-criteria TOPSIS method was used, so an important element of the research was to identify stimulants and destimulants among the diagnostic variables (selection criteria). Considering substantive requirements, it was determined that variables 2.3 and 3.10 are destimulants, while the remaining variables from areas II-IV are stimulants. Each of the criteria was considered equally important, so they were given the same weight. Furthermore, to enable comparison of values, the same (global) positive and negative ideal solutions were adopted for all years. The research period covered the years 2008-2023.

3.2. Presentation of selected Labour Market characteristics

Four characteristics were selected for the analysis of the Labour Market (Table 1). In addition to one of the most frequently studied variables, namely the unemployment rate (1.2), a variable describing average employment (1.1) and a variable representing long-term unemployment (1.3) were also included. In addition, a less typical characteristic was added to the group of variables, showing the dynamics of net number of workplaces (1.4).

The values of the first variable – average employment (1.1) – is shown in Figure 1.

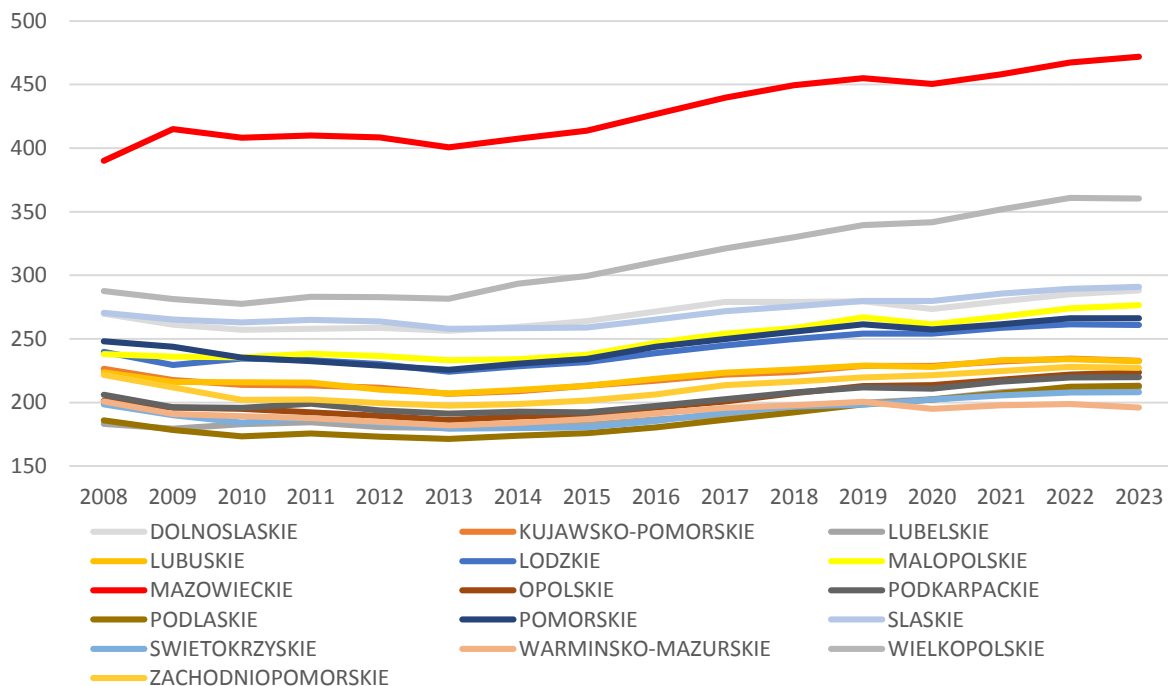


Figure 1. Values of variable 1.1 – Average employment per 1,000 inhabitants.

Source: Own research.

The highest average employment per 1000 inhabitants, significantly higher than in other voivodeships, was recorded in Mazowieckie². Throughout almost the entire period, the figures did not fall below 400 people per 1000 inhabitants. Since 2013, there has been a noticeable upward trend, with a slight slowdown in 2020 (the beginning of the coronavirus pandemic). Next in the ranking was the Wielkopolskie Voivodeship – a similar trend to that in the Capital Voivodeship (Mazowieckie), but with values ranging between 277 and 368 persons per 1000 inhabitants. The next two voivodeships, with similar average employment levels, were Dolnoslaskie and Slaskie. Here, the values ranged between 256 and 290 employees per 1000 inhabitants. The next voivodeships in the ranking are Lodzkie, Malopolskie and Pomorskie – the values ranged between 224 and 276. The voivodeships with the lowest number of people employed per 1000 inhabitants, between 171 and 213, are Podlaskie, Swietokrzyskie and Warminsko-Mazurskie. The above-mentioned trend – growing since 2013 with a slowdown in 2020 – continued in almost every voivodeship.

The second of the Labour Market variables, the registered unemployment rate, took on the values shown in Figure 2.

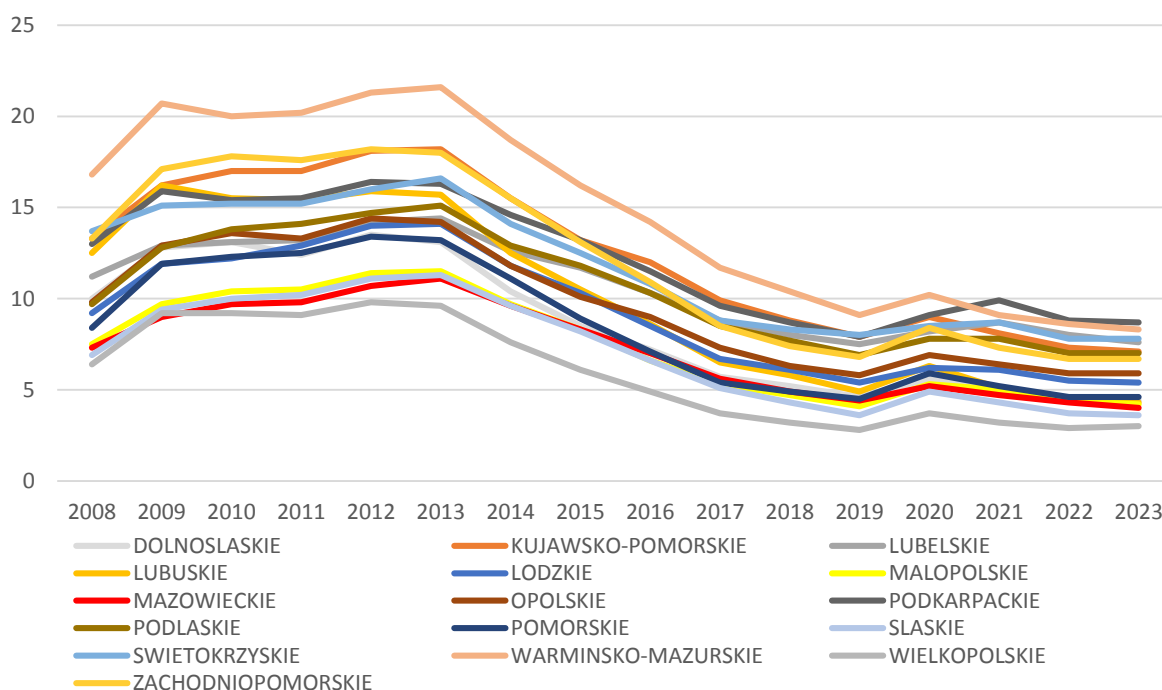


Figure 2. Values of variable 1.2 – Registered unemployment rate.

Source: Own research.

Figure 2 shows a certain pattern – an increase in registered unemployment in 2008-2013, followed by a decline until 2019, a renewed increase in 2020 or 2021 caused by the outbreak of the pandemic, and a slow decline until the end of the period under review. The highest values

² This is justified given that it is the capital voivodeship. It would be reasonable to exclude the capital city of Warsaw from the Mazowieckie voivodeship and conduct an analysis taking these two areas separately, but due to the unavailability of some data, no such division was made in the study.

throughout almost the entire period were recorded in the Warminsko-Mazurskie Voivodeship – in 2009-2013 they exceeded 20%. During the same period, in five voivodeships: Kujawsko-Pomorskie, Lubuskie, Podkarpackie, Swietokrzyskie and Zachodniopomorskie, the registered unemployment rate was over 15%. In turn, the lowest unemployment rate was recorded in the Wielkopolskie Voivodeship – it did not exceed 10% throughout the entire period, and since 2016 it has been below 5%. Other voivodeships with the lowest unemployment rates were: Malopolskie, Mazowieckie and Slaskie. In 2023, unemployment rates fluctuated between 3% and 9%.

The levels of the variable describing long-term unemployment (1.3) are shown in Figure 3.

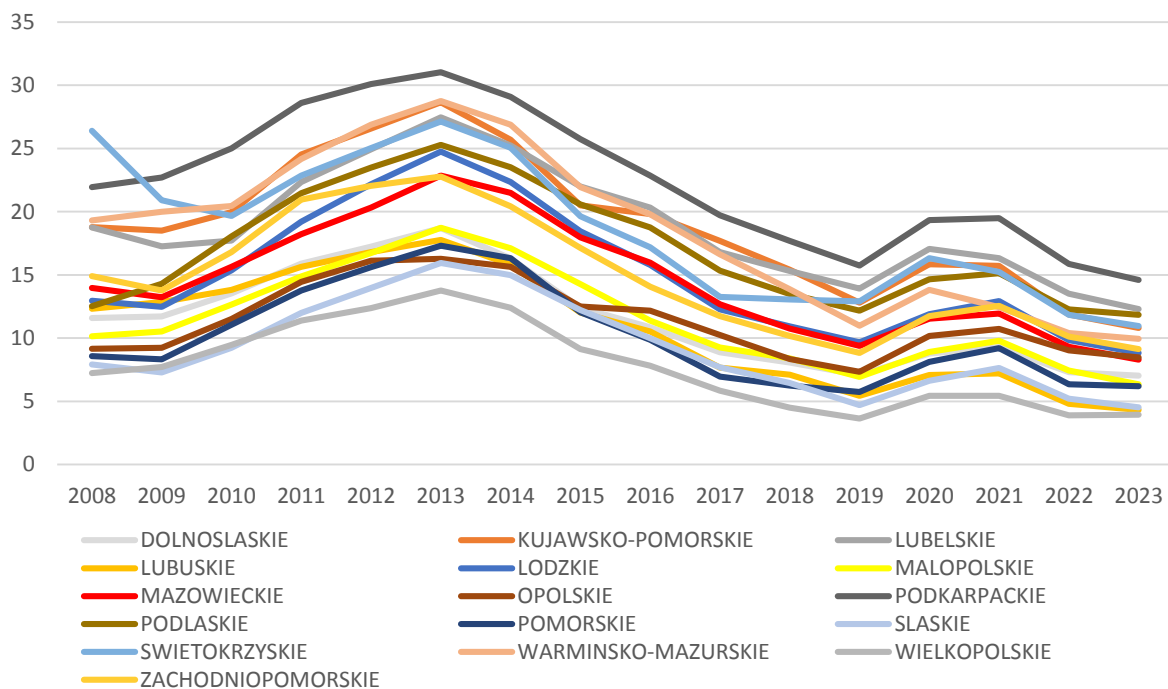


Figure 3. Values of variable 1.3 – Registered unemployed persons out of job for longer than 1 year per 1000 inhabitants.

Source: Own research.

The behaviour of this variable is analogous to that of the variable representing the registered unemployment rate. In almost every voivodeship, the number of long-term unemployed per 1000 inhabitants increased until 2013, then decreased until 2019, followed by another increase (2020-2021) and another decrease. The voivodeships with the highest levels of this variable are Podkarpackie (in 2008-2016 it did not fall below 20 people per 1,000 inhabitants), followed by Kujawsko-Pomorskie, Lubelskie, Swietokrzyskie and Warminsko-Mazurskie. The voivodeships with the lowest values for this variable are: Wielkopolskie, Slaskie, Pomorskie, Opolskie, Malopolskie, Lubuskie and Dolnoslaskie. In the last year considered (2023), the number of people unemployed for more than a year fluctuated between 4 and 15 persons per 1000 inhabitants.

The fourth variable considered – the net number of workplaces per 10,000 inhabitants – is presented in Figure 4.

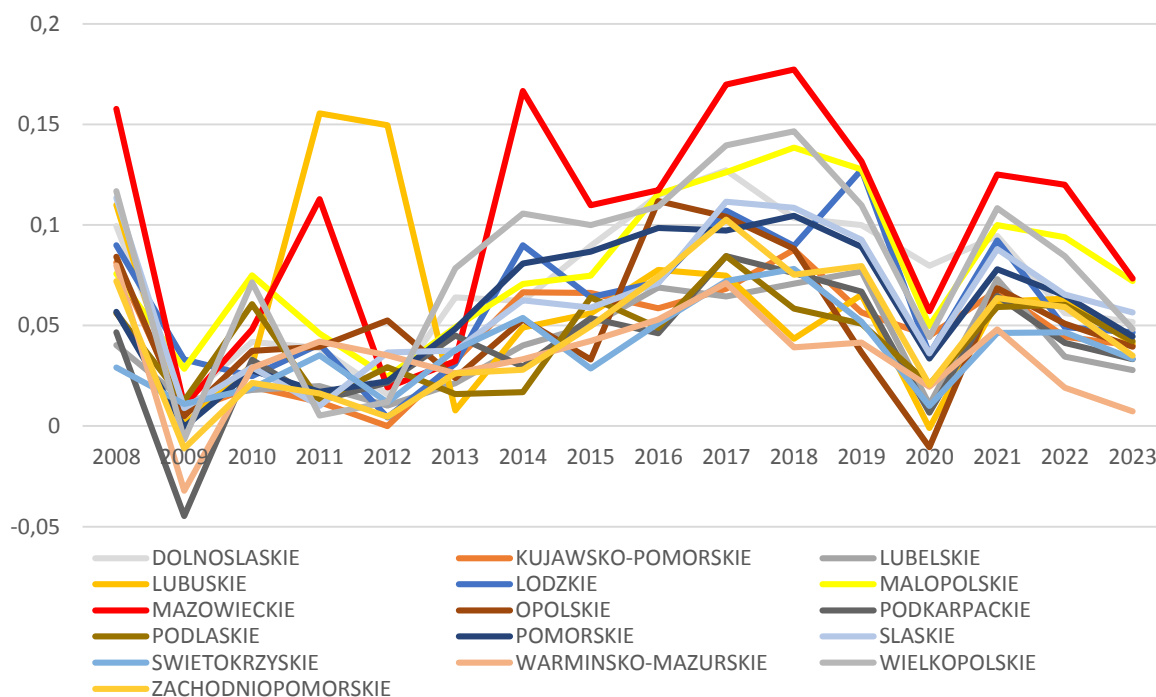


Figure 4. Values of variable 1.4 – Net number of workplaces per 10,000 inhabitants.

Source: Own research.

The net number of workplaces per 10,000 inhabitants over the period under review shows the dynamics of changes in the difference between newly created and liquidated workplaces. This variable is important because it represents the potential for hiring employees. It is characterised by high volatility in the period under review. However, it can be seen that, except for 2009 and 2020 which were strongly affected first by the global economic crisis and then by the onset of the coronavirus pandemic, the balance is positive. The highest values of this variable, especially after 2013, were recorded in the voivodeships of Mazowieckie, Wielkopolskie, Malopolskie and Dolnoslaskie, while the lowest values were observed in the voivodeships of Warminsko-Mazurskie, Podlaskie and Swietokrzyskie, among others. There is also a visible decline in the value of the variable after 2021, which may have been caused by the situation of employers or enterprises during and after the pandemic.

3.3. Assessment of voivodeships for the studied areas and their connections with the characteristics of the Labour Market

The voivodeships were assessed based on multi-criteria TOPSIS indicators obtained for each of the areas under consideration: Area II (Demographics), Area III (Economy), and Area IV (Innovations and R&D). The set of criteria in each area corresponds to the set of variables listed in Table 1. The values of the TOPSIS assessment for Area II – Demographics are shown in Figure 5.

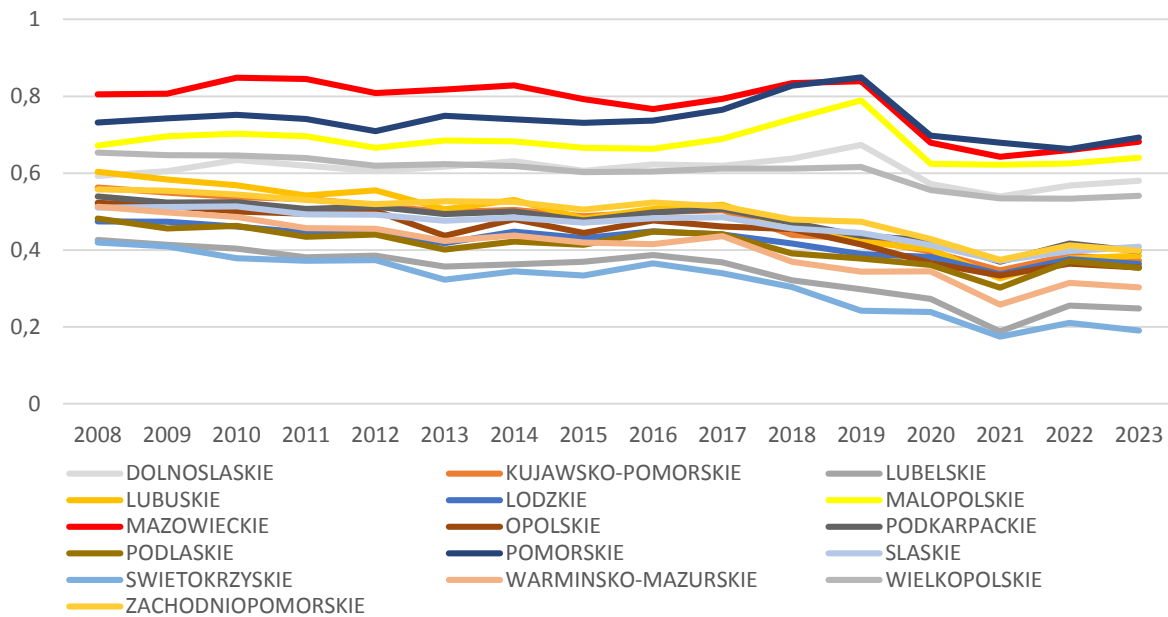


Figure 5. TOPSIS values for Area II (Demographics).

Source: Own research.

Throughout the period, the highest-ranked voivodeships maintained similar scores for this area, while for the remaining voivodeships a slight decrease was observed. The Mazowieckie Voivodeship was closest to the PIS and furthest from the NIS, followed by the Pomorskie, Malopolskie, Dolnoslaskie, and Wielkopolskie voivodeships. These voivodeships, therefore, performed best in the Demographics category. The Swietokrzyskie and Lubelskie voivodeships, on the other hand, were rated least favourably in this area. In each voivodeship, a significant decline in the values was noticeable after 2019, reflecting the "collapse" in the area caused by the COVID-19. This indicator's value did not increase until 2022.

Figure 6 shows the intensity of the indicator values describing the Demographics area in selected years: 2008 – the beginning of the period under study and the peak year of the global crisis; 2013 – the year in which turning points for many diagnostic variables were observed; 2020 – the beginning of the COVID-19 pandemic; and 2023 – the final year of the period under study. The darker the colour, the higher the value of the multi-criteria indicator and the higher the rating of the given voivodeship within the area under consideration. Because the ratings for the entire period under study were standardized, it is reasonable to compare the results of the analyses over time.

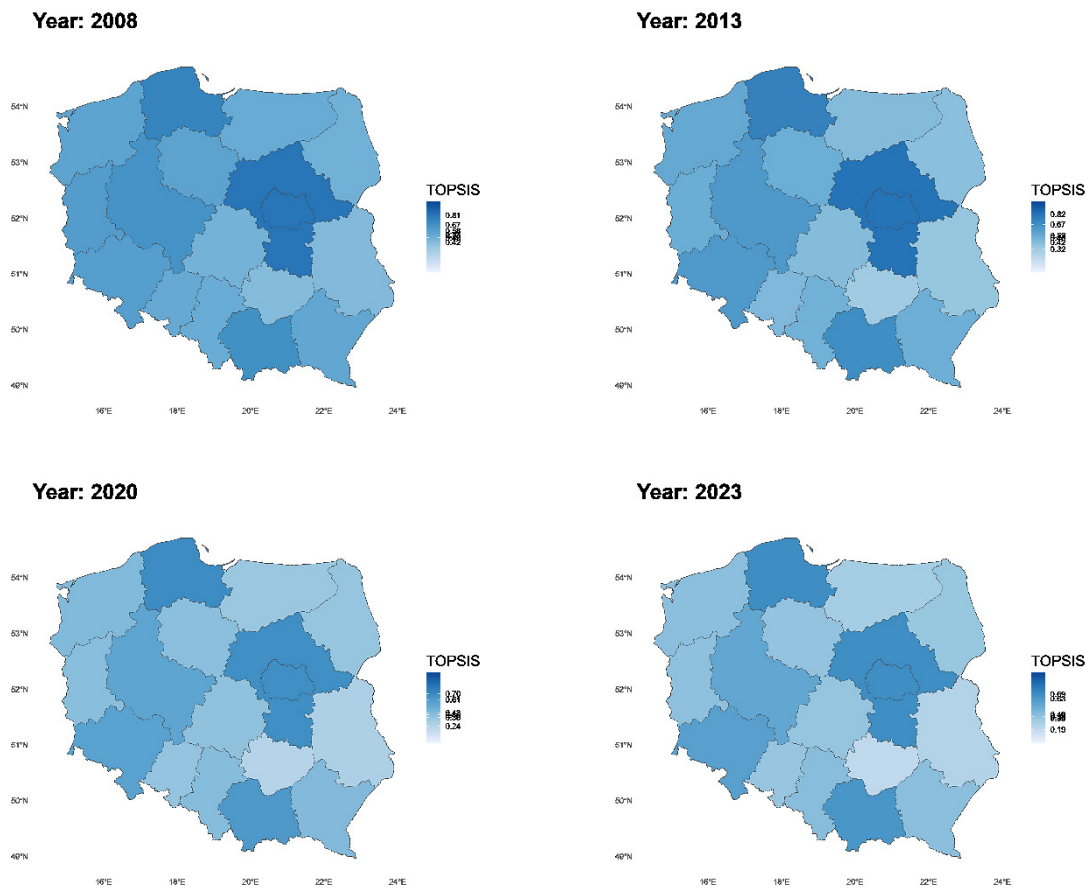


Figure 6. Intensity of the multi-criteria indicator value for Area II (Demographics).

Source: Own research.

At the beginning of the period, differences were noticeable between the Mazowieckie Voivodeship and most of the other voivodeships (the Pomorskie and Malopolskie voivodeships recorded the most similar multi-criteria values to the Mazowieckie Voivodeship). Over the years, the values have continued to diversify in favour of the Mazowieckie Voivodeship, but these differences are greater in the voivodeships located primarily in the eastern and northeastern regions, but also in comparison to some voivodeships in central and western Poland. In the final year of the period under review, the Malopolskie, Pomorskie, and Dolnoslaskie voivodeships achieved increasingly similar multi-criteria values to those for the Mazowieckie Voivodeship, demonstrating positive demographic changes in these regions. The differences in index values for the remaining voivodeships compared to the leaders are greater. Therefore, in the Demographics area, unfavourable changes are observed in the above-mentioned voivodeships of eastern, western, and central Poland.

Pearson's linear correlation coefficient³ was used to compare the obtained multi-criteria scores with the values of labour market variables. The following table was obtained (Table 2).

Table 2.

Correlation of multi-criteria assessments of Area II (Demographics) with variables from the Labour Market area

Year	Pearson correlation coefficients for Area II with the given variable			
	1.1	1.2	1.3	1.4
2008	0,770	-0,486	-0,485	0,610
2009	0,776	-0,453	-0,482	0,047
2010	0,786	-0,484	-0,420	0,488
2011	0,785	-0,515	-0,469	0,311
2012	0,782	-0,515	-0,498	0,047
2013	0,767	-0,536	-0,464	0,475
2014	0,784	-0,543	-0,473	0,712
2015	0,782	-0,616	-0,453	0,855
2016	0,761	-0,648	-0,510	0,763
2017	0,751	-0,624	-0,471	0,733
2018	0,737	-0,672	-0,525	0,764
2019	0,723	-0,674	-0,519	0,672
2020	0,711	-0,647	-0,553	0,657
2021	0,701	-0,694	-0,503	0,751
2022	0,707	-0,667	-0,484	0,753
2023	0,717	-0,703	-0,523	0,724

Source: Own research.

The correlation between average employment per 1000 inhabitants (variable 1.1) and the multi-criteria assessment of the Demographics area is strong, which is justified. This indicates that demographic conditions have a strong relationship with average employment. Variable 1.2 – the unemployment rate – is negatively correlated with the variable representing the Demographics area, weaker at the beginning of the period, but increasingly stronger over the years. This relationship seems justified – the higher the level of the indicator in the Demographics area, the lower the unemployment rate. Like the registered unemployment rate, long-term unemployment (variable 1.3) is negatively correlated with the multi-criteria assessment of the Demographics area. However, a slightly weaker correlation (at a moderate level) is visible compared to the registered unemployment rate, indicating that demographic factors are less strongly correlated with being unemployed for more than a year, and this area has a smaller impact on long-term unemployment. Assessing the correlation between the variable representing the net number of workplaces per 10,000 inhabitants (variable 1.4) and the study area, it can be observed that the correlation is rather low (positive) or moderate in the years 2008-2013. A stronger correlation for variable 1.4 (ranging between 0.657 and 0.855) is observed in the period 2014-2023. Reasons for this may include the fact that employees are currently more inclined to move between voivodeships for work.

³ For the absolute values of the Pearson correlation coefficient, the following interpretations were adopted: [0; 0.2) – very weak linear relationship, [0.2; 0.4) – weak linear relationship, [0.4; 0.7) – moderate linear relationship, [0.7; 1] – strong linear relationship (Ostasiewicz, Rusnak, Siedlecka, 1998).

The next area under consideration is Area III – Economy. The multi-criteria assessment levels obtained after applying the TOPSIS method are presented in Figure 7.

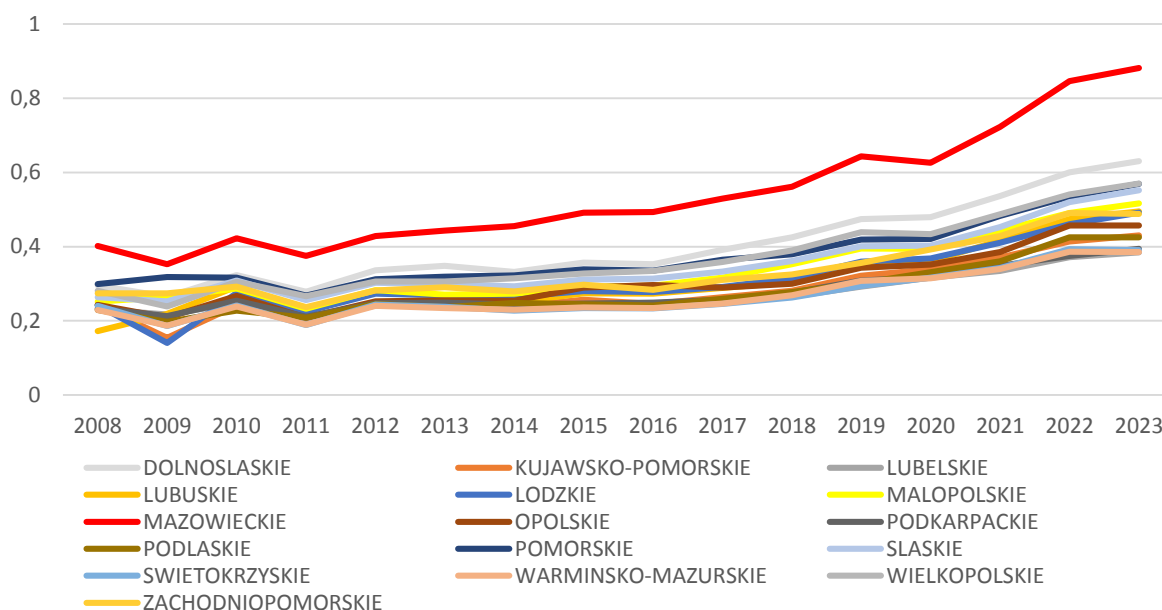


Figure 7. TOPSIS values for Area III (Economy).

Source: Own research.

The trend for all voivodeships is upward, so the multi-criteria assessment characterizing the Economy area is achieving increasingly higher values year by year. This is a positive sign, demonstrating the study area as a developing one. The highest scores, significantly outperforming the others, were achieved by the Mazowieckie Voivodeship. The next highest-scoring voivodeships were Dolnośląskie, Wielkopolskie, Pomorskie, and Śląskie. Among the voivodeships with the lowest multi-criteria assessments were the Warmińsko-Mazurskie, Podkarpackie, Świętokrzyskie, and Kujawsko-Pomorskie voivodeships.

Additionally, the evolution of the multi-criteria indicator value for Area III is presented on maps (Figure 8). Due to the upward trend in the multi-criteria assessment describing the Economy area in each voivodeship, especially in the two years specified at the end of the period (2020 and 2023), darker colours are visible, suggesting that the level of assessments within this area has significantly increased. The greatest differences are visible in 2023, when the Mazowieckie Voivodeship achieved very high values of the multi-criteria measure, while the remaining voivodeships, also despite noticeable increases, significantly differ from the level of the Mazowieckie Voivodeship.

The correlation of multi-criteria assessments of Area III with the Labour Market variables is presented in Table 3.

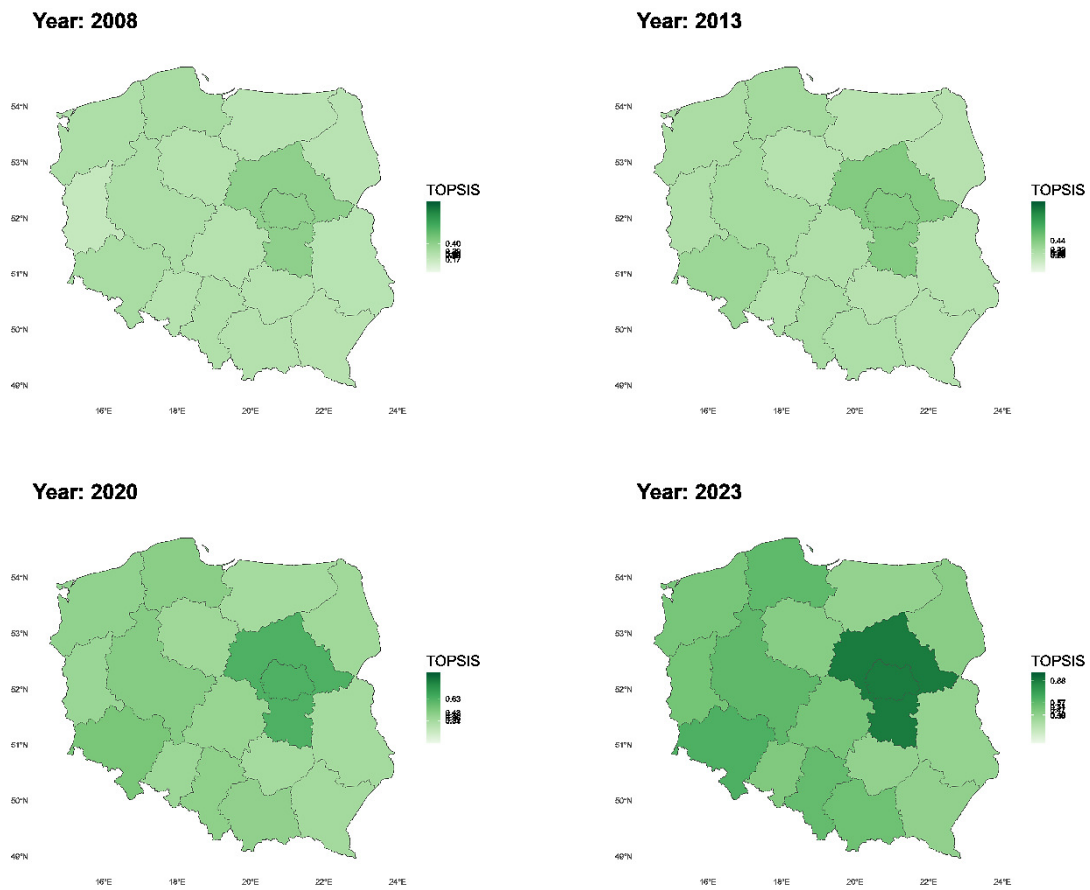


Figure 8. Intensity of the multi-criteria indicator value for Area III (Economy).

Source: Own research.

Table 3.

Correlation of multi-criteria assessments of Area III (Economy) with variables from the Labour Market area

Year	Pearson correlation coefficients for Area III with the given variable			
	1.1	1.2	1.3	1.4
2008	0,849	-0,498	-0,236	0,517
2009	0,692	-0,462	-0,457	-0,015
2010	0,937	-0,579	-0,482	0,255
2011	0,951	-0,624	-0,460	0,343
2012	0,947	-0,605	-0,475	-0,043
2013	0,932	-0,575	-0,405	0,346
2014	0,943	-0,598	-0,390	0,831
2015	0,938	-0,637	-0,430	0,784
2016	0,945	-0,660	-0,457	0,755
2017	0,946	-0,663	-0,465	0,886
2018	0,953	-0,687	-0,497	0,831
2019	0,957	-0,676	-0,484	0,705
2020	0,934	-0,659	-0,481	0,674
2021	0,933	-0,704	-0,469	0,829
2022	0,923	-0,670	-0,459	0,830
2023	0,938	-0,723	-0,500	0,754

Source: Own research.

Average employment per 1000 inhabitants (variable 1.1) is very strongly correlated with the multi-criteria assessment of the Economy area. This relationship is justified – increased employment stimulates the economy and its determinants. The correlation between the assessments for the considered area and the registered unemployment rate (variable 1.2) is negative – at the beginning of the period, this relationship is weaker (moderate), and it becomes increasingly stronger over the years. Again, this relationship is justified – lower unemployment and economic growth are interrelated. The correlation between the economic area assessment and the variable representing long-term unemployment (variable 1.3) is also negative, but weaker than that of the registered unemployment rate – it is stronger in the second part of the period under review than at the beginning. This observation again indicates that being unemployed for more than a year has a negative impact on the economy but is less strongly correlated with the area under review than the unemployment rate. The last of the considered variables from the Labour market area (variable 1.4) in the second part of the analysed period is strongly, positively correlated with the Economy area – this strong relationship has been observed since 2014. A larger number of newly created workplaces stimulates the development of the economy, and at the same time, a developing economy generates new workplaces.

The last area considered is Area IV – Innovations and R&D. The multi-criteria assessment values obtained using the TOPSIS method for this area are presented in Figure 9.

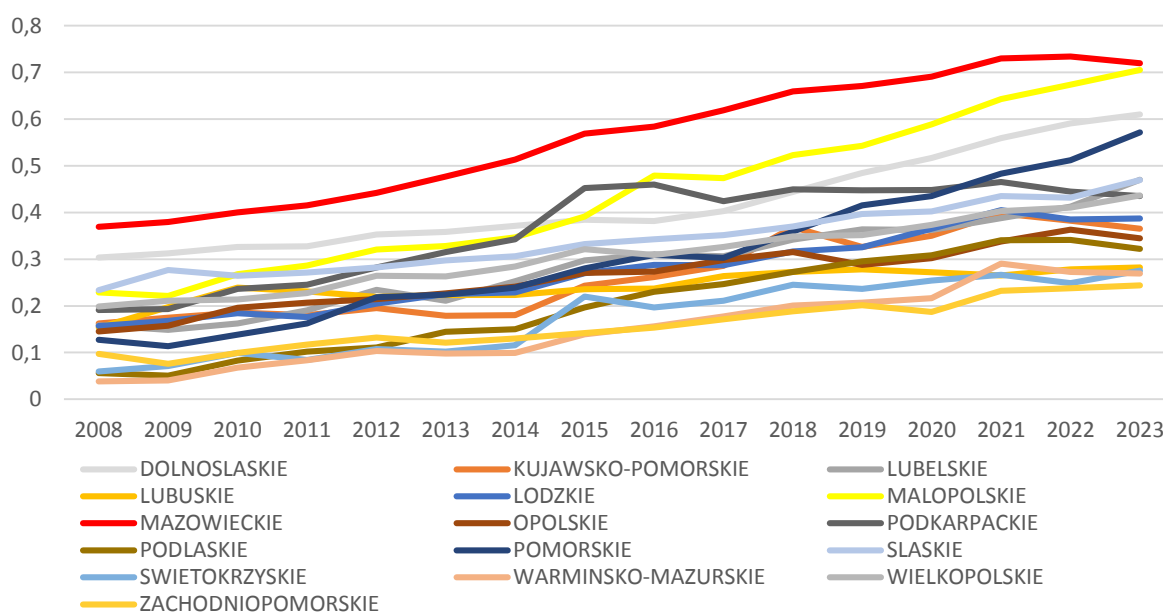


Figure 9. TOPSIS values for Area IV (Innovations and R&D).

Source: Own research.

In the case of the variable describing the area of Innovations and R&D, an upward trend is visible (although with varying intensity). Over the years, this area has played an increasingly important role in shaping many socio-economic phenomena. The highest values were again recorded for the Mazowieckie Voivodeship, with the multi-criteria assessments significantly exceeding those for the other voivodeships. The next voivodeships to rank high were the

Malopolskie Voivodeship, which almost equalled the Mazowieckie Voivodeship in 2023, and then the Dolnoslaskie Voivodeship. Interestingly, the Podkarpackie Voivodeship also achieved higher values for the multi-criteria measure describing this area between 2015 and 2018. This was the result of several factors, including the fact that real spending from the new EU perspective (2014-2020) began, companies and universities significantly increased their R&D expenditures, and the region benefited from a low base effect, making growth more visible than in wealthier voivodeships (Lichota, 2018). The least favourable results within the studied area were observed in the Swietokrzyskie, Warminsko-Mazurskie, and Zachodniopomorskie voivodeships.

Figure 10 shows the dynamics of changes in TOPSIS values in selected years of the period under consideration for all voivodeships.

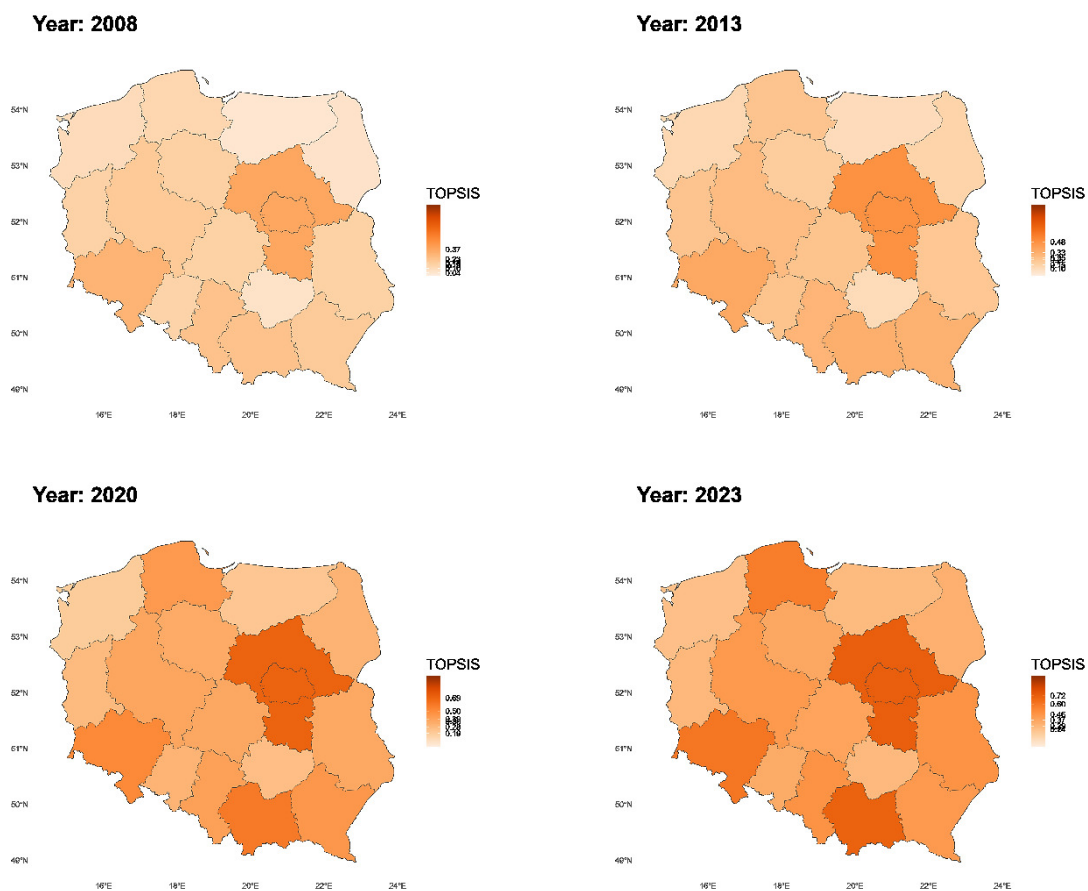


Figure 10. Intensity of the multi-criteria indicator value for Area IV (Innovations and R&D).

Source: Own research.

The intensity of colours on individual maps confirms the increasing importance of this area over the years under consideration. At the beginning of the period, in 2008, the least favourable area was in the northeastern voivodeships and the Swietokrzyskie Voivodeship. In subsequent years, the analysis revealed significantly improving scores for all voivodeships. At the end of the period under review (2023), the most favourable in this category were, as already mentioned, the Mazowiecki, Malopolskie, Dolnoslaskie, and Pomorskie voivodeships. It is confirmed that the voivodeships furthest from the PIS and closest to the NIS were the

Swietokrzyskie, Warminsko-Mazurskie, and Zachodniopomorskie voivodeships, as well as the Lubuskie Voivodeship.

The correlation analysis of Area IV with individual variables from the Labour Market category is presented in Table 4.

Table 4.

Correlation of multi-criteria assessments of Area IV (Innovations and R&D) with variables from the Labour Market area

Year	Pearson correlation coefficients for Area IV with the given variable			
	1.1	1.2	1.3	1.4
2008	0,812	-0,610	-0,361	0,687
2009	0,797	-0,624	-0,378	0,255
2010	0,790	-0,617	-0,327	0,336
2011	0,802	-0,675	-0,394	0,399
2012	0,806	-0,694	-0,385	-0,022
2013	0,809	-0,713	-0,334	0,393
2014	0,794	-0,684	-0,292	0,676
2015	0,726	-0,556	-0,060	0,616
2016	0,693	-0,522	-0,070	0,518
2017	0,759	-0,500	-0,103	0,723
2018	0,742	-0,463	-0,070	0,792
2019	0,748	-0,517	-0,133	0,701
2020	0,727	-0,559	-0,184	0,655
2021	0,718	-0,437	-0,123	0,813
2022	0,708	-0,482	-0,190	0,688
2023	0,687	-0,543	-0,267	0,765

Source: Own research.

The correlation between variable 1.1 – average employment per 1000 inhabitants – and the multi-criteria assessment of area IV is relatively strong, although it weakens slightly over the years – a greater share of innovation results to some extent in an increase in the number of people employed. The relationship between the registered unemployment rate (variable 1.2) and the indicator for the discussed area is at a moderate, negative level, weakening slightly over the years – a higher level of innovation and R&D expenditures favours a reduction in unemployment, as reflected by the negative correlation. Over the years, this relationship weakens slightly, as the impact of innovation on employment becomes indirect – alongside positive effects, there are also phenomena of automation and changes in the structure of labour demand. Negative values of the correlation coefficient between the Area IV measure and the variable representing long-term unemployment (variable 1.3) indicate that higher levels of innovation are accompanied by lower levels of long-term unemployment. However, this correlation is weak, and after 2014, very weak, indicating a weak connection between these characteristics. The last of the considered labour market variables, describing the net number of workplaces (variable 1.4), is weakly correlated with innovation in 2009-2013, after which the correlation becomes moderate to strong. Therefore, the relationship between this variable and innovation and research and development is increasingly strong.

4. Summary

The Polish labour market is characterized by low occupational and spatial mobility of workers, a high share of long-term unemployed individuals, and a mismatch between the skills structure and the needs of the economy (Gajdos, Lewandowska-Gwarda, 2022). Although active labour market policy does not permanently solve employment problems and has numerous limitations, it plays an important role in counteracting professional exclusion, particularly in the case of long-term unemployment.

This study examined the development and relationships between key labour market characteristics and selected socio-economic areas. In the case of the first variable – average employment (variable 1.1), the analyses showed that Area III – Economy – was most closely correlated with this variable. The observed correlations were very high and positive throughout almost the entire period. This indicates that increased employment has a positive impact on the economy, and a growing economy promotes hiring. The remaining two areas: Demographics (over the entire period) and Innovations and R&D (since 2014) are also strongly positively correlated with variable 1.1, confirming their significant relationship.

The second characteristic from the Labour Market area, the registered unemployment rate (variable 1.2), showed mainly moderate negative correlations with the areas under consideration. In the case of the Demographics and Economy areas, these relationships became stronger year by year – unfavourable (low) levels of demographic or economic indicators translate into higher unemployment rates. Area IV (Innovations and R&D) is also moderately and negatively correlated with variable 1.2, although the strength of this correlation has weakened slightly over the years. However, the moderate correlation confirms an important relationship between the studied areas and the registered unemployment rate.

The characteristic representing long-term unemployment (variable 1.3) shows the strongest, moderate, negative correlation with Area II, which, however, is weaker compared to the correlation of this area with the unemployment rate. A similar relationship is visible in the case of variable 1.3 with the Economy area. The weakest correlation, and in the second part of the analysed period, even negligible, was noted between long-term unemployment and the Innovations and R&D area – this weak correlation allows us to conclude that the development of this area has little impact on unemployment lasting longer than a year.

The fourth labour market characteristic (variable 1.4) – the net number of workplaces – in the initial period showed rather little correlation with the areas considered. A quite strong, positive correlation was noted in the second part of the area under consideration (since 2014), which was comparable across all three areas. Therefore, in recent years, the positive influence of demographic and economic factors, as well as research and development activity, has stimulated job creation.

A key focus of socio-economic policy should be investing in human capital and adapting competencies to the dynamically changing demands of the labour market. Better integration of regional policies with innovation and R&D policies by supporting projects that combine economic development with job creation, as well as adapting regional activities to the demographic and economic specificities of individual voivodeships, will enable the country's sustainable development.

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STAKEHOLDER COLLABORATION FOR SUSTAINABILITY-ORIENTED INNOVATIONS AND INITIATIVES IN THIRD-PARTY LOGISTICS

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Purpose: The main aim of the article is to identify and analyse sustainability-oriented innovations and initiatives undertaken by logistics service providers in cooperation with their stakeholders.

Design/methodology/approach: The research integrates a comprehensive literature review and empirical research. The literature review included a bibliometric analysis via the Scopus database and VOSviewer software. This review examined the classification and significance of sustainability in logistics sector, as well as the key assumptions underlying the concept of sustainability-oriented innovations (SOIs). In the empirical research, a questionnaire was administered to 36 logistics service providers (LSPs) to analyse SOIs and identify the roles of stakeholder collaboration in logistics service practices.

Findings: The article outlines SOIs and initiatives undertaken by 3PL providers in collaboration with stakeholders in each of sustainable development goals (SDGs). According to the research results, internal stakeholders are vital as they drive the implementation of initiatives and shape external relationships. Customers contribute to SDGs 3, 6, 9, and 12, while subcontractors are key for SDGs 3, 8, and 9 through innovative and low-emission practices. The research allowed to establish the roles of stakeholder collaboration for logistic service providers. Those roles were categorized into four main categories: organizational-executive, transactional-operational, regulatory-supervisory and supporting.

Research limitations/implications: The main limitation encountered during the research was the difficulty in obtaining enough responses from LSPs offering their logistics services in Poland. This was largely due to the limited availability of managers responsible for sustainable development issues. However, the obtained sample size met the minimum requirements for the established population.

Practical implications: The research findings on the role of stakeholder collaboration for sustainable innovation are highly relevant for LSPs. The presented list of SOIs and other initiatives can serve as a valuable source of inspiration for companies within the logistics sector.

Originality/value: This article provides an analysis of sustainability-oriented innovations and initiatives undertaken by 3PL providers, along with the distinct roles of stakeholder collaboration in these efforts.

Keywords: SOI, logistics service provider, stakeholders.

Category of the paper: research paper.

1. Introduction

Issues related to sustainable development are currently the subject of wide discussion in both the scientific and business communities. This topic is also an significant element of public discourse. There is no doubt that one of the sectors that contributes the most to climate change is logistics. The external impact of this industry is multi-dimensional, affecting both environmental and social aspects. A particularly important role in the sector is played by third-party logistics (3PL) providers. Those entities can be defines as companies that offer comprehensive logistics services of transport and warehousing to external clients. The characteristic of logistics service providers (LSPs) is that they operate in a complex network, within which they cooperate with various types of stakeholders. Their cooperation mainly takes the form of operational partnership, but increasingly also focuses on environmental issues. Considering the expectations of individual stakeholder groups within these relationships, there is a possibility of joint implementation of sustainability-oriented innovations (SOIs). Initiatives focused on sustainable development can include activities of varying levels of complexity. Given the increasing prominence of SOIs in academic discourse (Nicoletti, Appolloni, 2024), it is pertinent to explore the influence of stakeholders on the sustainable initiatives undertaken by 3PL providers. Although the sustainable development of the logistic sector has been addressed in numerous studies (Neutzling et al., 2018; Ozbekler, Ozturkoglu, 2020; Lazar et al., 2021), there remains a notable gap in the literature concerning the specific role of stakeholder collaboration in this context. Arising from the recognized gap in existing research, two research questions were developed:

- Q1 - what types of sustainability-oriented innovations and initiatives can be implemented by 3PL providers in each of sustainable development goals?
- Q2 - what roles does cooperation with stakeholder groups play in implementing sustainable practices for 3PL providers?

The main aim of the research is to identify and analyse sustainability-oriented innovations and initiatives undertaken by logistics service providers in cooperation with their stakeholders. To address the research questions, a combination of literature review and empirical research was undertaken. The literature review included a bibliometric analysis via the Scopus database and VOSviewer software, focusing on SOIs and sustainability aspects in the 3PL services. This review examined the classification and significance of sustainability in logistics sector, as well as the key assumptions underlying the concept of sustainability-oriented innovations. It also considered the role of stakeholder collaboration in implementing sustainability initiatives. Based on the literature review, a questionnaire for 3PL providers was developed. In the empirical phase, this questionnaire was administered to enable the identification and analysis of SOIs in logistics service practices. The article concludes with a synthesis of the key findings and a critical reflection on its principal limitations.

2. The concept of sustainability in logistics services

The concept of sustainable development was formed in the second half of the 20th century. The year 1992 during the Earth Summit in Rio de Janeiro was of particular importance in promoting this concept. During the event, two important documents were adopted: the Rio Declaration and Agenda 21. On the one hand, the concept of sustainability emphasizes ensuring development both in the economies of states and individual organizations. On the other hand, it focuses on ensuring that this development does not contribute to the deterioration of the environment and does not cause negative effects on society (Skowroński, 2006). The Sustainable Development Goals (SDGs) are at the core of this concept. They are a set of 17 interconnected goals adopted by all UN member states in 2015 as part of the 2030 Agenda. The goals are often grouped into thematic clusters under the five P pillars: People (SDGs: 1, 2, 3, 4, 5), Planet (SDGs: 6, 12, 13, 14, 15), Prosperity (SDGs: 7, 8, 9, 10, 11), Peace (SDG: 16) and Partnership (SDG: 17). Companies around the world are expected to integrate the SDGs into their strategies and operations (Smith et al., 2018).

Researchers underline that the approach to sustainability of the organisations should be firmly embedded in the culture (Ekins, Zenghelis, 2021). Research on the topic of sustainable development of enterprises was conducted by B. Willard, within which he adopted the assumptions of the four quadrants of sustainability, presented in Figure 1. In accordance with these assumptions, companies mature in their sustainability efforts by moving beyond basic compliance to strategically employ disruptive innovation, creating environmentally superior products and processes for existing and new markets (Willard, 2012).

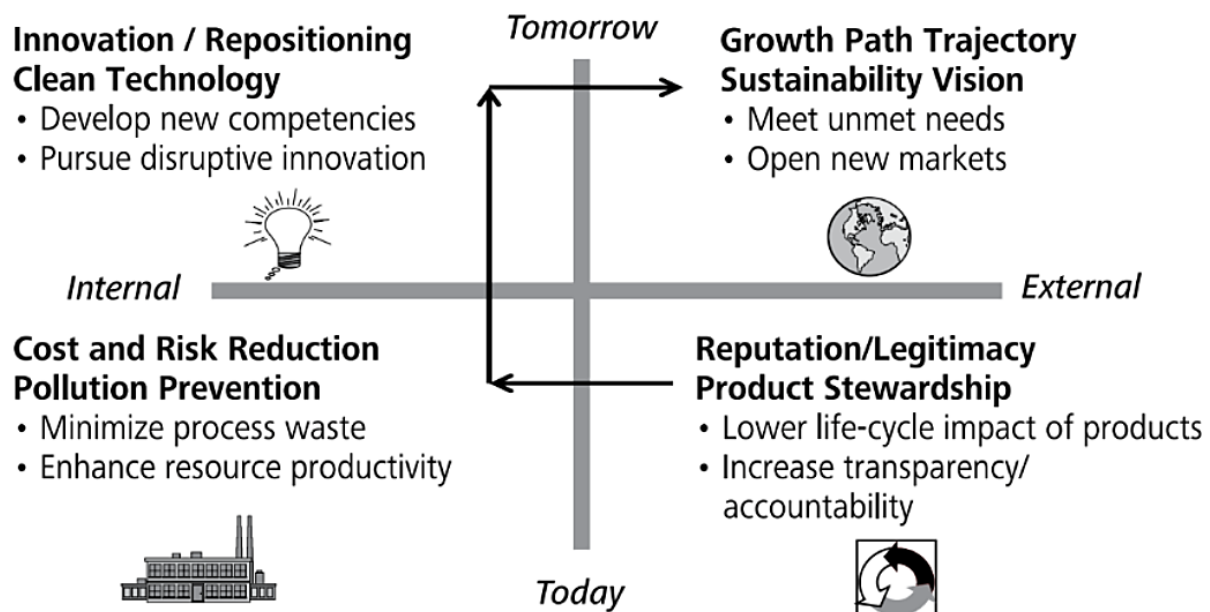


Figure 1. Four quadrants of enterprise sustainability.

Source: Willard, 2012, p. 3.

2.1. Sustainability-Oriented Innovations

The concept of sustainability-oriented innovations (SOIs) concerns the implementation of a new or improved product, service or system that leads to environmental and/or social benefits (Hansen et al., 2012). From the above definition it can be concluded that SOI goes beyond the area of technological innovation, covering a much broader spectrum of initiatives. The authors also draw attention to the aspect of measurability of SOIs effects, which can be qualitative or quantitative indicators. According to the concept presented by Adams et al., three dimensions of SOIs can be distinguished: technical/people; stand-alone/integrated, and insular/systemic. The first of the analysed dimensions focuses on technical and social aspects. The authors emphasize the gradual evolution of innovations from those focusing on the product itself to methods that go beyond technical aspects and simultaneously consider socio-technical issues. According to this assumption, to introduce sustainable innovations, research on business models, the way innovations are used and the people responsible for their implementation should be considered. The second of the proposed dimensions considers the way in which SOIs is treated within the organization. This dimension focuses on the way innovation is approached as an additional activity or as an activity deeply rooted in the company's culture. The last dimension analysed considers the company's view of its importance in relation to the whole society. It can take one of two forms: the insular dimension (when innovations are directed mainly at internal problems of the organisation) or the systemic dimension (when innovations are directed at the wider social system) (Adams et al., 2016).

There are three main criteria for classifying SOIs: orientation, type and nature. The first type divides innovations into Sustainability-Relevant (SRI), Sustainability-Informed (SII) and Sustainability-Driven Innovation (SDI). SRI refers to innovations that unintentionally support sustainability. SII integrates sustainability considerations without making them central, while SDI is explicitly driven by the goal of achieving substantial sustainability impact. In terms of types, technological, organizational, institutional or social innovations are distinguished. However, innovation can also concern a process or infrastructure. The last type divides innovations in terms of their nature into disruptive and sustaining. Within it, one can also distinguish between the radical and incremental degrees (Jay, Gerard, 2015).

The SOIs implementation process can be presented in four steps. The first is the identification of needs within the organization's activities. The second step concerns the attempt to define the problems within which the innovation is to be implemented, considering available resources. The third step involves generating solutions. The last step focuses on the implementation of the created innovations (Jay, Gerard, 2015). The SOI process requires the organization to establish an appropriate strategy in advance and determine the direction in which it should go. Based on this, the management staff, in consultation with individual stakeholder groups, should decide on the validity of undertaking new initiatives in a given area of the company's operation (Jum et al., 2022).

2.2. Implementation of SOIs by logistics service providers

The SOIs implementation process for 3PL providers should consider their wide range of environmental and social impacts. Researchers draw attention to the links between SOIs and the concepts of industry 5.0 and green logistics 5.0. Among the potential solutions in this aspect, the authors mention business models and operational activities concerning, among others, the optimization of planning transport routes, warehouse processes, but also activities aimed at the local community (Nicoletti, Appolloni, 2024). H. Jumadi and S. Zailani in their article describe four approaches to sustainable innovation in logistics services: green transportation, green storage, green packaging and reverse logistics (Jumadi, Zailani, 2010). Evangelista et al. also focus attention on green initiatives in logistics services. They concentrate on solutions in terms of vehicle optimisation, warehouse infrastructure, recycling, certification and collaboration with partners (Evangelista et al., 2018). Among sustainability initiatives in logistics services, most are focused on the SDG of sustainable cities and communities. According to the analysis conducted by Lazar et al., goals related to cooperation, responsible consumption, reducing inequalities, and innovation are also particularly important (Lazar et al., 2021).

Based on the presented approaches to SOIs in logistics services, a strong aspect of their division into the area of processes of warehousing and transportation is visible. In both services, innovations can be effectively supported by the latest technologies. In the first of them, the use of the Internet of Things (IoT) and RFID identification is particularly important. Automation of warehouse processes and smart warehouse solutions can be included in this way as one of the examples of sustainable oriented innovations (Aravindaraj, Chinna, 2022). Systems for tracking the location of goods in real time shorten the operation time and can contribute to reducing resource consumption. IoT sensors also enable ongoing monitoring of energy consumption in the warehouse. This solution allows for the identification of areas requiring optimization. The use of this tool is also possible in the aspect of intelligent control of lighting and air conditioning in the warehouse (Aksu, 2025).

When analysing the potential of using SOI in transport processes, special attention in research is paid to the aspect of using alternative fuels. Currently, some of the companies representing the transport sector are intensively conducting research on alternative fuels. An example is the work on increasing the use of hydrogen, biofuels, and e-fuels by some of the largest logistics service providers operating in Europe. Despite the growing interest in this issue, there are still many barriers, among which the most frequently mentioned are high costs and the need to adapt the infrastructure. A solution that can reduce gas emissions in transport processes and at the same time increase the level of revenues is pooling. It is defined as a method of combining deliveries in order to optimize the use of the vehicle's cargo space (Mrabti et al., 2021). To evaluate the implemented SOIs, it is possible to use appropriate indicators.

In the case of transport processes, they may concern the level of carbon dioxide equivalent emissions, but also fuel consumption or noise emission levels (Jourmad, Gudmundsson, 2010).

Sustainable initiative solutions do not focus solely on operational aspects but can also impact the broader area of impact of an organization. Based on the literature review, a list of activities for sustainable development was created that can be implemented by a logistics service providers in each of the 17 SDGs, which is presented in Table 1.

Table 1.

Sustainability-oriented innovations and initiatives in 3PL services

SDG	Sustainability-oriented innovations and initiatives in 3PL services
1.	(1) Supporting the local community, (2) creating jobs, (3) engaging in charitable activities
2.	(4) Innovative solutions in food logistics, (5) supporting local farmers, (6) organizing educational programs on healthy eating
3.	(7) Ensuring compliance with health and safety rules, (8) reducing the number of road accidents involving the fleet, (9) reducing the noise emitted by the activities of 3PL providers
4.	(10) Continuous improvement of employees' competences, (11) supporting local schools and universities by enabling them to carry out internships, (12) supporting students by financing scholarships
5.	(13) Implementing policies and practices that support gender equality in employment and career advancement, (14) implementing policies and training aimed at eliminating violence and discrimination in the workplace, (15) promoting gender equality among business partners
6.	(16) Ensuring appropriate sanitary conditions in the workplace, (17) rational use of water resources in the company's operations, (18) use of ecological solutions in the field of wastewater treatment
7.	(19) Effective management of energy consumption in the warehouse, (20) increasing the share of renewable energy sources, (21) investing in an electric fleet of vehicles
8.	(22) Ensuring favorable working conditions and counteracting all forms of exploitation, (23) implementing innovative business solutions, (24) creating partnerships with local companies and suppliers to support economic growth at the local level
9.	(25) Implementation of warehouse management systems based on IoT technology, (26) implementation of innovative technologies in logistics operations to increase efficiency, (27) use of the latest IT solutions and ensuring their compatibility with partners' systems
10.	(28) Implementing employment practices that promote diversity in the workplace, (29) eliminating pay gaps related to ethnicity and other factors, (30) Creating mentoring programs in the company that support the professional development of employees from minorities or marginalized social groups
11.	(31) Location of logistics centres outside highly urbanised areas, (32) route planning bypassing city centres, (33) increasing the share of intermodal transport
12.	(34) Minimising the use of single-use packaging and promoting sustainable packaging materials, (35) supporting the recycling (36) organising educational campaigns on sustainable consumption
13.	(37) Increasing the share of low-carbon fleets, (38) implementation of greenhouse gas emission monitoring systems, (39) offsetting of greenhouse gas emissions
14.	(40) Minimising the negative impact of maritime transport on aquatic ecosystems, (41) minimising the use of water resources, (42) supporting scientific research on the state of life below water
15.	(43) Study the impact of logistics activities on biodiversity, (44) work with partners to minimize soil degradation and deforestation, (45) support projects for the conservation of endangered species
16.	(46) Implementing anti-corruption policies within the company and supporting anti-corruption activities, (47) providing education for employees and business partners to raise awareness of human rights, (48) ensuring fair and timely remuneration
17.	(49) Establishing partnerships with NGOs and local organizations to develop sustainable projects, (50) supporting local businesses and suppliers, (51) regular reporting of sustainable activities, to increase transparency and accountability to stakeholders

Source: own elaboration based on: General Assembly resolution A/RES/70/1: The 2030 Agenda for Sustainable Development, pp. 16-40.

For each of the SDGs, three actions were selected, based on the assumptions of the 2030 Agenda. This allowed for the identification of a total of 51 SOIs and initiatives. The table tried to include activities that are mainly innovative in nature, but the main selection criterion of the actions was the impact on the sustainable development of the 3PL providers.

2.3. Stakeholders collaboration in the implementation of SOI by logistics service providers

Logistics service providers cooperate with numerous stakeholder groups. Their classification can be based on many criteria, the most basic of which is the division into internal and external stakeholders (Stocker et al., 2020). Internal stakeholders of a 3PL providers include employees and management staff. However, the classification of external stakeholders is much broader. They include, among others: customers, suppliers, logistics infrastructure managers, authorities (both state and local), local communities, non-profit organizations, and universities. The presented classification is universal, but it should be noted that the actual number of stakeholders included in each of the above groups may vary depending on the specificity of the operator's activity and the complexity of the logistics services provided. Each of the stakeholder groups presented above may be characterized by a different level of influence and involvement in the logistics operator's activity. Depending on these two factors, an appropriate stakeholder relationship management strategy can be selected (Rane et al., 2021). The assumptions of this approach are presented in the power/interest matrix on the Figure 3.

Power	High	KEEP SATISFIED	KEY SUBJECTS
	Low	MINIMAL EFFORT	KEEP INFORMED
		Low	High
		Level of interest	

Figure 3. Power/interest matrix.

Source: Johnson, Scholes, 1999.

The created matrix is used to select appropriate initiatives and courses of action regarding building relationships with the organisation within a given stakeholder group (Johnson, Scholes, 1999). Depending on these factors, the logistics service providers can select SOI that would be possible to implement together with a given group of stakeholders and would meet their expectations. An example of such initiatives at the local level could be enabling school students to complete an internship. This solution doesn't require high financial outlays from the logistics service provider and allows meeting the expectations of one of the stakeholder groups, while at the same time bringing additional value to the organisation (Kurbatova, 2020).

3. Methods

To achieve the main objective of the article, which is to identify and analyse SOIs and initiatives undertaken by logistics service providers in cooperation with their stakeholders, research was conducted using a survey questionnaire. The research focused on the largest 3PL providers in Poland. After analysing the TSL 2024 Report and other industry reports, it was determined that there are approximately 235 such companies on the Polish market. Assuming the following parameters: population (235), confidence level (95%), maximum error (7%), fraction size (95%), it was determined that the minimum number of responses from the survey should be 33. The research was conducted using the CAWI method. The questionnaires were addressed to the management staff of departments responsible for issues related to the sustainable development. The research was conducted in the period from July 2024 to January 2025. During the research, LSPs determined which of the SOIs identified at the literature research in Table 1. have the greatest impact on their organisation using a Likert scale. In addition, for each SOI, LSPs selected stakeholder groups with whom they cooperate.

4. Results

A total of 36 LSPs participated in the research. Considering the calculated minimum population size of 33 entities, the total number of responses obtained is sufficient. The average time of filling out a single questionnaire by a person representing an LSP was 30 minutes. The surveyed entities were diverse both in terms of size and geographical scope of the logistics services provided. Their characteristic is presented in Figure 4.

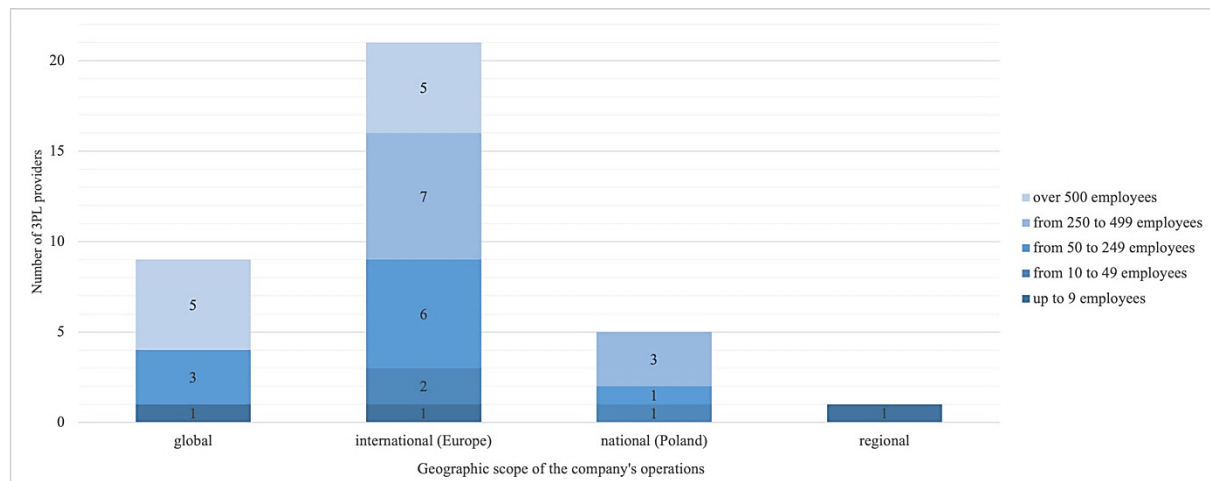


Figure 4. Characteristics of the surveyed LSPs.

Source: own elaboration.

In terms of the scope of services provided, international companies dominated. There were 21 entities among them (58.33%), 9 entities (25%) declared global scope, 5 (13.89%) national and 1 (2.78%) regional. 21 companies (58.33%) defined their form of ownership as private with domestic capital, while 15 (41.67%) as private with foreign capital. In the following questions, 3PL providers assessed the level of influence and involvement of individual stakeholder groups. Based on the answers provided in the following questions concerning individual stakeholder groups on logistics operators, a stakeholder map was created, which is presented in Figure 5.

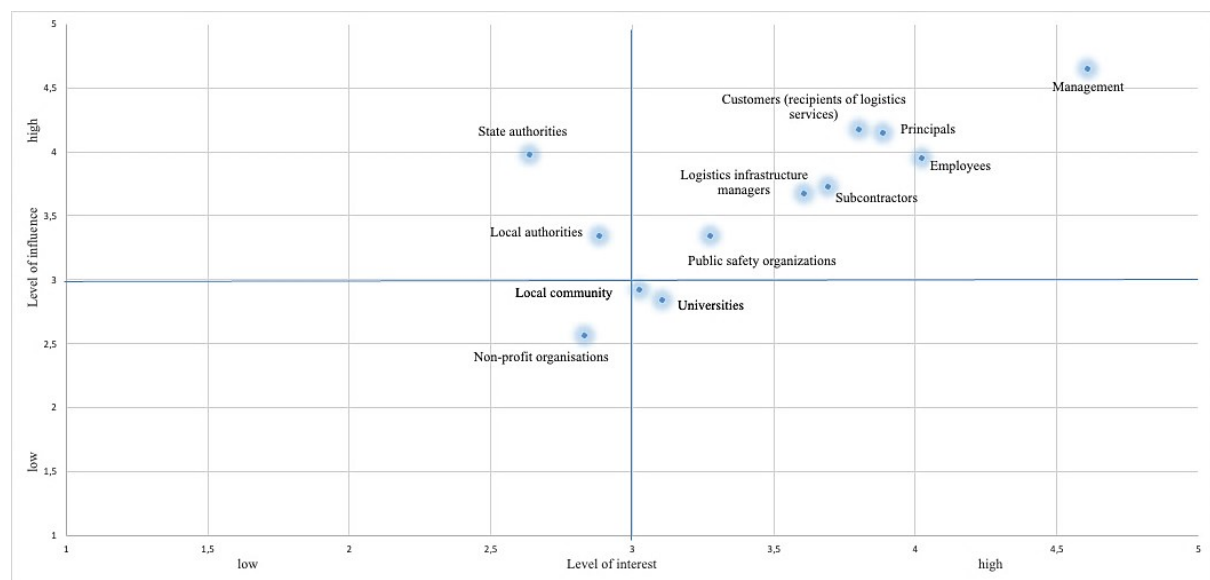


Figure 5. Results of power/interest matrix.

Source: own elaboration.

The aim of the map was to determine the directions of 3PL providers actions in relation to individual groups in accordance with the concept of the G. Johnson and K. Scholes matrix, the assumptions of which are presented in the literature part of the article. This matrix is a tool often used in the identification and analysis of stakeholders. According to the obtained results,

internal stakeholders (management staff and employees) were characterized by the highest level of average involvement and influence on the organization. Other stakeholder groups to which the strategy of close cooperation should be applied also include: customers, clients, subcontractors, managers of logistics infrastructure and organizations related to public safety. Both in the case of local and state authorities, LSPs should adopt a strategy of maintaining satisfaction - most often these two stakeholder groups were characterized by a high level of influence, but a low level of involvement. The information strategy should be used in the case of cooperation with the local community and universities. In turn, the strategy of monitoring expectations should be used in the case of a non-profit organization, which was the only stakeholder group characterized by both low levels of influence and involvement. It should be emphasized that the created map can only be a guide for 3PL providers in terms of selecting appropriate strategies and should be discussed by top management during the formulation of the strategy for individual stakeholder groups.

The next question concerned the sustainability-oriented innovations and initiatives implemented by LSPs within each of the 17 SDGs. The number of operators who declared the implementation of tasks within each of the goals is presented in Figure 6.

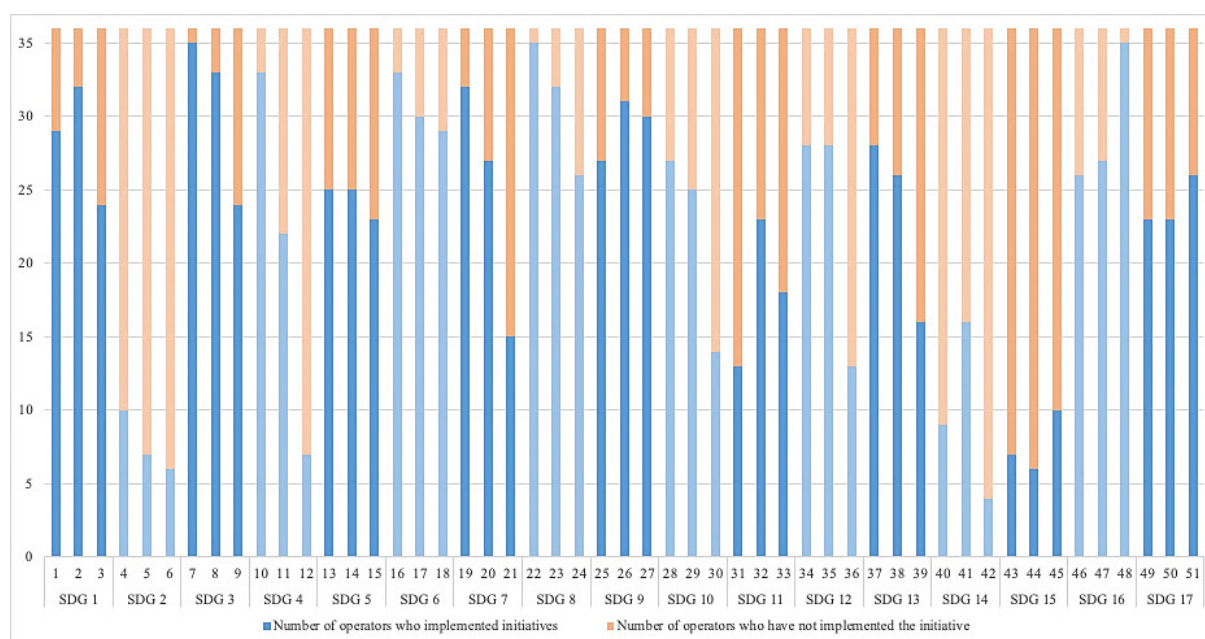


Figure 6. Number of LSPs who implemented initiatives in each of the 17 SDGs.

Source: own elaboration.

The analysis of the presented graph made it possible to determine which initiatives are currently being implemented by LSPs in particular SDGs. Each initiative was given its number in brackets from Table 1. The largest number of LSPs (35 entities) declared the implementation of three initiatives: compliance with occupational health and safety rules (initiative 7), ensuring favorable working conditions and counteracting forms of exploitation (initiative 22) and ensuring fair and timely remuneration for employees (initiative 46). It should be noted that the implementation of these activities results directly from the applicable legal regulations.

33 LSPs declared the implementation of activities to reduce the number of road accidents (initiative 8), increase employee competences (initiative 10) and ensure appropriate sanitary conditions at the workplace (initiative 16). The next positions were occupied by effective energy consumption management (initiative 19), job creation (initiative 2), and implementation of innovative business solutions. At the other end of the scale, there were activities related to supporting scientific research on the state of life under water (initiative 42), which were declared by only 4 LSPs. Activities related to cooperation with partners to minimize soil degradation and deforestation (44), as well as organization of educational programs on healthy nutrition (initiative 5) also received a low score. Analysing the graph, it is worth noting that the low level of implementation concerned mainly 2 and 15 SDG.

During the analysis of the responses to the previous question, attention was also given to evaluating the impact of stakeholder cooperation on the implementation of each identified initiative. The results of this analysis are presented in Figure 7. In the graph, the bars represent the average assessment of stakeholders' influence on each initiative, the green line indicates the median, and the red line shows the standard deviation. It should be noted that, according to the surveyed LSPs, stakeholder cooperation is most strongly associated with ensuring compliance with health and safety regulations (initiative 7), which received an average Likert scale score of 4.36. Activities aimed at maintaining appropriate sanitary conditions in the workplace (initiative 16) also proved significant, with an average score of 4.08, as did effective energy consumption management in logistics warehouses, which scored 4.00. All other initiatives received average ratings below 4.00. Seven initiatives were rated below 2.50, primarily those related to SDGs 2 and 15. When analysing the graph, it is important to note a relationship between the number of initiatives implemented by operators (as shown in Figure 5) and the average perceived impact of stakeholder cooperation on their implementation.

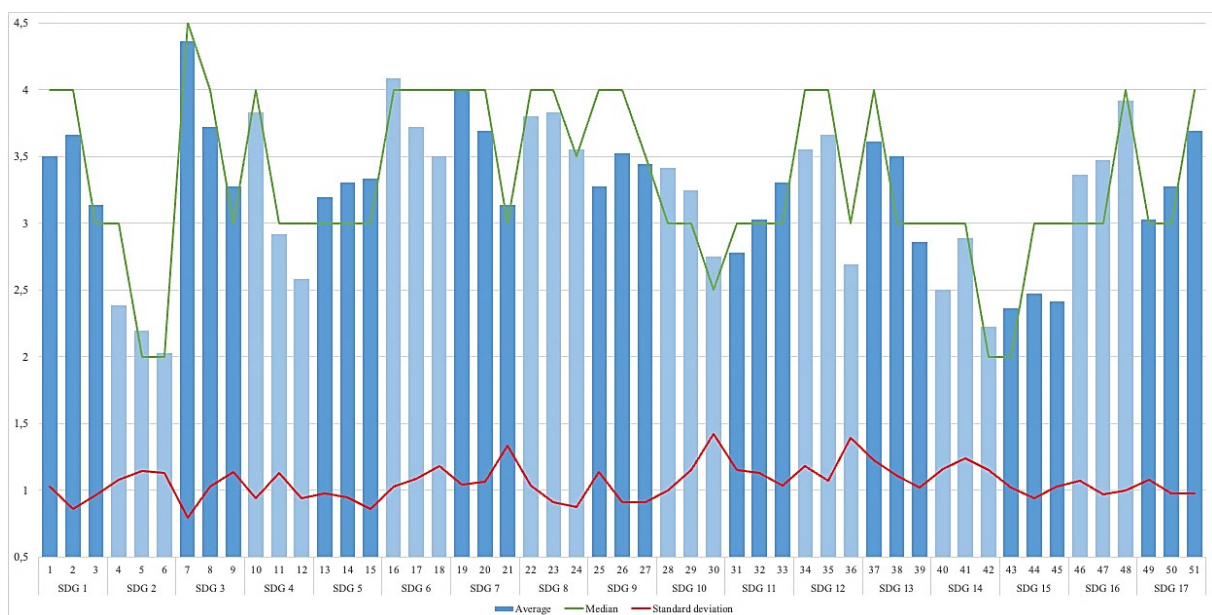


Figure 7. Number of LSPs who implemented initiatives in each of the 17 SDGs.

Source: own elaboration.

It should be emphasized that a particularly large group of stakeholders was indicated in initiatives concerning 1, 3, 8, 9 and 17 SDGs. Among the initiatives listed in each of the goals, particularly high scores were obtained by: ensuring compliance with health and safety rules (initiative 7 – a total of 127 stakeholders), supporting the local community (initiative 1 – 124 stakeholders) and implementing innovative business solutions (initiative 23 – 117 stakeholders). The smallest number of stakeholder groups with which cooperation takes place concerns 2, 14 and 15 SDGs. The lowest rated activities were: supporting scientific research on the state of life under water (initiative 42 – only 5 stakeholder groups), organizing educational programs on healthy eating (initiative 6 – 7 stakeholders).

Analysing the consistency of the presented results, a positive correlation was shown between the total number of declared stakeholder groups and the average assessment of the impact of cooperation with them on the implementation of sustainable development goals. The Pearson correlation coefficient was 0.83, which indicates a strong positive relationship between the variables. The classification of identified stakeholder groups in terms of their roles in the implementation of SDGs is illustrated in Figure 8.

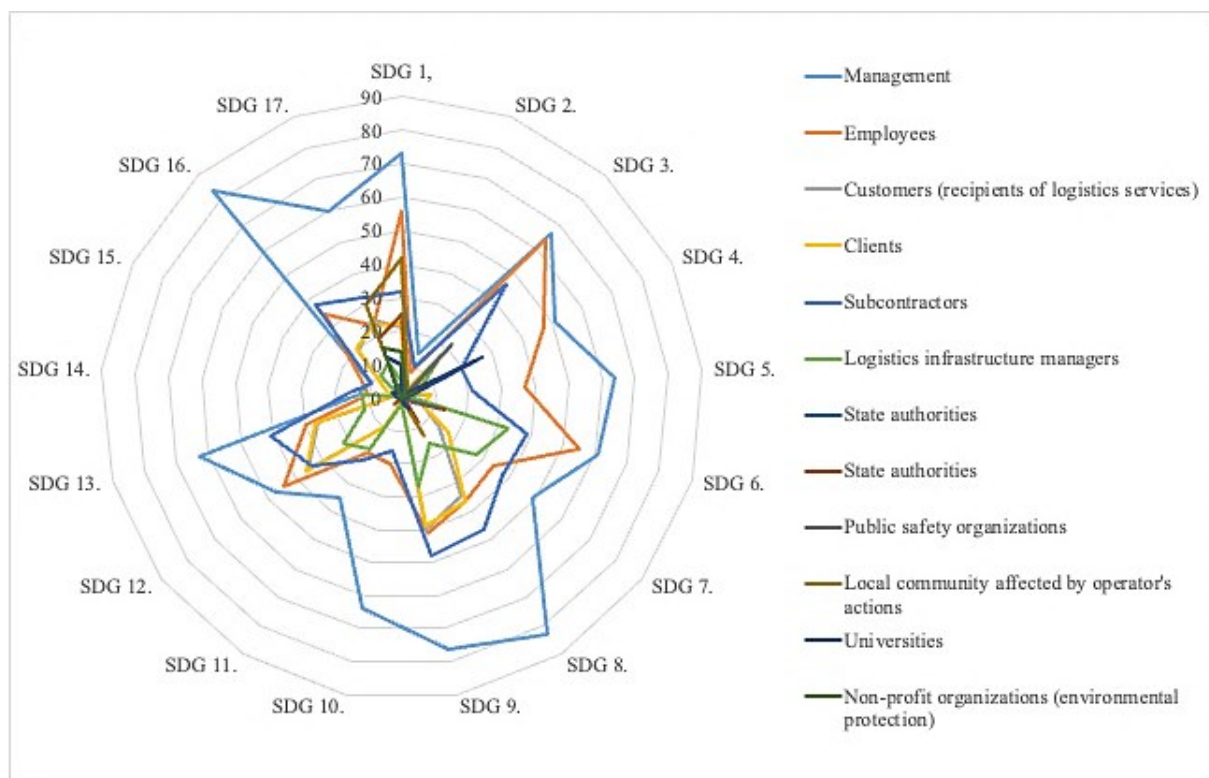


Figure 8. Classification of stakeholder groups in terms of their roles in implementing the SDGs.

Source: own elaboration.

To increase its level of transparency, it was decided to sum up the number of stakeholder groups that were mentioned by LSPs in initiatives within each of the sustainable development goals. It should be noted that the vast majority of responses are dominated by internal stakeholders (management staff and employees). Their role is particularly important in the implementation of 1, 3, 5, 6, 8, 9, 13 and 16 SDGs. It should be noted that this group was

mentioned most often due to the fact that regardless of the initiative undertaken, there is always a party that in some way represents the logistics operator. One of the most important groups of external stakeholders of a logistics operator are customers and principals. As the results of the questionnaire show, these relations are not only transactional in nature, but may also concern the implementation of 3, 6, 9 and 12 of the sustainable development goals. As the research shows, LSPs are open to cooperation with this group of stakeholders. When defining the role of principals and customers of a logistics service providers, it should be strongly emphasised that, to an increasingly large extent, the choice of a given logistics service offer is no longer determined solely by economic aspects, but also by environmental and social ones.

Subcontractors also play an significant role in shaping the sustainable development of logistics service providers. According to the results presented in Figure 8, their importance is significant from the point of view of the 3, 8 and 9 of the SDGs. Within the framework of individual tasks, cooperation with them takes place in the implementation of innovative business solutions (initiative 23-21) and increasing the share of the low-emission fleet (initiative 37-21). Cooperation with logistics infrastructure managers most often focuses on the operational area. Among the tasks undertaken in cooperation with this group of stakeholders, respondents mentioned effective management of energy consumption in the logistics operator's warehouses (initiative 19-15) and ensuring appropriate sanitary conditions on the premises of the workplace (initiative 16-13). When analysing relations with other stakeholder groups, the strength of influence and involvement of a given group should also be considered. In view of the above, LSPs should focus on regulatory requirements regarding sustainable development established at the level of state authorities, which implement the assumptions of the EU policy (average impact score: 3.97). Among the activities listed in the questionnaire, cooperation in the area of regular reporting on sustainable activities (initiative 51) seems to be particularly important. At the local level, the LSPs should cooperate with city and regional authorities, considering supporting the local community (initiative 1-12) as a separate stakeholder group, using ecological solutions in the field of wastewater treatment and disposal (initiative 18-10) and cooperating in creating jobs (initiative 2-10). Cooperation at the local level may also concern the implementation of activities of a charitable nature. This function may be supported by non-profit organizations in the form of partnerships with non-governmental organizations to develop sustainable projects (initiative 49-14). In addition, according to some of the surveyed respondents, it is also worth cooperating with universities, mainly by enabling the implementation of internships and apprenticeships (initiative 11-14).

In view of the analysis, it was decided to propose a classification of stakeholders of the LSPs, which included a division into 4 groups in terms of their role in shaping SDGs, distinguishing the following roles: organizational-executive, transactional-operational, regulatory-supervisory and supporting. The first role is mainly fulfilled by internal stakeholders and concerns the formation and implementation of strategies and activities concerning sustainable development within the organization. The transactional-operational role, in turn,

refers to the groups of stakeholders on which the 3PL providers is dependent to the greatest extent, i.e. principals and subcontractors. The regulatory-supervisory role in the scope of compliance with environmental standards is fulfilled by the authorities at the national and local level, with the help of bodies related to public safety. The last, but not least important role was tasks supporting sustainable development carried out by other groups of stakeholders (local community, non-profit organizations and universities). It should be emphasized that the presented classification may be adjusted to the needs of a given 3PL provider in accordance with its individual expectations.

5. Discussion and Conclusion

The initiatives and sustainability-oriented innovations that logistics service providers can undertake are diverse, varying in nature and in the stakeholder groups involved in their implementation. The findings from the survey-based research can guide LSPs in strategic decision-making regarding their organizational sustainability efforts. This analysis addresses the first research question (Q1) by identifying SOIs and initiatives implementable by 3PL providers. The results of this analysis are presented in Table 1 within the literature review section of the article. In response to the second research question (Q2), the roles of LSPs stakeholder groups were identified based on the survey results. A significant majority of 3PL providers prioritize initiatives driven by legal compliance, such as occupational health and safety and fair employee practices, indicating a foundational commitment to social sustainability. Analysis reveals a concentrated focus of stakeholder engagement on SDGs 1, 3, 8, 9, and 17, with prominent initiatives including health and safety compliance, local community support, and innovative business solutions. A strong positive correlation (Pearson coefficient = 0.83) was observed between the number of engaged stakeholder groups and the perceived impact of their collaboration on SDGs implementation. Internal stakeholders play the most critical role, as they determine which initiatives are implemented and how relationships with external stakeholders are shaped. Beyond transactional interactions, customer and principal relationships significantly contribute to sustainable development goals 3, 6, 9, and 12. Subcontractors are crucial for SDGs 3, 8, and 9, particularly through their adoption of innovative solutions and low-emission fleets. Collaboration with logistics infrastructure managers primarily focuses on operational efficiencies, such as energy management and sanitary conditions. Furthermore, LSPs prioritize regulatory compliance with state authorities regarding sustainable development and engage with local authorities on community support and ecological initiatives. The article also proposes a classification of stakeholder roles into four main categories: organizational-executive, transactional-operational, regulatory-supervisory, and supporting.

The main limitation encountered during the research was the difficulty in obtaining a sufficient number of responses from LSPs offering their logistics services in Poland. This limitation was primarily due to the limited availability of managers responsible for sustainable development issues, however, the number of responses obtained meets the requirements for the minimum sample size, in accordance with the established population size. The presented research findings on the role of stakeholder collaboration for sustainable innovation are highly relevant for LSPs. The obtained results are important for conducting future research, which could potentially be extended to a wider range of 3PL providers, as well as to include initiatives proposed by individual stakeholder groups of LSPs.

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INDICATIVE ASSESSMENT OF THE FUNCTIONING OF SUPPLY LOGISTICS IN A SELECTED DISTRIBUTION CENTRE

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Purpose: The main objective of the article is to analyse and evaluate the effectiveness of the procurement process using the index method, with particular emphasis on the possibility of improving the fluidity and quality of this process.

Design/methodology/approach: The study used qualitative research methods such as participant observation and interviews, as well as indicator analysis.

Findings: Empirical studies indicate that the problems occurring in a distribution centre in the procurement process are mainly caused by the use of two non-integrated WMS (Warehouse Management System) systems.

Originality/value: The results of the study may be useful for improving the procurement process in the entity under study.

Keywords: metrics and indicators, procurement logistics, logistics processes.

Category of the paper: research paper.

1. Introduction

Contemporary market developments create vast opportunities for businesses and distribution centres alike, encouraging creativity and the implementation of innovative solutions. These changes affect many areas directly or indirectly related to logistics, including supply logistics, warehousing, inventory management, and customer distribution (Dyczkowska, 2013).

As a key element of any company's operations, supply logistics is an integral part of the supply chain. It encompasses the processes of planning, organising, and executing the delivery of the raw materials, components, and other goods necessary for production or service provision. It plays an equally important role in distribution centres, directly affecting their profitability and competitiveness. This is particularly important in food distribution, where

market dynamics, specific quality requirements and the need to maintain the cold chain present additional challenges.

For this reason, procurement processes must be continuously improved and integrated with other business activities, as they form the foundation of operations and future development.

Additionally, effective control of procurement processes is becoming increasingly important in logistics. To this end, various metrics and indicators have been developed to monitor procurement activities. Analysing the results provides a comprehensive overview of the state of procurement processes and enables the implementation of changes aimed at enhancing the efficiency and effectiveness of the entire supply chain.

The main objective of this article is therefore to evaluate the functioning of supply logistics in a selected distribution centre using the following measures and indicators: the share of defective deliveries, the inventory level indicator and the receiving efficiency indicator.

2. The procurement process in the literature – selected issues

The tasks carried out as part of supply logistics focus primarily on the delivery of the necessary raw materials, materials, semi-finished products, spare parts and finished products, as well as other elements enabling the effective use of material and human resources. Deliveries are accompanied by the flow of relevant information supporting the entire process. Goods are delivered both to the recipient's supply warehouses and directly to their places of use. Close cooperation with all departments of the company is of key importance here, as it allows for a better understanding and planning of material needs, and thus maintains the expected quality of products and services (Jurczak, Konecka et al., 2024).

The main task of supply logistics is to ensure that the materials necessary for operations are delivered exactly when they are needed. The following tasks are performed as part of this function (Sharma, 2023; Szczepanik, Sobala, 2021):

- purchasing materials necessary for production,
- quality control of delivered raw materials and components,
- searching for new suppliers and developing lasting relationships with them,
- negotiating favourable pricing and contractual terms,
- maintaining stocks at an optimal, sufficient and safe level,
- deliveries tailored to current needs,
- close cooperation with departments using supplies in order to identify and understanding their needs,
- ensuring timely procurement of materials.

In supply logistics, four basic criteria for assessing the effectiveness of activities are of key importance (Wojtynek, 2020):

- Delivery time - refers to the period between the moment the order is placed and the actual receipt of the goods by the recipient.
- Quality - means the compliance of the delivered materials or products with the requirements and expectations of the purchaser.
- Reliability - the supplier's ability to deliver on time according to a pre-agreed schedule.
- Flexibility - includes the supplier's ability to respond to changing customer needs, including the ability to modify orders and adapt to unusual or individual requirements.

Supply logistics, as a key element of the supply chain, requires proper inventory management and close cooperation with suppliers. The integration of activities in this area allows for cost optimisation, increased efficiency and the building of competitive advantage (Bedey, Eklund et al., 2008).

Nowadays, procurement no longer focuses on the products themselves, but on the capabilities of suppliers. It takes on a proactive character, building and managing networks of connections and the processes that occur within them. This stems from the concept of supply chain management, which applies to all areas of a company. This translates into the essence of modern management, i.e. supply chain integration (Nogalski, Niewiadomski, 2013).

3. Metodology

A wide range of logistics indicators is used to measure and evaluate a company's performance.

Indicator analysis is a relatively simple method of examining the processes carried out in a company. It is based on constructing and evaluating relationships between different variables. It is very important to select and estimate the values of the parameters under study appropriately and to interpret the results correctly, which is done on the basis of a comparison with accepted reference bases (Dmuchowski, 2019).

The concepts of a measure and an indicator are related to index analysis. A measure is a number characterising a certain phenomenon, expressed in an appropriate unit of measurement allowing it to be compared with other phenomena (Twaróg, 2003). Measures in logistics serve an informational function and do not have evaluative properties in themselves. Expressed in absolute units, the values of measures determined on the basis of research allow the actual state to be quantified. Measures can also be used to create indicators. Logistics indicators are used to measure the effectiveness of logistics systems, define quantitative objectives, check the level of achievement of the company's objectives and the degree to which customer needs are met. Properly formulated logistics indicators enable early recognition of

negative and positive trends in the process (early recognition function) and contribute to the proper control of logistics processes (control function) (Twaróg, 2003).

Indicator analysis enables the acquisition of relevant information about the logistics processes being implemented, as well as the identification of deviations from the adopted planning assumptions. Thus, it indicates the need to introduce appropriate improvements. Indicators serve as a tool for evaluating previously made decisions and, at the same time, provide a basis for formulating directions for further action (Gaschi-Uciecha, 2018).

The following indicators were used in the analysis:

- share of defective deliveries,
- warehouse stock level indicator,
- receiving efficiency ratio.

The indicator analysis made it possible to assess the efficiency of the procurement process in the company under study, which helped identify areas for improvement.

4. Results

Based on data received from the research entity, an indicator analysis was conducted for the priority disruption, i.e. discrepancies in inventory levels, which were identified using the FMEA method (Gaschi-Uciecha, Osińska, 2024). This analysis provided a better understanding of the scale and impact of the problem on the organisation's operations in individual months from December 2023 to May 2024.

The measures and quantitative indicators selected for the analysis of the research subject are presented in Table 1.

Table 1.
Selected quantitative indicators

Name	Method of calculation	Description
Percentage of defective deliveries	$LWD = \frac{\text{Liczba wadliwych dostaw w badanym okresie}}{\text{Łączna liczba dostaw w badanym okresie}} * 100\%$	This indicator expresses the ratio of defective deliveries to the total number of deliveries. Defective deliveries include products that do not meet the parameters specified by the recipient, were damaged during transport, or do not comply with the customer's order.

Cont. table 1.

Inventory level indicator	$Mzp=Zi+(Omp-Omr)$	The indicator provides information on how much stock is in the warehouse at a given moment.
	Zi – inventory volume at the beginning of the period under review [thousands of items]	
	Omp – warehouse turnover by revenue in the period under review [thousand units]	
Receiving efficiency indicator	Omr – volume of warehouse turnover by expenditure in the period under review [thousands of items]	This indicator reflects the effectiveness of the goods receipt process. It is calculated for the lines of goods received and allows the warehouse efficiency to be determined.
	$WP = \frac{\text{Ilość linii przyjętych towarów w badanym okresie}}{\text{nakłady czasu pracy [rbh] w badanym okresie}} * 100\%$	

Source: Own study based on literature (Miłaszewicz, Wengel, 2015; Twaróg, 2003).

The indicators and metrics presented above were calculated taking into account the division into two WMS systems – WAPRO MAG and QGUAR – presenting the results for individual months of the analysed period (December 2023 – May 2024).

A summary of data on the number of deliveries and the number of defective deliveries from both WMS systems is presented in Table 2.

Table 2.

Summary of the number of deliveries and defective deliveries from both WMS systems

		December	January	February	March	April	May
Number of deliveries		46	39	35	40	43	40
Number of defective deliveries	WAPRO Mag	40	28	27	30	33	28
	QGUAR	37	29	27	28	30	29

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

The summary of the results of the number of defective deliveries indicator is presented in Table 3 and Figure 1.

Table 3.

Summary of results for the indicator – number of defective deliveries

	December	January	February	March	April	May
WAPRO Mag	86.96	71.79	77.14	75.00	76.74	70.00%
QGUAR	80.24%	74.36%	77.14	70.00%	69.77%	72.50%

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

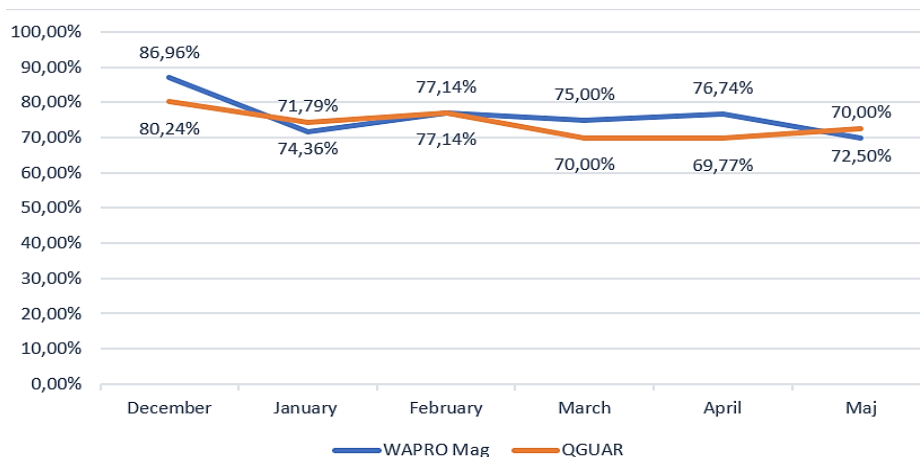


Figure 1. Chart for the defective delivery rate.

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

The summary of the results for the warehouse stock index is presented in Table 4 and Figure 2.

Table 4.

Summary of results for the indicator - warehouse stock levels

	December	January	February	March	April	May
Actual quantity	4,364	4,453	4418	4472	4413	4455
WAPRO Mag	4390	4475	4465	4495	4450	4480
QGUAR	4353	4449	4431	4458	4408	4437

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

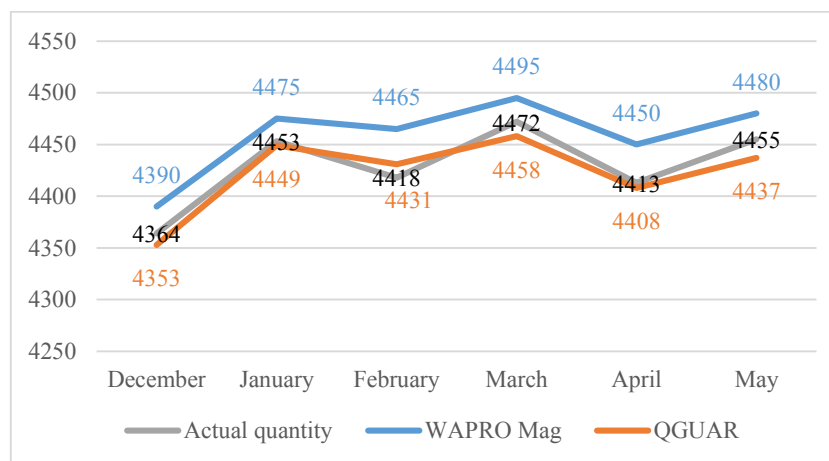


Figure 2. Chart for the warehouse stock level indicator.

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

The results of the acceptance efficiency indicator are presented in Table 5 and Figure 3.

Table 5.

Summary of results for the acceptance efficiency indicator

	December	January	February	March	April	May
WAPRO Mag	0.1139	0.1899	0.1805	0.2041	0.1848	0.1613
QGUAR	0.1236	0.2011	0.1874	0.2174	0.1965	0.1676

Source: Engineering work materials: Osińska (2023), promoter A. Gaschi-Uciecha.

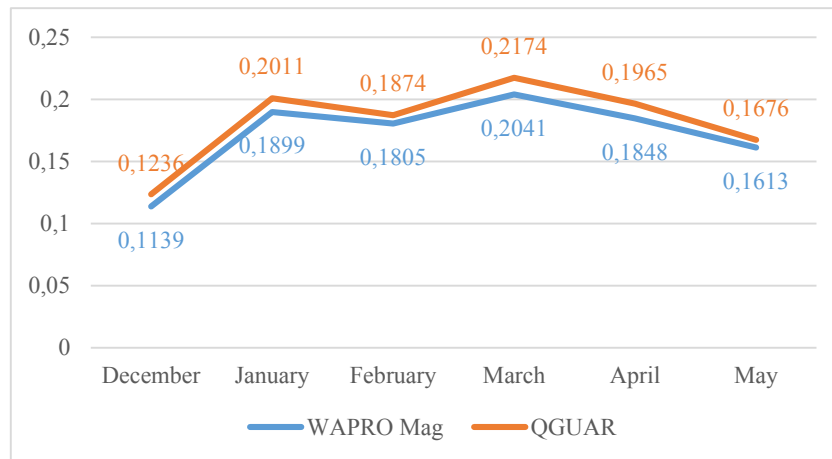


Figure 3. Graph for the admission efficiency indicator.

Source: Engineering work materials: Osińska (2024), promoter A. Gaschi-Uciecha.

The analysis revealed significant differences between the two WMS systems. Although they handle the same deliveries, the results in each programme differ, mainly due to human error and manual acceptance procedures.

The defective delivery rate indicator primarily points to a high percentage of deliveries with irregularities. The most common problem is that the products' expiry date is too short. Fresh food products usually have a shelf life of several days, while the minimum period required by the customer is usually 5 days. In practice, however, this requirement is often not met. In addition, the indicator reveals slight differences between the systems, suggesting errors resulting from manual data entry. The solution to this problem is process automation.

The warehouse stock indicator also revealed differences between WMS systems. There is a clear trend towards lower stock levels in the QGUAR system. This is due to its simpler operation – compared to WAPRO Mag – which translates into fewer errors made by employees. As a result, the data in QGUAR more often reflects the actual situation. Nevertheless, discrepancies with reality are still observed, which is why it is recommended to implement a single, integrated WMS system with an automatic data entry function, which will reduce human error and minimise differences in reported stock levels.

The warehouse goods receipt efficiency indicator showed that this process usually takes longer when entering data into the WAPRO Mag system than into the QGUAR programme. This is one of the reasons why the warehouse uses the latter system more often – QGUAR is more transparent and easier to use than WAPRO Mag. Regardless of the software used, however, the time taken to receive deliveries remains too long – in extreme cases, it is almost 4 hours. Therefore, it is recommended to implement a single, integrated WMS system with the ability to automatically enter data using RFID technology.

5. Conclusion

Discrepancies in stock levels are the most serious problem in the company, contributing both to slow processes and to growing employee frustration resulting from the need to repeatedly enter the same data manually and verify it at each stage of the procedure. The main cause of this phenomenon is the parallel use of two independent and non-integrated WMS systems, which additionally require manual data entry, significantly complicating operational processes.

The most effective improvement would be to standardise and integrate the systems by implementing a single WMS solution that would meet the needs of all departments and provide a comprehensive approach to warehouse processes. In addition, it is recommended to replace the equipment with newer models and update the software, which will eliminate technical errors and speed up operations. It is important to note that the research entity has already begun discussions on the implementation of a single, integrated WMS system equipped with RFID technology support.

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RETURNS ON IPOS IN THE POLISH CAPITAL MARKET: SHORT AND LONG TERM PERSPECTIVE

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Purpose: The purpose of the study was to assess the development of short- and long-term stock returns from initial public offerings (IPOs) on the Warsaw Stock Exchange. The in-house study aimed to verify the hypothesis assuming the existence of anomalies on the WSE's main market in relation to IPO companies, consisting in the undervaluation of share prices in the short term and their overvaluation in the medium and long term.

Design/methodology/approach: The main research method was the analysis of historical stock returns from initial public offerings. The existence of undervaluation in the prices of shares participating in IPOs was verified using the initial return (IR) and the adjusted initial return (AIR). On the other hand, the measurement of overvaluation in the long term was made using simple rates of return (BHR) and abnormal rates of return (BHAR).

Findings: The study confirmed the phenomenon of undervaluation of share prices in IPOs on the Polish capital market between 2010 and 2024, where the average initial return (IR) was 9.73%. The highest average returns in the short term were recorded in 2020. (over 40%), mainly due to gaming companies and ALLEGRO. On the other hand, in the longer term, the worst performance, with negative average returns (BHAR) in all the time intervals analysed, occurred in the period 2019-2024, due to post-pandemic economic problems and the dominance of companies generating negative returns.

Research limitations/implications: Our own research partially fills the information gap regarding the Polish capital market after 2016, thanks to the analysis of data from 2010-2024. Taking into account a longer time horizon allows for a more comprehensive assessment of investment effectiveness, which is rare in previous Polish studies. The use of an approach that takes into account economic cycles makes it possible to compare the results of IPOs in different phases of the economy.

Practical implications: the analysis provides valuable insights for market participants. The results on undervaluation in the short term and volatility of returns in the long term are of direct relevance to investors (e.g. in the context of 'buy and hold' investment strategies, issuers (e.g. in the context of IPO pricing) and financial intermediaries.

Originality/value: The value and originality of the study stems from the analysis of current data for the Polish WSE main market (2010-2024), which fills the information gap after 2016. The study is comprehensive, covering both short and long periods and considering different

investment horizons, which is rare in Polish studies to date. The analysis takes into account different time frames reflecting business cycles.

Keywords: undervaluation, overvaluation, IPO, public offering.

Category of the paper: Research paper.

1. Introduction

The term 'initial public offering' is defined in general terms in the literature and has various interpretations (Sobotnik, 2009, pp. 268-269). It usually refers to the public offering of shares of a company, which is equivalent to its debut on the stock market (Siwek, 2005, pp. 12-13). An initial public offering may include the issuance of shares on the public market for the first time (first subscription) and the sale of existing shares by existing shareholders but for the first time on the public market (first sale) (Siwek, 2005, p. 13; *Act of 29 July 2005...*, art. 4(5)). According to Polish and European law, "a public offer of securities means a communication addressed to the public in any form and by any means, presenting sufficient information on the terms and conditions of the offer and the securities offered, in order to enable an investor to take a decision to purchase or subscribe to those securities (*Regulation of the European Parliament and of the Council of the EU 2017/1129...*, art. 2(d)). As of 21.07.2019, a communication with the above content addressed to at least two persons (previously it was 150 persons) is considered a public offer (FSC, 2025).

Initial public offerings (IPOs) are often associated with the phenomenon of rising share prices in the short term, particularly during the IPO, which is referred to as *underpricing*. On the other hand, in the longer term, a phenomenon of falling share values, known as *underperformance*, is usually observed (Lizinska, 2014, p. 384). IPO underpricing is common on stock exchanges around the world, but its intensity varies by market, period of analysis and business cycle (Ibbotson et al., 1995, pp. 994-996). The phenomenon of *underperformance* means that long-term stock returns are lower than those of the broad market, as measured by the WIG index, or relative to companies with a similar profile that have not conducted an IPO in the same period (Wieczorek, 2020, p. 359).

Taking up this research topic is justified by the identified gaps in the existing scientific literature and the specificity of the Polish capital market. There is a distinct lack of up-to-date and detailed analyses of the phenomenon of undervaluation and overvaluation on the Warsaw Stock Exchange (WSE). The existing studies for the Polish market are characterised by a limited time horizon, usually focusing on two- or three-year ranges, which is a significant departure from the comprehensive analyses of several years conducted on developed markets, as exemplified by J.R. Ritter's studies for the US market. Furthermore, most of the available work is based on data prior to 2016, resulting in an information gap with regard to current market dynamics and the behaviour of returns.

Despite the fact that the WSE's main market plays a key role in raising financing for companies, research to date has mainly focused on the long-term effectiveness of IPOs on large capital markets in a homogenous geographic space, such as the US, Germany or China. Comprehensive analyses for the Polish market are lacking. Previous studies on emerging markets have often been limited to companies in specific industries, such as gaming, which prevents a full understanding of the overall trends.

In the context of the above shortcomings, a detailed study of the Polish IPO market is essential. This market requires constant monitoring and analysis of phenomena due to its importance for capital raising. Thus, a comprehensive analysis of the long-term effectiveness of IPOs on the WSE, going beyond the current methodological and time constraints, is fully justified and will fill important gaps in the academic literature and provide valuable insights for capital market participants.

The aim of the study was to assess the development of short- and long-term returns on initial public offerings (IPOs) on the Warsaw Stock Exchange. A research hypothesis was formulated as follows: anomalies are assumed to exist on the WSE's main market in relation to IPO companies, consisting in the undervaluation of share prices in the short term and their overvaluation in the medium and long term.

The study formulates the following research questions:

1. What were the short-term rates of return on shares (IR and AIR) of companies debuting on the main market of the Warsaw Stock Exchange in 2010–2024, in particular on the day of their debut, and was there any undervaluation of share prices during this period?
2. What were the medium- and long-term rates of return on shares (BHR and BHAR) of companies debuting on the main market of the WSE in 2010–2024, depending on the investment horizon (from 1 month to 72 months after debut), and was there any underperformance (worse results compared to the broad market) during this period? compared to the broad market)?

2. A review of the literature research on returns on first issue shares

2.1. Short-term stock returns according to foreign and domestic studies to date

In the short term, especially on the day of the debut, *underpricing* is common. This means that the closing share price on the day of the debut is higher than the issue price (Wieczorek, p. 359). Miller and Reilly (1987) argue that market valuation on the day of the debut is often inappropriate. Paleari and Vismara (2007) noted that issuers and analysts often 'overvalue' new companies, which is beneficial as it increases investor confidence and builds a positive image of the issuer.

Empirical studies confirm the occurrence of the phenomenon of undervaluation both on foreign markets and in Poland. Ibbotson, Sindelar and Ritter's (1994) research on US stock exchanges between 1960 and 1992 showed that the average undervaluation of shares of debuting companies varied depending on the decade, e.g. amounting to 21.3 per cent in the 1960s and 10.9 per cent in the 1990s. Loughran, Ritter and Rydqvist (2020), analysing data from 54 countries, proved that the average returns on the first day of the debut were in the range of a few to several per cent. Examples of return values are: USA - 16.9 per cent (1960-2019), Germany - 23 per cent (1978-2014) and the UK - 15.8 per cent (1959-2016). Perz's (2025) compilation of data for emerging and mature markets showed that the phenomenon of undervaluation was stronger in emerging markets than in mature markets. For example, China had an average return of 388.0% between 1989 and 1996, while mature markets, such as the US, had a return of 15.8% between 1960 and 1996.

The most recent survey results for the US market, conducted by Ritter (2025) for the period 1980-2023, show that the highest average initial rate of return was recorded between 2019 and 2023 at 158.0%. A high rate of return also occurred between 1998 and 2000 (149.40%).

Lyn and Zychowicz (2003), analysing IPOs on the Polish and Hungarian markets between 1991 and 1998, found that the average first-day return in Poland, adjusted for the WIG index, was 15.1%. A study by Czapiewski et al. (2014) on the WSE between 1991 and 2011 showed that the magnitude of IPO undervaluation decreased as the capital market developed. The average adjusted initial return for total offerings was 34.1% in 1991-2000, while it was 13.6% for the period 2001-2011. Pomykalski and Domagalski's (2015) study found that the average undervaluation for the period 2005-2013 was 11.89%.

Trąpczyński (2017) found that the average undervaluation for 200 IPOs on the WSE between 2007 and 2016 was 7.89%, which was significantly lower compared to the results of previous studies on the Polish market, where the average undervaluation between 1991 and 1997 was 19.8%. Lizińska and Czapiewski (2014), analysing IPOs on the WSE between 2004 and 2009, reported an average first-day return of 10.98%. They also found that higher pre-issue company profitability correlated with higher levels of undervaluation.

Sukacz (2005), studying 185 IPOs between 1991 and 2002, found an average undervaluation of 26%. He also observed that industries such as construction, media, publishing, electrical machinery and IT achieved the highest returns on the first day of listing. Podedworna-Tarnowska's (2024) research on IPOs between 2017 and 2021 showed that among the largest listings, the average first-day return was 13.68%, while for the smallest listings it was 22.90%. Among the smallest listings, high returns were recorded in the gaming industry.

Aziewicz and Dobrowolski (2014) showed a high volatility of returns on debut day between 2005 and 2013, implying no clear regularity for a long-term investment strategy. Nearly 64% of the companies provided returns above the average return of the WIG index on the debut date. Frydrych (2022) analysed the years 2007-2020 and found, that 60.22% of companies had

a higher price at the end of the first day of trading than the issue price, and that debuts of penny companies (below PLN 1) played a dominant role.

In summary, undervaluation in the short term is a common phenomenon, globally stronger in emerging markets. Polish research confirms its occurrence, indicating a potential tendency to reduce its magnitude as the capital market develops.

2.2. Long-term stock returns according to foreign and domestic studies to date

Over the long term, the share price reaction of IPO companies on the main market is often negative. This phenomenon is referred to as *long-run underperformance*, meaning that investors tend to lose out on their investment in the shares of such companies compared to the market index or other companies.

The occurrence of abnormal returns over the long term was pointed out by Ritter (2025). His study for the US market between 1980 and 2023 showed that average 3-year adjusted returns (BHAR) were typically negative, e.g. -20.20% for the entire period 1980-2023. For the period 2019-2023, the average BHAR was -296.40%. This suggests that there was no systematic positive overvaluation of equities in the US market among the group of debut companies. Similar negative 3-year returns were observed in Spain, Sweden and Switzerland, ranging from -12% to -42% (Schuster, 2003).

International studies tended to confirm that buying shares in IPOs and holding them for up to three years was not a profitable strategy, with company prices below their benchmark indices. The exceptions were Sweden (+1.20%) and Korea (+2.0%), where relative returns over the long term turned positive (Sehgal, Singh, 2007). Goergen et al (2007) found that the more profitable the company prior to the IPO and the greater the ownership dilution following the IPO, the more negative the long-run returns. On the other hand, they noted that more favourable long-term returns occurred for larger companies.

Polish empirical studies have shown that returns on investments in shares of IPO companies in the medium and long term were significantly lower than on the day of the debut. Their values were similar to the results for developed countries. Sieradzki (2013) pointed out that holding shares one year after the IPO yielded, after adjusting for the change in the WIG index, an average negative abnormal return of -4.2%. Zielinski (2013), analysing the WSE between 1994 and 2016, found that the adjusted BHAR 36M return ranged from -14% to -28.6% depending on the target group. Rzewuska and Wrzesinski (2016) proved that investments in companies from IPOs conducted in 2006 yielded an average return 9% lower than the stock market index over a two-year period, while over a three-year period it was as high as 26%.

Kwit (2006) estimated that if one decided to buy shares of companies debuting during the first trading session and kept them in one's portfolio for three years, one could gain 17% less compared to the shares of other companies listed on the Warsaw Stock Exchange.

A study by Kochalski and Ratajczak (2025) showed that the average stock return of companies with IPOs from 2009-2011 showed a downward trend until the 370th day of trading. The average return (BHR) over the first 370 days was -19.35%. Aziewicz and Dobrowolski (2014) confirmed that the phenomenon of companies being overvalued 12 months after listing with above-average returns was not sustained between 2006 and 2014, with a more pronounced trend of negative returns emerging three years after listing. Some studies, such as the one by Wieczorek (2020) on 29 gaming companies, cast doubt on the long-term underperformance by showing positive average BHAR levels for this group.

In summary, studies on capital markets, including the WSE, over the long term indicate that investors holding shares of debut companies perform statistically worse compared to the market. Although most studies confirm the *underperformance* phenomenon, not all have shown the existence of systematic overvaluation in the medium term, and returns have been variable from year to year.

3. Survey methodology

Verification of the existence of undervaluation in the prices of shares participating in the IPO was carried out using the *initial return* (IR) and the *adjusted initial return* (AIR).

The formula for calculating the instantaneous rate of return is as follows (Wieczorek, 2020, pp. 367-368; Trąpczyński, 2017, p. 150; Wieczorek, 2019, p. 88):

$$IR_i = \frac{(P_i - E_i)}{E_i} * 100\%, \quad (1)$$

where:

IR_i – the initial return on investment in the company's shares *and* offered in the IPO on the first day of trading,

P_i – the closing price of the company's shares (or rights to shares) *and* at the close of trading on the day of the IPO,

E_i – the price of the shares offered by the company i (issue price or reference price).

The main advantage of the simple rate of return is that it is the only such rate whose use in portfolio theory is mathematically justified (Piasecki, Tomasik, 2013, p. 31). Calculating the rate of return on the basis of the presented formula allows us to assess the profitability of investing in the shares of a given company at the time of the IPO.

In order to infer for the groups of companies debuting on the WSE that are separated within the research sample, the rates of return determined on specific listing days of individual companies can be aggregated and divided by the number of companies in the group, which allows the average adjusted initial rate of return to be calculated. The formula for the average initial rate of return on the day of listing is as follows (Siwek, 2005, p. 146):

$$\overline{IR} = \frac{1}{N} \sum_{i=1}^N IR_i, \quad (2)$$

where:

$\overline{IR}$ - average initial rate of return,

N – total number of companies surveyed.

Research papers also use the adjusted initial rate of return for the relative change in the stock market index (AIR). This rate takes into account the change in the broad market, which allows an analysis of the profitability of the investment relative to the overall market. In the empirical part, the WIG index was taken as the benchmark for stock returns reflecting the efficiency of investments in the broad stock market due to the fact that it is considered the primary barometer of the Polish stock market (Zimny, 2017, p. 114). The formula for the initial adjusted rate of return was as follows (Wieczorek, 2020, p. 368; Podedworna-Tarnowska, Kielpsz, 2024, p. 56; Wieczorek, 2019, p. 88):

$$AIR_i = \frac{(P_i - E_i)}{E_i} - \frac{(M_i - M_0)}{M_0} * 100\%, \quad (3)$$

where:

AIR_i – the initial return on investment in the company's shares *and* IPO offerings adjusted for the relative change in the stock market index,

P_i – the closing price of the company's shares *and* on the first day of trading,

E_i – the price of the shares offered by the company (issue price or reference price),

M_i – value of the stock exchange index on the first day of trading of the company i ,

M_0 – value of the stock market index at the date of allotment of the company's shares i .

The following formula (Siwek, 2005, p. 155) was used to calculate the average adjusted initial stock return of all companies for a given time interval:

$$\overline{AIR} = \frac{1}{N} \sum_{i=1}^N AIR_i. \quad (4)$$

The average adjusted initial return indicates what the abnormal return was in each of the consecutive quotations considered.

With regard to the initial adjusted stock return in the empirical part, a verification of statistical significance was also carried out. Accordingly, two research hypotheses were formulated:

$$H_0: AIR_i = 0$$

$$H_1: AIR_i > 0 \quad (5)$$

A parametric test t_{stat} for the sample mean value with a one-sided rejection area, based on the Student's t-statistic, which is determined according to the following formula, was used to verify the hypotheses:

$$t_{stat} = \frac{AIR_i}{\hat{S}(AIR_i)} \sqrt{n} \quad (6)$$

where $\hat{S}(AIR_i)$ - The standard deviation of the adjusted stock return on the first day of trading.

Assuming a normal distribution of instantaneous rates of return and the truth of the statistical hypothesis H_0 the test statistic t_{stat} has a Student's t-distribution with $n-1$ degrees of freedom. If the decision is made to reject the null hypothesis, the instantaneous rate of return will differ from zero and the result obtained will be statistically significant. For the determined rates of return, the value of the test statistic t_{stat} was calculated together with the critical probability (Sosnowski, 2014, p. 201).

In order to calculate returns over longer time intervals, the BHR '*buy-and-hold*' (BHR) approach is used in the literature to verify the occurrence of overvaluation of share prices over the longer term. This assumption is based on the fact that the investor will hold the purchased shares in the portfolio at the time of the IPO until the exit (Wieczorek, 2020, p. 368). The timing of the sale in the empirical part was denoted as 1M/3M/6M/12M/24M/48M/60M/72M, respectively, where M refers to the number of months since the IPO for each time interval t . The return on BHR shares was calculated as follows (Wieczorek, 2020, p. 368; Podedworna-Tarnowska, Kiełpsz, 2024, p. 56):

$$BHR_{i,T}^{IPO} = \frac{P_{it} - P_{i1}}{P_{i1}} * 100\%, \quad (7)$$

where:

$BHR_{i,T}^{IPO}$ – simple rate of return on investment in company i shares at date t ,

P_{it} – the closing price of i 's shares on the day of quotation t ,

P_{i1} – the allotment price of the company's i shares on the allotment date $t=1$.

The following formula was used to calculate the average stock return of all companies (BHR) for a given time interval:

$$\overline{BHR_{i,T}^{IPO}} = \frac{1}{N} \sum_{n=1}^N BHR_{i,T}^{IPO}, \quad (8)$$

where N – total number of companies surveyed.

On the other hand, if the rate of return on specific financial instruments is compared to the returns on the benchmark portfolio, then the so-called *abnormal* rate of return, BHAR (*buy and hold abnormal return*), is determined. In order to calculate the BHAR, the simple rate of return on shares of the company i for the quotation t ($BHR_{i,T}^{IPO}$) should be adjusted by the hypothetical rate of return on the WIG income index, which is calculated according to the following formula (Kochalski, Ratajczak, p. 137):

$$BHR_{i,T}^{WIG} = \frac{I_{it} - I_{i1}}{I_{i1}} * 100\% \quad (9)$$

where:

$I_{n,t}$ – the closing price of the WIG index corresponding to quotation t for company i ,

$I_{i,1}$ – the closing price of the WIG index on the day of allotment $t=1$ share of company i .

The abnormal rate of return for each company on successive trading days was determined according to the following formula (Kochalski, Ratajczak, p. 369):

$$BHAR_T^i = BHR_{i,T}^{IPO} - BHR_{i,T}^{WIG}. \quad (10)$$

In order to calculate the abnormal return of all companies considered under the time criterion, the equation for the average abnormal return was used (Podedworna-Tarnowska, Kiełpsz, 2024, p. 56):

$$\overline{BHAR}_T = \frac{1}{N} \sum_{i=1}^N BHAR_T^i. \quad (11)$$

As for instantaneous returns, two statistical hypotheses were also formulated for returns resulting from the implementation of a buy-and-hold strategy (Sosnowski, 2014, p. 224):

$$\begin{aligned} H_0: BHAR_T &= 0 \\ H_1: BHAR_T &< 0. \end{aligned} \quad (12)$$

A parametric test t_{stat} with a one-sided rejection area was used to verify the hypotheses, whose Student's t-statistic was determined according to the following formula (Sosnowski, 2014, p. 224):

$$t_{stat} = \frac{BHAR_T}{\hat{S}(\overline{BHAR}_T)} \sqrt{n}, \quad (13)$$

where $\hat{S}(\overline{BHAR}_T)$ - standard deviation of the BHAR return.

Assuming a normal distribution for BHAR returns and the truth of the statistical hypothesis H_0 , the test statistic t_{stat} has a Student's t-distribution with $n-1$ degrees of freedom. Rejecting the null hypothesis will mean that the BHAR return rate is significantly different from zero and the result obtained is statistically significant.

Below is a Diagram 1 illustrating the analytical steps of the WSE's own study on IPO returns.

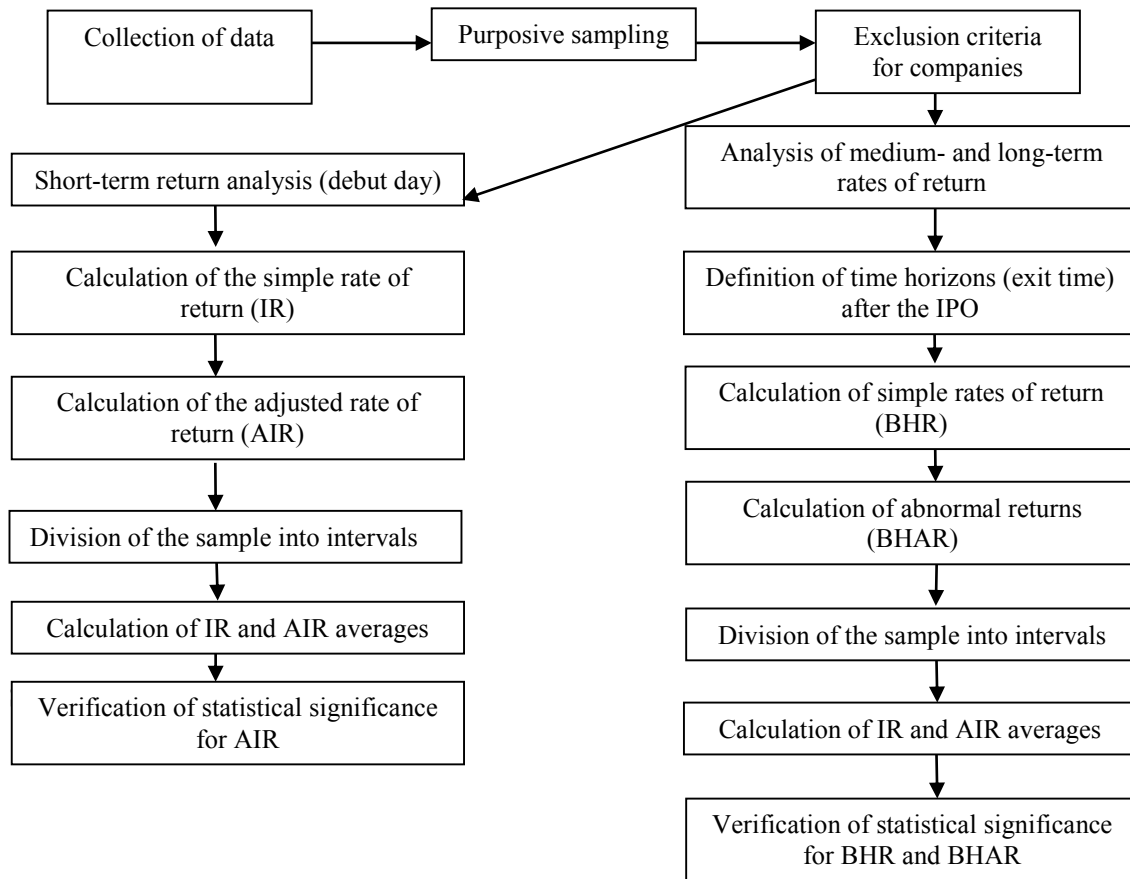


Diagram 1. Stages of own research.

4. Short- and long-term stock returns in the light of own research

4.1. Research assumptions and sampling

The data used in the study to calculate returns on shares of companies debuting on the main market were secondary data obtained from the WSE's official website (issue price), as well as the website <https://stooq.pl/> (closing price of shares and WIG stock index quotations). The advantage of the data provided on this website is that they take into account the following operations (Stooq.pl):

- dividends,
- subscription rights,
- acquisition rights,
- allotment rights,
- stock splits,
- denominations or redenominations.

All the events mentioned have been taken into account in the historical share prices of the companies by converting them with the appropriate divisor value, so that they did not distort the rates of return for the periods in which they occurred.

The sampling for the study was purposive and based on the following criteria:

1. Companies that made an initial public offering (IPO) on the Warsaw Stock Exchange between 2010 and 2024 and at the same time were listed on 31.12.2024 were included, which means that entities debuting on the alternative market - NewConnect - were excluded from the research sample.
2. The study excludes IPOs which, although they took place on the main market, had the character of a transition from the NewConnect market, as well as those of a so-called *cross-listing* nature, i.e. those which took place simultaneously on several stock exchange floors.
3. Companies for which there was no classic IPO on the WSE, i.e. the offering was a dual listing, were excluded from the analysis; the excluded companies are: Sopharma AD, Eurohold Bulgaria, Tatry Mountain Resorts, AB Inter Rao, City Service or debut was the result of a spin-off: Marvipol Development.
4. Shares of the company for which the initial price (issue price, offer price) was known at the time of the IPO on the Warsaw Stock Exchange were included.
5. Shares of the company on the first day of trading on the Warsaw Stock Exchange for which the closing price of the shares was known were included.

In addition, it should be emphasised that, as in T. Sosnowski's study, if the company used rights shares (rights issue shares) in its IPO, then in the empirical study the price of rights shares was treated equivalently to the price of shares. In contrast, if both types of securities were listed on the day of the IPO, then the closing price of the shares was taken into account (Sosnowski, 2014, pp. 197-198).

Based on the aforementioned criteria, the total sample under study comprised 90 companies. For the research sample, stock returns were analysed due to the criterion concerning the investment horizon since the IPO.

In calculating long-term returns, it was assumed that the investor follows a passive investment strategy, which is characterised by the fact that the shares purchased are held by the investor for a certain period of time, regardless of the economic situation in the country and market fluctuations.

Taking into account the investment horizon, an initial return (IR) and adjusted initial return (AIR) were calculated for each company in the sample, while simple stock returns (BHR) and relative returns, i.e. adjusted for the WIG index (BHAR), were calculated for longer periods, assuming an appropriate number of trading sessions:

- a) one-month returns - 1M, taking quotes from the 21st trading session,
- b) three-month returns - 3M, taking quotes from the 63rd trading session,
- c) six-month returns - 6M, taking quotes from the 126th trading session,

- d) twelve-month returns - 12M, taking quotes from the 252nd trading session,
- e) twenty-four-month returns - 24 M (2-year), taking 504 quotes from the trading session,
- f) thirty-six-month returns - 36 M (3-year), taking the 756th quotation of the trading session,
- g) forty-eight month returns - 48M (4-year), taking the 1008th quotation of the trading session,
- h) sixty-month returns - 60 M (5-year), taking the 1260th quotation of the trading session,
- i) seventy-two month returns - 72M (6-year), taking 1512 quotations from the trading session.

Returns were calculated for each company participating in the IPO during the analysis period, and average returns were then determined for the following time periods:

- 2010-2012,
- 2013-2015,
- 2016-2018,
- 2019-2024.

The division of the research period into five time periods was dictated, *inter alia*, by the fact that the sample included a similar and sufficient number of companies, which is important for the reliability of statistical analyses. In addition, the intention was to capture in the selected time periods the different phases of the business cycle and market conditions prevailing in Poland and Europe at the time under analysis, as well as to group the years with similar macroeconomic and market characteristics, which facilitates the comparison of rates of return of debuting companies in different periods. For the indicated time periods, in addition to the averages for the stock returns of the companies included in the study, the median and standard deviation were also calculated.

4.2. Characteristics of the research sample

The number of companies debuting on the WSE main market (excluding NewConnect) between 2010 and 2024, as well as the number of companies that were active on the WSE as of 31 December 2024 and included in the research sample and the percentage of active companies in the total number of debuts in a given year are presented in Table 1.

Table 1.

Number of companies on the WSE included in the sample and the share of the sample companies in the number of IPOs on the WSE between 2010 and 2024

Year of the company's debut	Number of companies newly listed on the WSE (excluding NewConnect)	Number of companies in the research sample (companies active on the WSE as at 31.12.2024)	Share of companies in the sample in the total number of companies newly listed on the WSE
1	2	3	4=(col. 3/col. 2) x 100
2010	27	14	52%
2011	32	13	41%
2012	17	6	35%
2013	16	9	56%
2014	18	7	39%
2015	17	9	53%
2016	12	6	50%
2017	8	3	38%
2018	5	4	80%
2019	1	1	100%
2020	5	5	100%
2021	12	11	92%
2022	0	0	-
2023	1	1	100%
2024	1	1	100%
Total	172	90	52%

Source: own calculations.

Table 1 shows that 52% of the companies that debuted on the WSE between 2010 and 2024 were still listed on the market at the end of 2024. On the other hand, it should be emphasised that 82 companies out of 172 that debuted on the WSE in the analysed period were not included in the research sample for various reasons, e.g. mergers, acquisitions, bankruptcy, delisting. Between 2010 and 2016, the share of companies included in the survey ranged from 35% to 56%. In years with a very low number of IPOs (2018-2021, 2023-2024), the share of companies in the sample was very high (often reaching 100%). The year 2017 was characterised by a low number of IPOs (8) and at the same time a relatively low share of companies included in the sample (38%).

In the next step, basic statistics were calculated: arithmetic mean, standard deviation and coefficient of variation for the number of IPOs included in the sample. Due to the significant range of observations in the sample, these statistics referred to aggregated data for the period 2010-2024. The calculated values of the mentioned statistics are included in Table 2.

Table 2.

Selected descriptive statistics on the number of IPOs included in the sample for the period 2010 to 2024

Statistics	Average	Standard deviation	Coefficient of variation
Value	6,00	4,49	74,80%

Source: own calculations.

Table 2 shows that, on average, there were six IPOs on the WSE in a given year. The standard deviation related to the dispersion around the average and amounted to 4.49 debuts. This value confirms that in some of the years covered by the analysis, the number of debuts varied, which could be due to economic, political and other external factors. The value of the coefficient of variation around 75% indicates a high variability in the number of debuts with respect to the average. Such a high result suggests that the number of IPOs was not stable and may imply difficulties in forecasting its value for the future.

4.3. Results of own research

4.3.1. Short-term stock returns in the light of own research

Table 3 summarises the companies, in each year of the study period from 2010 to 2024, with an increase in the IPO price, a decrease in the IPO price and no change in the closing price from the issue price.

Table 3.

Number of companies with upside, downside and no volatility in closing price relative to issue price between 2010 and 2024

Year	N	Price increase on debut		Price drop on debut		Issue price = closing price on debut	
		n	%	n	%	n	%
2010	14	11	78,57	3	21,43	0	-
2011	13	8	61,54	4	30,77	1	7,69
2012	6	5	83,33	1	16,67	0	-
2013	9	6	66,67	2	22,22	1	11,11
2014	7	6	85,71	0	0,00	1	14,29
2015	9	3	33,33	5	55,56	1	11,11
2016	6	3	50,00	2	33,33	1	16,67
2017	3	2	66,67	1	33,33	0	-
2018	4	4	100,00	0	0,00	0	-
2019	1	1	100,00	0	0,00	0	-
2020	5	4	80,00	0	0,00	1	20,00
2021	11	5	45,45	6	54,55	0	-
2022	0	0	-	0	-	0	-
2023	1	1	100,00	0	0,00	0	0,00
2024	1	0	0,00	0	0,00	1	100,00
Total	90	59	-	24	-	7	-

Source: own calculations.

An analysis of the annual data shows that a greater proportion of companies that proceeded with an IPO recorded an increase in their IPO price. It is worth noting that in 2015, only 33.33% of companies recorded an increase, indicating a slightly weaker performance that year compared to other years. In 2018-2019, all companies that participated in the IPO achieved an increase in the closing price relative to the issue price. 2015 saw the highest percentage of companies with a decrease in closing share price (55.56%), which may suggest that market conditions were difficult for new companies. Over the period under review, there were seven years of IPOs in which the issue price and the closing price on debut were equal. It is worth

noting that no IPOs were registered in 2022, which may suggest a decline in interest in IPOs. In recent years (2023-2024), there has been little activity in the capital market.

First, Table 4 presents the results of the analysis with initial returns (IR) and returns adjusted for the change in the broad market, as expressed by the WIG index (AIR).

Table 4.

Immediate unadjusted (IR) and adjusted (AIR) returns from 2010 to 2024

Year	N	Average	Median	Standard deviation	Average	Median	Standard deviation	<i>t-statistics for AIR</i>	<i>The p-value</i>
		Initial rate of return (IR)			Adjusted initial rate of return (AIR)				
2010	14	8,48%	7,07%	8,81%	7,06%	5,17%	8,33%		
2011	13	2,32%	1,52%	11,73%	5,94%	5,00%	12,21%	1,75	9,94%
2012	6	17,42%	7,68%	25,48%	16,89%	6,02%	23,16%	1,79	6,67%
2013	9	10,56%	18,59%	13,20%	9,44%	14,91%	14,91%	1,90	4,70%
2014	7	1,44%	1,72%	0,85%	2,33%	2,09%	1,59%	3,88	0,41%
2015	9	0,62%	-1,29%	4,70%	2,90%	2,90%	5,09%	1,71	6,28%
2016	6	4,32%	2,39%	7,75%	5,03%	2,89%	9,34%	1,32	12,20%
2017	3	2,83%	1,82%	7,06%	2,19%	2,05%	7,35%	0,52	32,74%
2018	4	10,83%	3,53%	13,86%	9,60%	4,61%	15,92%	1,21	15,65%
2019	1	14,74%	14,74%	-	17,57%	17,57%	-	-	-
2020	5	43,88%	49,96%	41,40%	40,92%	46,95%	35,51%	2,58	3,07%
2021	11	4,84%	-0,01%	12,04%	3,98%	0,34%	11,15%	1,19	13,08%
2022	0	-	-	-	-	-	-	n.a.	n.a.
2023	1	13,94%	13,94%	-	8,97%	8,97%	-	-	-
2024	1	0,00%	0,00%	-	1,62%	1,62%	-	-	-
average	90	9,73%	8,69%	13,35%	9,60%	8,65%	13,14%	-	-

Source: own calculations.

The average initial return (IR) for the period 2010-2024 was 9.73% (with a median of 8.69%), while the adjusted return (AIR) was slightly lower at 9.60% (with a median of 8.65%). As in other empirical studies, the differences between unadjusted and adjusted values were insignificant. The highest IR and AIR were reached in 2020 at 43.88% and 40.92% respectively, mainly due to two gaming companies, i.e. GAMES OPERATORS and PCF GROUP, where IR and AIR were 100% (90.80%) and 49.96% (46.95%) for both companies, as well as ALLEGRO, for which IR was equal to 62.79% and AIR was 64.94%. The lowest average returns were recorded for 2015. - 0.62% (IR) and 2.90% (AIR) mainly due to 4 companies that showed negative values, i.e. ATAL, DEKPOL, KORPORACJA KGL, KRYNICA VITAMIN. This means that the phenomenon of the occurrence of share price undervaluation in IPOs has been confirmed for the studied sample.

As the average adjusted rates of return calculated separately for each year covered by the analysis turned out to be statistically insignificant for the most part, the amounts of these rates after the first day of the debut were determined in time intervals selected in such a way as to include a comparable number of companies. These intervals were calculated by grouping companies into three groups, for which: the issue price turned out to be lower than the closing price, the issue price was higher than the closing price and those for which the closing price at the end of the debut day corresponded to the price on the issue day. The results of the calculations are shown in Table 5.

Table 5.

Initial unadjusted (IR) and adjusted (AIR) returns over several year intervals for the period 2010-2024

Year	N	Average	Median	Standard deviation	Average	Median	Standard deviation	t-statistics for AIR	The p-value
		IR			AIR				
2010-2012									
Total	33	7,68%	3,86%	14,42%	8,41%	5,00%	14,14%	3,42	0,09%
issue price< closing price	24	12,07%	7,14%	13,95%	11,97%	7,10%	13,91%	4,22	0,02%
issue price>closing price	8	-4,52%	-1,49%	7,69%	-1,30%	-0,13%	10,21%	-0,36	63,53%
issue price=closing price	1	0,00%	0,00%	0,00%	0,58%	0,58%	-	-	-
2013-2015									
Total	25	4,43%	1,72%	9,42%	5,09%	2,90%	8,97%	2,84	0,45%
issue price< closing price	15	9,46%	6,82%	8,47%	10,00%	8,48%	7,69%	5,03	0,00%
issue price>closing price	7	-4,44%	-4,11%	3,26%	-3,13%	-2,92%	5,07%	-1,64	92,39%
issue price=closing price	3	0,00%	0,00%	0,00%	-0,23%	0,21%	2,75%	-0,14	54,93%
2016-2018									
Total	13	5,98%	2,94%	10,45%	5,78%	3,79%	10,59%	1,97	3,62%
issue price< closing price	9	9,90%	4,78%	10,30%	9,87%	6,23%	25,78%	1,15	14,17%
issue price>closing price	3	-3,78%	-3,85%	1,24%	-3,65%	-3,74%	2,57%	-2,46	93,35%
issue price=closing price	1	0,00%	0,00%	0,00%	-2,82%	-2,82%	-	-	-
2019-2024									
Total	19	15,86%	8,00%	27,11%	14,56%	14,56%	14,56%	4,36	0,02%
issue price< closing price	11	29,69%	14,74%	12,38%	27,78%	27,78%	27,78%	3,32	0,39%
issue price>closing price	6	-4,21%	-1,21%	6,15%	-4,94%	-4,94%	-4,94%	2,45	2,90%
issue price=closing price	2	0,00%	0,00%	0,00%	0,32%	0,32%	1,30%	0,35	39,28%

Source: own calculations.

Table 5 shows that the highest average IR returns were recorded between 2019 and 2024 (15.86%). The AIR over this period was 14.56%. In the different groups of companies studied (issue price < closing price, issue price > closing price, issue price = closing price), a variation in performance is observed. In the group of companies where the issue price was lower than the closing price, between 2019 and 2024, the average IR was 29.69%, while AIR was slightly lower at 27.78%. In the group of companies where the issue price turned out to be higher than the closing price on the debut day, the IR and AIR return values were negative, suggesting that the investments closed at the end of the debut day were loss-making. The average values of adjusted returns proved to be statistically significant for companies whose shares turned out to be undervalued in 2010-2012, 2013-2015 and for all companies in the sample, included in the period 2019-2024. The last sub-period studied was a time when the stock market experienced dynamic growth, which favoured higher stock returns. Expansionary monetary policy and economic recovery from the pandemic crisis (in 2019-2021) had a positive impact on the valuation of IPO stocks.

4.3.2. Medium - long term stock returns - findings from own research

Considering post-IPO time frames of 3 years (for the period 2010-2018) and 5 years for the period 2019 to 2024, the levels of unadjusted and adjusted stock returns over a longer period than one day from the IPO date are included in Table 6. Exit time frames after a period of 1/3/6/12/24/36/48/60/72 months are included.

Table 6.

Unadjusted (BHR) and adjusted returns (BHAR) on first issue shares by investment horizon from the date of listing (in months) over the period 2010 to 2024

Year	N	Average	Median	Standard deviation	Average	Median	Standard deviation	t-statistics for BHAR	The p-value
		BHR 1M			BHAR 1M				
2010-2012	33	2,78%	0,38%	15,42%	2,03%	1,17%	15,67%	0,74	23,23%
2013-2015	25	2,16%	0,23%	8,12%	2,85%	3,07%	7,17%	1,99	2,90%
2016-2018	13	5,00%	0,00%	11,65%	3,79%	-0,72%	13,42%	1,02	16,39%
2019-2024	19	-1,20%	-3,15%	11,96%	-3,20%	-2,62%	11,65%	-1,20	87,72%
Return on shares		BHR 3M			BHAR 3M				
2010-2012	33	7,75%	0,94%	39,33%	7,46%	3,07%	38,29%	1,12	13,55%
2013-2015	25	5,11%	4,34%	13,78%	4,49%	5,93%	13,43%	1,67	5,40%
2016-2018	13	11,48%	-2,86%	24,91%	8,46%	4,46%	26,48%	1,15	13,63%
2019-2024	19	-1,23%	2,43%	16,85%	-4,79%	-1,74%	15,00%	-1,39	90,93%
Return on shares		BHR 6M			BHAR 6M				
2010-2012	33	1,68%	-5,06%	35,71%	0,97%	-4,30%	34,04%	0,16	43,69%
2013-2015	25	19,64%	13,77%	36,20%	19,17%	17,07%	31,70%	3,02	0,30%
2016-2018	13	13,55%	1,10%	46,33%	7,10%	-2,82%	46,16%	0,55	29,62%
2019-2024	19	-10,52%	-7,70%	24,05%	-18,87%	-15,40%	26,52%	-3,10	99,69%
Return on shares		BHR 12M			BHAR 12M				
2010-2012	33	-3,25%	-10,32%	66,01%	0,01%	-3,71%	63,42%	0,00	50,00%
2013-2015	25	19,33%	14,12%	34,80%	18,71%	11,53%	32,84%	2,85	0,44%
2016-2018	13	16,45%	-18,69%	69,04%	2,79%	-17,02%	68,05%	0,15	44,16%
2019-2024	18	-23,98%	-16,47%	23,20%	-25,83%	-20,27%	34,50%	-3,18	99,73%
Return on shares		BHR 24M			BHAR 24M				
2010-2012	33	-2,45%	-27,60%	81,96%	-5,19%	-21,94%	79,09%	-0,38	64,68%
2013-2015	25	30,44%	23,99%	43,90%	23,13%	21,52%	47,72%	2,42	1,17%
2016-2018	13	54,17%	18,98%	149,83%	48,03%	-11,11%	154,14%	1,12	14,23%
2019-2024	17	-29,04%	-26,68%	28,43%	-32,01%	-21,01%	33,61%	-3,93	99,94%
Return on shares		BHR 36M			BHAR 36M				
2010-2012	33	11,31%	-10,99%	92,32%	-2,17%	-25,47%	91,43%	-0,14	55,52%
2013-2015	25	38,68%	26,98%	62,42%	29,38%	27,54%	60,68%	2,42	1,17%
2016-2018	13	123,86%	61,11%	238,26%	117,18%	71,42%	241,16%	1,75	5,28%
2019-2024	17	-28,56%	-39,18%	42,87%	-53,08%	-66,09%	45,25%	-4,84	99,99%
Return on shares		BHR 48M			BHAR 48M				
2010-2012	33	5,28%	-15,17%	86,15%	-11,40%	-31,72%	85,78%	-0,76	77,36%
2013-2015	25	48,34%	7,10%	91,59%	29,57%	-10,27%	92,04%	1,61	6,02%
2016-2018	13	144,21%	69,65%	287,80%	140,45%	51,98%	287,07%	1,76	5,19%
2019-2024	11	-16,26%	0,00%	46,76%	-43,86%	-27,34%	58,38%	-2,49	98,40%
Return on shares		BHR 60M			BHAR 60M				
2010-2012	33	29,96%	-21,01%	130,38%	13,74%	-28,26%	135,76%	0,58	28,30%
2013-2015	25	40,83%	1,52%	95,10%	30,00%	15,26%	96,45%	1,56	6,59%
2016-2018	13	171,87%	111,05%	300,38%	155,00%	65,46%	292,18%	1,91	4,02%
2019-2024	2	-5,30%	0,00%	15,70%	-13,09%	0,00%	40,02%	-0,46	63,72%
Return on shares		BHR 72M			BHAR 72M				
2010-2012	33	43,74%	-21,61%	176,12%	23,48%	-28,20%	177,39%	0,76	22,64%
2013-2015	25	37,05%	15,40%	84,79%	20,89%	21,93%	79,88%	1,31	10,13%
2016-2018	13	165,58%	50,13%	318,73%	140,47%	-0,63%	321,67%	1,57	7,12%
2019-2024	1	-2,89%	0,00%	12,28%	-6,28%	0,00%	26,65%	-	-

Source: own calculations.

The results obtained indicated the volatility of unadjusted returns and WIG index-adjusted returns depending on the time horizon adopted from the date of debut. Between 2010 and 2012, stock returns (BHARs) were generally positive, with the exception of the 24M, 36M and 48M time intervals. It is worth noting that the overstatement of average returns from the third month to three years after the debut was influenced by the high stock returns (even more than 200% increase relative to the issue price) of PCC EXOL. From one year after the debut to five years, significant returns (100-200%) were also achieved by the company ZAMET INDUSTRY. Good results in this period, especially two years after the debut, were recorded for the companies: EUROPEJSKIE CENTRUM ODSZKODOWAŃ, BENEFIT SYSTEMS, KRUK and AC.

Optimistic results were observed between 2013 and 2015, where BHR and BHAR returns took on positive values and were statistically significant for the time intervals: 1M, 6M, 12M, 24M, 36M. Particularly good results - not infrequently returns exceeding 100% 3 years after listing - were recorded for companies: MFO, ATAL, ENTER AIR. In 2016-2018, the average returns of BHR and BHAR were higher especially 3 years after the debut, mainly due to the good performance of the companies: AUTO PARTNER, DINO POLSKA, TEN SQUARE GAMES, ML SYSTEM. A statistically significant rate of return of BHAR was recorded for 60 months after the debut. The lack of statistical significance for returns with longer time intervals is due to a decrease in the number of companies included in the formula for the arithmetic average.

Across all time intervals, the worst performing, negative returns for BHR and BHAR occurred between 2019 and 2024, which can be explained by the post-pandemic economic problems that translated into negative investment performance. For the period described, the median for returns also remained negative.

To better illustrate the number of companies with positive and negative adjusted returns over the analysed period, the results of the analysis are summarised in Table 7.

Table 7.

Number of companies with negative and positive average BHAR returns sampled in 1M to 72M post-IPO intervals over the period 2010-2024

Period	Description	BHAR 1M	BHAR 3M	BHAR 6M	BHAR 12M	BHAR 24M	BHAR 36M	BHAR 48M	BHAR 60M	BHAR 72 M
2010-2012	Negative	14	13	19	19	22	21	22	21	23
	Positive	19	20	14	14	11	12	11	12	10
2013-2015	Negative	8	10	5	6	7	9	14	12	11
	Positive	17	15	20	19	18	16	11	13	14
2016-2018	Negative	7	5	7	8	7	6	6	5	7
	positive	6	8	6	5	6	7	7	8	6
2019-2024	negative	12	11	16	13	16	16	10	2	1
	positive	7	8	3	5	1	1	1	0	0

Source: own calculations.

Analysis of the data in Table 7 shows changes in the number of companies with negative and positive average BHAR returns over different investment periods from 2010 to 2024. Between 2010 and 2012, holding shares of companies debuting for up to 3 months generated the addition of returns, but during this period the number of companies whose shares were in investors' portfolios for at least 6 months and yielded negative returns increased significantly. In favour of investors, the situation changed between 2013 and 2015, when the number of companies debuting with positive stock returns - BHAR - was significantly higher compared to companies with negative returns. This situation suggests that the market was favourable to debut companies during this period. Over time, the number of companies with shares initially with positive returns in the years (2016-2018, 2019-2024) showed a downward trend. For the period 2019-2024, companies with shares generating negative abnormal returns dominated in all time intervals.

5. Discussion

With regard to short-term rates of return, our own research confirmed the phenomenon of undervaluation of IPO share prices on the Polish capital market in the analysed period. The average immediate rate of return (IR) for 2010-2024 was 9.73%, while the adjusted immediate rate of return (AIR) was slightly lower, at 9.60%. These results are within the range of values obtained by other researchers for the Polish market in similar periods, suggesting a continuation of the trend of a decrease in the scale of the phenomenon of undervaluation compared to the 1990s and the beginning of the 21st century. For example, research by Czapiewski et al. (2014) on the WSE in 1991–2011 showed an average adjusted IR of 34.1% in 1991-2000 and 13.6% in 2001-2011. Trąpczyński (2017) found an average undervaluation of 7.89% for 2007-2016, which was lower than 19.8% in 1991-1997. Lizińska and Czapiewski (2014) recorded an average return on the first day of 10.98% for 2004-2009. Pomykański and Domagalski (2015) showed an average undervaluation of 11.89% in 2005-2013. Research by Podedworna-Tarnowska (2024) on IPOs in 2017-2021 showed an average IR of 13.68% for the largest offers and 22.90% for the smallest ones. Sukacz's research (2005) from 1991-2002 showed an average undervaluation of 26%.

Comparing the results of our own research with foreign literature, the phenomenon of undervaluation is common on stock exchanges around the world, but its intensity varies depending on the market, the period of analysis and the economic cycle. A compilation of data by Perza (2025) shows that undervaluation was stronger in emerging markets than in mature markets. For example, in China, the average IR in 1989-1996 was 388.0%, while in mature markets, such as the US, it was 15.8% in 1960-1996. The latest results for the US market (Ritter, 2025) for the period 1980-2023 show the highest average IR at 158.0% in 2019-2023. Average IRs on the Polish market, both in our own study (9.73% for 2010-2024) and in other Polish studies, are noticeably lower than these extreme values from emerging markets or certain periods on the US market, but are within the typical range for mature or more developed emerging markets (several to several dozen percent).

An analysis of annual data in our own research showed that the majority of companies recorded an increase in price on their debut, although there were differences between individual years. The highest average rates of return (IR and AIR) were achieved in 2020 (43.88% and 40.92%), mainly due to companies from the gaming industry and ALLEGRO. Aziewicz and Dobrowolski (2014) also showed high volatility of returns on the debut date in 2005-2013. Our own study showed that average adjusted rates of return (AIR) were statistically significant for undervalued companies in 2010-2012, 2013-2015 and for all companies in the sample in 2019-2024. These results confirm the first part of the hypothesis of short-term undervaluation.

With regard to long-term rates of return, our own research only partially confirmed the underperformance phenomenon (a decline in share value over a longer horizon) observed in the literature. This phenomenon means that investors usually lose money on investments in newly listed companies compared to the market index or other companies. Ritter (2025) in his study for the US market (1980-2023) showed that average 3-year adjusted rates of return (BHAR) were usually negative, e.g. -20.20% for the entire period and -296.40% for 2019-2023. Polish empirical research also indicated lower IPO returns in the medium and long term compared to the IPO date or the market index. Sieradzki (2013) indicated an average negative abnormal return of -4.2% one year after debut. Zieliński (2013) found that the BHAR 36M adjusted return on the WSE in 1994-2016 ranged from -14% to -28.6%. Rzewuska and Wrzesiński (2016) proved that investments in IPO companies in 2006 yielded an average rate of return 9% lower than the index over a two-year period and 26% lower over a three-year period. Kwit (2006) estimated that after three years, it was possible to earn 17% less compared to the assets of other companies listed on the WSE. Kochalski and Ratajczak (2025) showed a downward trend in the average rate of return (BHR) on shares of companies with IPOs from 2009 to 2011 up to 370 days of trading, reaching an average of -19.35%. Aziewicz and Dobrowolski (2014) confirmed that the phenomenon of overvaluation after 12 months was not permanent, and a clearer trend of negative returns appeared three years after the IPO.

The results of our own research for the period 2019-2024 are consistent with these observations, showing negative average BHR and BHAR rates in all analysed time intervals. However, our own research also identified periods in which the average BHAR rates were positive, suggesting that underperformance is not a systematic phenomenon in all the time intervals analysed. In 2010-2012, BHAR rates were generally positive, with the exception of the 24M, 36M and 48M intervals. The results for 2013-2015 were optimistic, with BHR and BHAR rates positive and statistically significant for the 1M, 6M, 12M, 24M and 36M intervals. In 2016-2018, average BHR and BHAR rates of return were higher after 3 years following the IPO, and a statistically significant BHAR rate of return was recorded for 60 months after the IPO. This volatility corresponds to the observation by Aziewicz and Dobrowolski (2014) that the phenomenon of overvaluation after 12 months was not permanent.

An analysis of the number of companies with positive and negative BHAR rates also indicates volatility over time. While in 2010-2012 and 2013-2015, companies with positive BHARs prevailed in the short and medium horizons, in 2019-2024, companies generating negative abnormal returns dominated in all time intervals.

In summary, the results of our own research confirm the occurrence of short-term stock undervaluation on the main market of the WSE. However, in the medium and long term, the results are variable and do not indicate systematic overvaluation (negative rates of return) in all the time intervals analysed, although the phenomenon of underperformance was evident in some periods, particularly in 2019-2024. This is consistent with the second part of the

research hypothesis for 2019-2024, but not for the entire medium- and long-term period under review.

6. Conclusion

The aim of this study was to assess the short- and long-term returns on initial public offerings (IPOs) on the Warsaw Stock Exchange. The author's own research aimed to verify the hypothesis that there are anomalies on the main market of the WSE, consisting in the undervaluation of share prices in the short term and their overvaluation in the medium and long term. The main research method was an analysis of historical rates of return on shares from IPOs in 2010-2024.

The study confirmed the phenomenon of undervaluation of IPO share prices on the Polish capital market in the analysed period. The average immediate rate of return (IR) for 2010-2024 was 9.73%, and the adjusted immediate rate of return (AIR) reached 9.60%. These results confirmed the first part of the research hypothesis regarding short-term undervaluation.

With regard to medium- and long-term rates of return, our own research only partially confirmed the underperformance observed in the literature, which means that investors usually lose on investments in the shares of debuting companies compared to the market index or other companies. Although negative average abnormal rates of return (BHAR) occurred for some periods, and the underperformance phenomenon was particularly pronounced in 2019-2024, where negative average BHARs were recorded in all analysed time intervals, the results in other periods (e.g. 2013-2015, 2016-2018 in some intervals) showed positive average BHARs. This means that the own study does not indicate systematic overvaluation (negative rates of return) in all analysed time intervals. This is consistent with the second part of the research hypothesis for 2019-2024, but not for the entire medium- and long-term period under review.

This study is valuable and original due to its analysis of current data for the main Polish market of the WSE from 2010 to 2024, which fills an information gap after 2016. The study is comprehensive, covering both the short and long term, considering different investment horizons, which is rare in previous Polish studies. In addition, the analysis takes into account different time intervals reflecting economic cycles.

One of the limitations of the study is the lack of statistical significance for longer-term rates of return due to the decline in the number of companies included in the analysis. Of the 172 companies that debuted during this period, 82 were not included in the sample for various reasons, such as mergers, acquisitions, bankruptcies or delisting. This means that the long-term analysis only covers companies that survived on the market until the end of 2024, which may affect the picture of long-term rates of return (potential bias due to the survival effect).

The research sample was deliberately selected based on specific criteria. The analysis excludes companies debuting on the NewConnect alternative market, those that have moved from NewConnect to the main market, as well as those with cross-listing (listed simultaneously on several trading floors) or dual listing. Companies for which there was no data on the issue price or closing price on the debut date were also excluded. These criteria limit the scope of the study to classic IPOs on the main market of the WSE carried out by companies meeting specific conditions of data availability and market presence, which may affect the possibility of generalising the results to all types of debuts or all companies that have ever debuted.

The information obtained in the study can be further used as a database and reference point for future analyses, for example, comparing the effectiveness of IPOs on the WSE with other markets (especially emerging markets), examining the determinants of short- and long-term rates of return for the Polish market, or analysing the impact of specific market and macroeconomic factors on the performance of IPOs in specific periods.

The results obtained provide valuable insights for market participants. Information on short-term undervaluation and long-term volatility of rates of return is of direct relevance to investors (e.g. in the context of investment strategies), issuers (e.g. in the context of IPO pricing policy) and intermediaries.

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FROM RELATIONAL LEADERSHIP TO RESILIENCE: THE ROLE OF SOCIAL CAPITAL AND MANAGERIAL COMPETENCIES

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Purpose: The study aims to identify the mechanisms through which social capital and relational leadership strengthen organizational resilience. The rationale for this research stems from the growing need to understand the "soft" factors that enable organizations to adapt and thrive in an environment characterized by instability, complexity, and uncertainty.

Design/methodology/approach: The analysis of the issue was carried out based on a systematic literature review, including both international and Polish sources. The review focused on publications concerning social capital, relational leadership, and organizational resilience.

Findings: The publication demonstrates a clear causal pathway: relational leadership fosters the development of social capital (networks, trust, shared norms), which in turn serves as a critical resource enabling organizational resilience. This relationship is operationalized through specific managerial competencies such as emotional intelligence, effective communication, and conflict management.

Research limitations/implications: The study is conceptual and based on a literature review, indicating a need for further empirical research to quantitatively verify the proposed relationships. Future studies should investigate the strength of these links in different organizational and cultural contexts.

Originality/value: The value of the article lies in integrating the concepts of relational leadership, social capital, and organizational resilience into a single, coherent conceptual model. This provides a clear framework for understanding how leadership behaviors translate into tangible resilience outcomes, offering valuable insights for both researchers and practicing managers seeking to build more adaptive organizations.

Keywords: Relational Leadership, Social Capital, Organisational Resilience, Managerial Competencies, Conceptual Paper.

Category of the paper: Literature review.

1. Introduction

Nowadays, organisations are forced to operate in an environment characterized by growing instability, complexity and uncertainty. Technological changes, market globalization, regulatory volatility and social and economic crises, which are often difficult to predict, can be considered challenges faced by modern organisations. Such circumstances mean that the success of an entity can often be linked primarily to its ability to adapt and build and strengthen resilience.

With this in mind, researchers are paying increasing attention to the resilience of organisations and their soft' factors, which include organisational culture, the quality of interpersonal relationships, the level of trust and the leadership skills of managers. It can therefore be concluded that social capital plays an important role, as networks, norms of cooperation and trust are the foundation for building lasting organisational resilience. It should be emphasized that at the same time, the development of relational leadership is noticeable. Its premise is the active support of team members by leaders through building strong relationships with them, open communication and creating an environment that enables them to cooperate and exchange information, experiences and ideas.

The aim of this article is to identify the mechanisms through which social capital and relational leadership can strengthen organisational resilience. This analysis will help to understand how social relations, shared values and trust, as well as the way leaders engage and support employees, can enable organisations to build their capacity to adapt and function effectively in conditions of uncertainty and dynamic changes in their environment. The aim is pursued with the following research questions:

- How are the core concepts of relational leadership, social capital, and organizational resilience defined and theoretically conceptualized in the contemporary management literature?
- What are the specific mechanisms and leader behaviors through which relational leadership contributes to the development of social capital within an organization?
- How does the social capital, built through relational leadership, functionally enhance an organization's capacity for adaptation, response, and recovery during crises and periods of uncertainty?
- What is the nature of the conceptual pathway linking relational leadership, social capital, and organizational resilience, and what is the role of managerial competencies in enabling this relationship?

The originality of this paper lies in its integration of these three distinct but interrelated concepts—relational leadership, social capital, and organizational resilience—into a single, coherent conceptual model. While these areas are often studied in pairs, this article provides a comprehensive pathway that explicitly links leadership behaviors to resilience outcomes

through the mediating mechanism of social capital, offering a more holistic understanding of how "soft" factors drive organizational adaptability.

The questions are addressed through a systematic literature review of international sources from databases such as Scopus and Web of Science.

2. Literature Review

To establish a robust theoretical foundation for this study, this literature review systematically examines the core constructs underpinning the research model. It begins by exploring the paradigm of relational leadership, tracing its evolution as a response to the limitations of traditional, authority-based leadership models (Uhl-Bien, 2006) and detailing its core principles centered on processes and interactions (Cunliffe, Eriksen, 2011). The review then delves into the multifaceted concept of social capital, synthesizing various definitions (Nahapiet Ghoshal, 1998; Putnam, 1995) to articulate its key dimensions—networks, trust, and shared norms—and its relevance at different analytical levels (Halpern, 2005). Finally, it investigates the construct of organizational resilience, moving beyond mere survival to encompass adaptive capacity and the ability to thrive in uncertainty, as reflected in standards like ISO 22316 (2017) and academic research (Lengnick-Hall et al., 2011; Weick, Sutcliffe, 2007). The central aim of this review is not only to define these concepts in isolation but to critically analyze the existing scholarly conversations that connect them, thereby setting the stage for proposing their integration into a cohesive conceptual pathway.

2.1. Relational Leadership as a New Management Paradigm

The contemporary organizational landscape, characterized by unprecedented volatility, technological disruption, and global interconnectedness (Bennett, Lemoine, 2014), has exposed the limitations of traditional, authority-based leadership models (Uhl-Bien et al., 2007). In response to these complex challenges, relational leadership has emerged as a critical new management paradigm fundamentally reconceptualizing how leadership functions within modern enterprises (Uhl-Bien, 2006). This approach represents a significant departure from other influential leadership styles, such as transformational leadership. While transformational leadership primarily focuses on inspiring followers toward achieving an organizational vision, often through charismatic influence and motivational appeals (Bass, Riggio, 2006), relational leadership establishes its foundation in the continuous, day-to-day cultivation of mutual relationships, trust-building, and shared responsibility (Uhl-Bien, 2006). The paradigm shift lies in understanding leadership not as a formal position of authority but as a dynamic social process that emerges from the quality of interactions and connections among organizational members (Cunliffe, Eriksen, 2011).

The distinctive power of this leadership paradigm manifests through several interconnected core attributes that directly facilitate the development of social capital, which serves as the bedrock of organizational resilience: Cultivating Trust-Based Relationships as a Strategic Foundation, where beyond being a desirable quality, the deliberate building of trust constitutes the essential cornerstone of relational leadership. Leaders who consistently demonstrate authenticity, integrity, and reliability create an environment of psychological safety. This environment encourages open dialogue, risk-taking, and vulnerability, which are indispensable for innovation and adaptive problem-solving, particularly during crises (Mayer et al., 1995; Edmondson, 2018).

Empathy and Deep Listening as Catalysts for Connection, an attribute that extends far beyond passive hearing. It involves the active and disciplined practice of striving to understand the unique perspectives, emotional states, and underlying motivations of team members. By demonstrating genuine empathy and engaging in deep listening, leaders validate their employees' experiences, which in turn fortifies relational bonds and fosters a profound sense of belonging and value within the organization (Goleman, 1998; Irwin, 2021). Championing Shared Responsibility and Distributed Leadership, where in contrast to models that centralize power and decision-making, relational leaders actively distribute authority and involve team members collaboratively in strategic and operational processes.

This approach cultivates a powerful sense of collective ownership and joint accountability for outcomes, which significantly enhances employee engagement, unlocks latent potential, and strengthens the organization's overall adaptive capacity (Yukl, 2012; Peace Conger, 2003).

2.1.1. The Critical Role of Managerial Competencies in Operationalizing Relational Leadership

Translating the philosophical principles of relational leadership into consistent, daily practice requires the deliberate application of a specific set of tangible managerial competencies. These competencies serve as the practical mechanisms through which leaders build and sustain the high-quality relationships that define this paradigm:

- **Mastery of Effective Communication:** The ability to communicate with transparency, clarity, and purpose is a fundamental competency. It is the primary tool for creating a shared understanding, ensuring strategic alignment, and facilitating the open exchange of ideas that is vital for collaborative success (Yukl, 2012; Men; Bowen, 2017).
- **Development of High Emotional Intelligence:** This competency is paramount, as it equips leaders with the capacity to accurately perceive, understand, and manage their own emotions while being attuned to the emotions of others. Such self-awareness and social skill are prerequisite for demonstrating authentic empathy, building lasting trust, and navigating the complex interpersonal dynamics of a modern workforce (Goleman, 1998; Miao et al., 2017).

- **Proficiency in Constructive Conflict Resolution:** The relational paradigm does not seek to avoid conflict but rather to harness it constructively. The skill to facilitate difficult conversations, mediate disagreements, and guide parties toward integrative solutions is essential for maintaining healthy, resilient relationships and turning potential disruptions into opportunities for growth and innovation (Rahim, 2003; Todorova et al., 2014).

In summary, relational leadership constitutes a profound evolution in management philosophy. It establishes a paradigm wherein a leader's ultimate effectiveness is intrinsically linked to their ability to nurture robust interpersonal connections and generate rich social capital. This social capital, in turn, becomes the organization's most valuable strategic asset for thriving in an environment of constant change and uncertainty.

2.2. Social Capital and Organizational Resilience

Social capital is a subject of discourse among representatives of social sciences (Nahapiet, Ghoshal, 1998; Halpern, 2005; Runiewicz-Wardyn, 2020) and economics (Woolcock, 1998; Łobocki, 2013; Libertowska, 2018). Interest in this construct may result from changes taking place in the environment of many entities. According to researchers, both in organisations (Włodarkiewicz-Klimek, 2016; Hebibi et al., 2019; Yaw, 2023) and in the economy (Kefela, 2010; Beyer, 2011; Shiryayev et al., 2016), knowledge related to social capital can be considered a very important resource today.

Social capital has been analysed by researchers for many years, but no consistent definition of the concept has been developed to date. It has been suggested that the reasons for this may lie in the interdisciplinary nature of social capital (Castle, 2009; Stankiewicz, 2016) and the difficulty of measuring it (Grootaert, Van Bastelar, 2002; Theiss, 2005; Carrillo Álvarez, Riera Román, 2017). Based on a review of the literature, Table 1 presents selected definitions of social capital by various authors.

Table 1.
Selected definitions of social capital

Author/Authors (year)	Definition
P. Bourdieu (1986)	‘The set of actual and potential resources linked to the possession of a durable network of more or less institutionalized relationships based on mutual acquaintance and recognition – or in other words, membership in a group – which provides each of its members with support in the form of collective-specific capital’.
E. Cox (1995)	‘A set of social processes occurring between groups and individuals leading to the development of networks, norms, and trust, the measure of which is satisfaction’.
R. Putnam (1995)	‘Trust, norms, and connections that can enhance the efficiency of society by facilitating coordinated actions’.
A. Portes (1998)	‘The capacity of actors to secure benefits through membership in social networks and other social structures’.
J. Nahapiet, S. Ghoshal (1998)	‘The sum of actual and potential resources embedded, available, and derived from the network of relationships possessed by a social actor’.

OECD (2002)	'Networks, together with shared norms, values, and understandings, that facilitate cooperation within or among groups'.
World Bank (2002)	'Institutions, relationships, attitudes, and values that govern interactions among people and contribute to economic and social development'.
F. Fukuyama (2003)	'A set of informal norms and ethical values shared by a specific group, enabling effective cooperation'.
J. Stachowicz (2005)	'Social capital of a social group, organization, or institution refers to human capacities (or rather their potential) such as: 1) abilities, competences, and knowledge of people to create specific structures of interpersonal and interorganizational relations; 2) social norms that trigger and support cooperative behaviours within groups, organizations, and institutions; 3) shared sets of values within the social group, organization, or institution – including trust'.
J. Czapiński (2006)	'Social networks regulated by moral norms or custom (and not, or not only, formal legal rules) that bind an individual to society in a way that enables cooperation with others for the common good'.
P. Sztompka (2007)	'Resources and benefits deriving from a specific position in social networks'.
J. Stachowicz, A. Stachowicz-Stanusch (2011)	'The abilities and skills of people (members of a given community, organization, or social group), their entrenched and shared value systems (...) and social networks constituting that community'.
Y. Pan et al. (2023)	'Material or immaterial resources made available to individuals through all their strong and weak 'social ties' (e.g., family, close friends, and strangers), including emotional, informational, and economic support'.

Source: Own study.

Based on the analysis of the definitions of social capital presented in Table 1, it is important to emphasise the complex and multifaceted nature of this concept. The authors' focus on various elements allows us to identify several basic ways of understanding it.

Social capital treated as resources and potential has been emphasised in definitions by authors such as P. Bourdieu (1986), J. Nahapiet and S. Ghoshal (1998), P. Sztompka (2007), Y. Pan et al. (2023). Researchers emphasise the tangible and intangible resources that an individual or group derives from participation in social networks. It is therefore important to locate the individual in a network of connections, as knowing certain people and the type of relationships maintained can determine access to support and specific benefits. Social capital understood as networks and relationships is emphasised in the definitions provided by the OECD (2002), the World Bank (2002), J. Czapiński (2006), J. Stachowicz and A. Stachowicz-Stanusch (2011). In this context, social capital is treated through the role of social networks, ties and relational structures, which form the foundation of cooperation between individuals and groups. These networks may be regulated by norms and values, including those of an informal nature (e.g. custom). Social capital treated as norms and values has been presented in the definitions of F. Fukuyama (2003), E. Cox (1995), R. Putnam (1995) and J. Stachowicz (2005). The authors understand this construct in the context of trust, customs, ethical norms and the shared values of group members. These elements create a desire to cooperate and a willingness among individuals to act for the common good of a given group. It should be emphasised that social capital can be understood as a combination of relationships, social networks, trust and community values. These elements can be considered the foundations of cooperation, enabling individuals and social groups to achieve their goals.

Due to the varying interpretations of social capital by researchers, this construct can be analysed at the micro, meso and macro levels (Sampson, 1999; Bankston, Zhou, 2002; Halpern, 2005). The micro level is treated by the authors as the individual level (Analia et al., 2020). The meso level, on the other hand, refers to internal and external relationships within a given group that enable individuals to achieve their goals. Therefore, social capital should be defined at the group level (Coleman, 1988). The macro level of social capital refers to a country or region, together with its social and political environment (Wang et al., 2022).

In conclusion, social capital can be considered a multidimensional construct. It can exist as a resource within a given organisation and in relations with the external environment. Therefore, the literature on the subject distinguishes between different levels of understanding of this concept – micro, meso and macro. In this context, the elements of social capital, such as relationships, social networks, trust and values, are also extremely important. With this in mind, it can be concluded that social capital is not only a social category, but also a strategic resource for organisations. This raises the question: how can this construct contribute to building the resilience of entities to the challenges and disruptions they face?

According to G. Hamel (2014), resilience is a multidimensional construct comprising elements such as flexibility, adaptability, resourcefulness and redundancy (Hamel, 2014). In the literature on the subject, social scientists point out that the issue of organisational resilience or the resilience of organisations in this field is a relatively new area of interest, which began to develop in the 21st century (McManus et al., 2007). Due to the diverse understanding of this term by researchers, Table 2 presents selected definitions of organisational resilience.

Table 2.
Selected definitions of organisational resilience

Author/Authors (year)	Definition
K.E. Weick, K.M. Sutcliffe (2007)	The ability of an organization to cope with crises, emergencies, and accidents.
J.J. Chrisman et al. (2011)	The ability of an organization to absorb, respond to, and emerge from situations that may pose potential threats to its existence.
I. Park et al. (2015)	The capability of an organization's internal systems, manifested in the effective return to continuity of operations after crises, disruptions, or catastrophic events.
ISO 22316:2017 (2017)	'The ability to absorb and adapt in a constantly changing environment to meet its objectives and prosper.'
W. Kahn et al. (2018)	The ability to cope with burdens and continue or improve performance even in the face of obstacles.
R. Manfield, L. Newey (2018)	The competencies to face uncertainty, overcome failures, and develop with greater strength in the face of challenges.
C. Ruiz-Martin et al. (2018)	'The measurable combination of characteristics, abilities, capacities or capabilities that allows an organization to withstand known and unknown disturbances and still survive'.
J. Hillmann, E. Guenther (2021)	The ability to take actions, their outcomes, process flows, the functioning of the organization and its employees, adopted strategies, or specific types of performance.
The UK Government Resilience Framework (2022)	'The ability of an organisation to achieve intended outcomes through uncertainty, disruption and change'.

Source: Own study.

An analysis of the definitions presented in Table 2 leads to the conclusion that most researchers identify common elements in their understanding of organisational resilience. An organisation's ability to cope with disruptions, crises or unforeseen events and to continue or restore continuity of operations is the most frequently emphasised element among the definitions of this construct presented. The ability to adapt and learn is another recurring aspect. It allows the organisation to develop and achieve its goals, as well as to survive in the face of challenges and obstacles. In many definitions, authors emphasise the importance of the organisation's internal competencies, processes, adopted strategies and employee behaviours. These factors can be collectively considered the basis for adaptive capacity. It should be emphasised that this construct is not only treated as a response to a crisis or difficulties. It is also a strategic element that enables an organisation to function and prosper in a changing and uncertain environment.

Taking into account the definitions of social capital presented in Table 1 and organisational resilience in Table 2, it can be concluded that social capital can be considered the basis of organisational resilience. Empirical research seems to confirm this, as it points to the role of social capital in building and strengthening trust, cooperation and knowledge exchange within an organisation (Tanner et al., 2022; Ben-Hador, Yitshaki, 2025). Thanks to this construct, an organisation is able to respond more quickly in crisis situations, mobilise resources more effectively and adapt better to changing environmental conditions. Given that organisations operate in specific communities, it should be emphasised that their resilience also depends on the stability, integration and adaptation of the social environment. Therefore, researchers in the field highlight the concept of “community resilience”. This term is understood as a process that combines a community's network of adaptive capacities with its ability to adjust to reality after disruptions or adversities (Ahmed et al., 2004; Pfefferbaum et al., 2005). It stems from four main adaptive capacities that lead to the development of disaster preparedness strategies: economic development, social capital, information and communication, and community competence (Norris et al., 2007).

It can therefore be concluded that social capital is an element connecting both levels – organisational and social. A high level of this construct in the organisation's environment can enable the development of the entity's ability to adapt to changes. On the other hand, actions taken by organisations can lead to strengthening the resilience of the community through, for example, CSR activities or involvement in cooperation with the local community and institutions.

3. Methods and Results

The literature review focused on determining the role of social capital and managerial competence as factors strengthening the impact of relational leadership on organisational resilience. The review was based on a systematic literature review (Czakoń, 2020; Lenart-Gąsiniec, 2021; Carrera-Rivera et al., 2022), aimed at determining the current state of knowledge in the analysed areas. Basic literature on the subject, as part of this method, was selected using databases such as Scopus and Web of Science. The selection of publications was the next step. The following keywords were considered: ‘social capital’, ‘organisational resilience’ and ‘relational leadership’. The set of publications was expanded by applying the ‘snowball’ method. The criteria for selecting the literature were the language of the publication (Polish and English) and the time period of publication (2004–2024). As a result of the selection process, a database of publications was created. Bibliometric analysis techniques were also used. The results were limited to keywords, fields (business, management and accounting, and social sciences) and document type (articles, conference publications, books and book chapters).

3.1. Bibliometric Analysis

Based on the Scopus and Web of Science databases, Figure 1 presents an analysis of the number of publications from 2004 to 2024 on social capital.

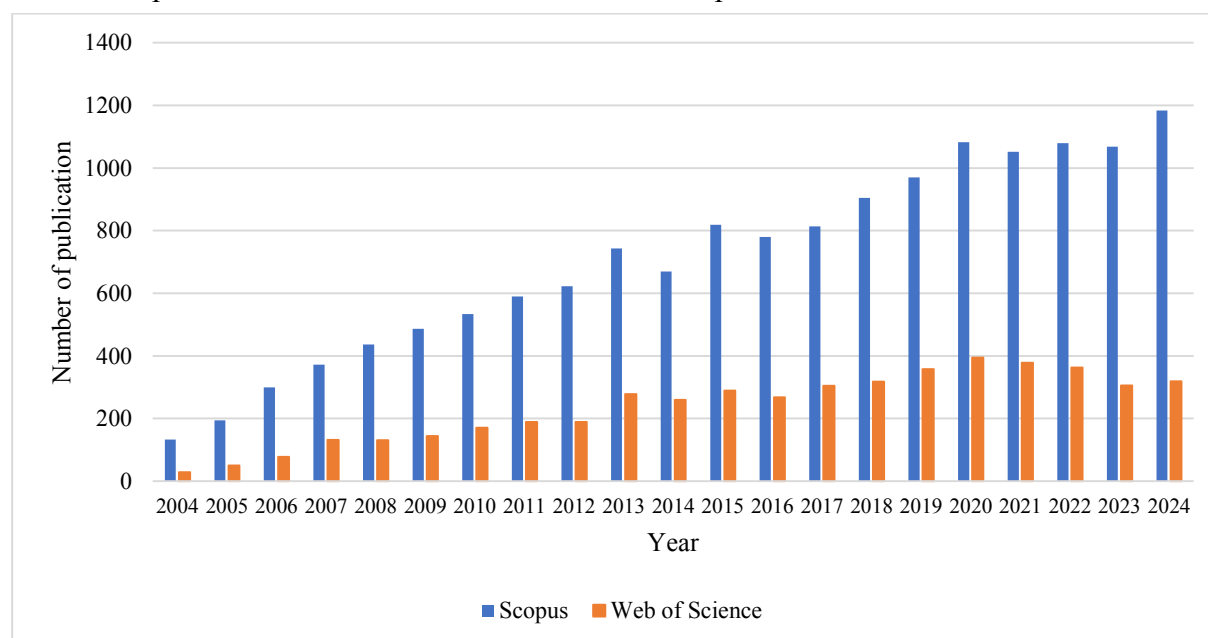


Figure 1. Number of publications on social capital from 2004 to 2024.

Source: Scopus and Web of Science databases.

Both the Scopus and Web of Science databases show a long-term upward trend in the number of publications on social capital. The Scopus database indexes significantly more works than Web of Science, and this difference has become more pronounced since 2010. Despite the different scales, the dynamics of change in both databases are similar, as periods of growth and decline occur in parallel. It is worth noting that the number of publications on social capital is steadily increasing, which indicates the growing importance of this construct in scientific discourse. Particularly intense growth was observed in 2010-2013 and 2018-2020. This may indicate an increase in researchers' interest in this topic in the context of the socio-economic challenges of the time. In the period 2021-2023, there is a noticeable stabilisation and a slight decline in dynamics, but data from 2024 indicate a rebound in the Scopus database. This may suggest a return to an upward trend.

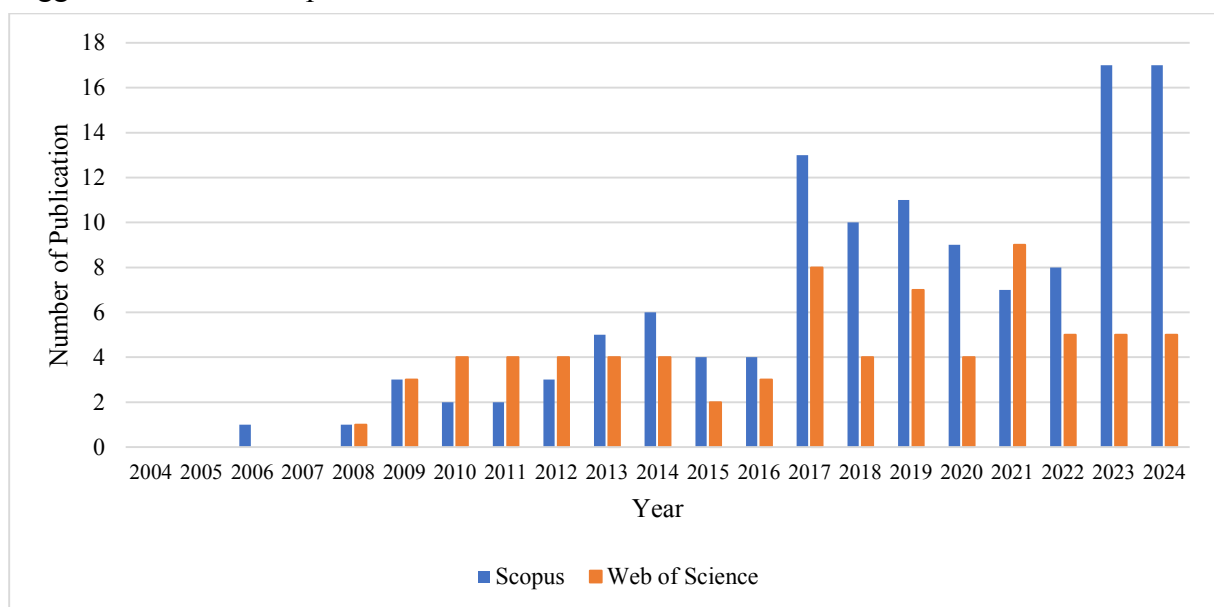


Figure 2. Number of publications on relational leadership from 2004 to 2024.

Source: Scopus and Web of Science databases.

An analysis of the number of publications on relational leadership between 2004 and 2024 in the Scopus and Web of Science databases shows a clear increase in interest in the topic during the period under review. At the same time, it should be emphasised that the scale of publications in the Scopus database is significantly higher than in the Web of Science database. In the Scopus database, the largest increase in publications occurred between 2016 and 2020. After 2020, however, there was a noticeable stabilisation in the number of publications, which remained at a high level in subsequent years. An analysis of Figure 2 shows that articles on this topic are not published as frequently in the Web of Science database. The results of the review of publications in the Scopus and Web of Science databases suggest that relational leadership is a developing area in scientific literature.

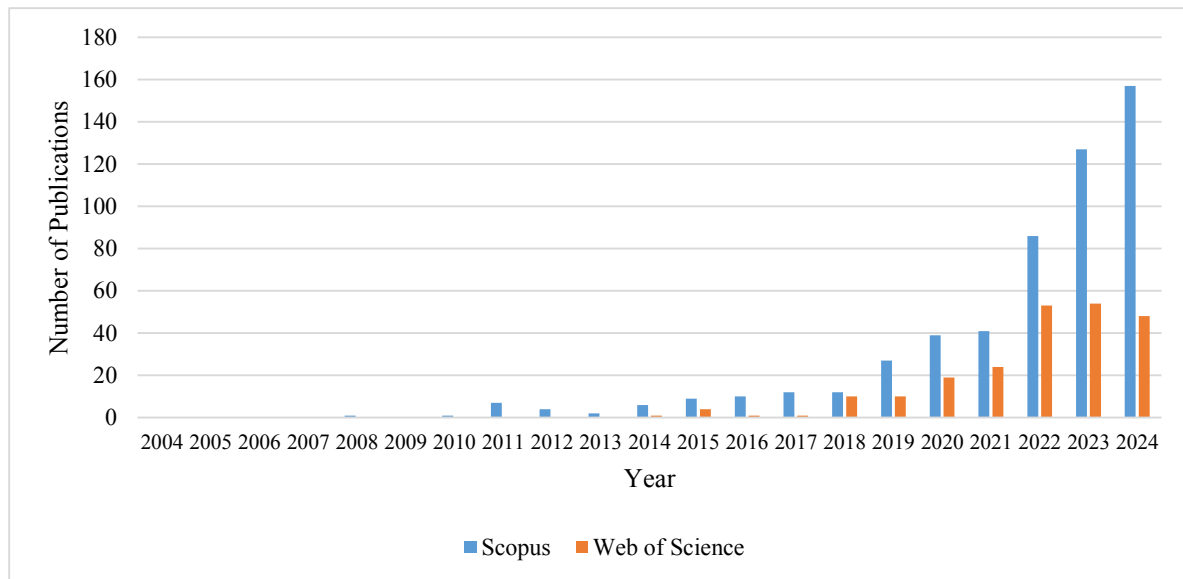


Figure 3. Number of publications on organisational resilience from 2004 to 2024.

Source: Scopus and Web of Science databases.

Based on the analysis of the data presented in Figure 3, it can be concluded that organisational resilience is gaining increasing interest in the scientific community. The Scopus database shows a clear increase in the number of studies in this area over the last ten years. In contrast, scientific papers on this topic appear much less frequently in the Web of Science database. The most dynamic growth in publications in the Scopus database can be observed in the years 2019-2024, while in Web of Science it can be observed in the period 2018-2022. It can therefore be concluded that organisational resilience is becoming an increasingly important area of research. Studies on this issue may be crucial in developing adaptation strategies in enterprises and risk management policies. The development of research on organisational culture that promotes adaptability is particularly important in the face of global uncertainty and the need for enterprises to adapt to changing conditions.

3.2. Relation Leadership and Social Capital in Building Resilience

The literature review reveals a clear sequence through which leadership influences an organization's ability to withstand shocks. This sequence can be defined as: **Relational Leadership** → **Social Capital** → **Organizational Resilience**. This pathway is supported by research indicating that relational leadership behaviors are fundamental to creating the social processes and networks that constitute social capital (Uhl-Bien, 2006). This social capital, in turn, has been identified as a critical antecedent that enables organizations to adapt and persevere through crises (Jia, 2018; Lengnick-Hall et al., 2011). Furthermore, effective navigation of this entire sequence depends on foundational managerial competencies, such as emotional intelligence and communication, that provide the practical skills necessary to build trust and foster collaboration (Yukl, 2012).

Relational leadership focuses on creating strong, positive connections within an organization. When leaders act with empathy, communicate openly, and demonstrate integrity, they directly contribute to the development of social capital (Uhl-Bien, 2006). This involves strengthening networks through encouraging collaboration that builds a dense web of relationships, improving communication and resource sharing (Chen et al., 2022). It also involves building trust through consistent and fair behaviour that fosters a reliable environment where employees feel secure (Fulmer, Gelfand, 2013). Furthermore, it involves developing shared values by involving team members in creating common goals that ensure everyone is working towards the same objectives (Khatoon et al., 2022). In short, the practices of relational leadership generate the very foundations of social capital: networks, cooperative norms, and trust (Carmeli et al., 2009).

The social capital created by leadership becomes a strategic asset during times of challenge (Tanner et al., 2022). When a crisis occurs, an organization rich in social capital is better equipped to respond effectively because coordination becomes faster as strong relationships and trust enable employees to collaborate quickly, bypassing slow formal procedures (Tanner et al., 2022). Problem-solving improves because a climate of trust allows people to openly discuss problems and experiment with solutions without fear of punishment (Edmondson, 2018). Adaptation is enhanced since employees are more willing to adapt and support necessary changes when they feel connected to and supported by their leaders and colleagues (Kahn et al., 2013). Thus, social capital provides the flexibility and collective strength that allows an organization to absorb shocks, adapt, and continue moving forward (Norris et al., 2008).

For relational leadership to be successful, specific managerial skills are required. These competencies allow leaders to build social capital effectively. They include effective communication as the ability to share information clearly and listen to others (Yukl, 2012). Emotional intelligence involves understanding and managing one's own emotions and recognizing the emotions of others to build strong relationships (Miao et al., 2017). Conflict management focuses on resolving disagreements in a way that strengthens, rather than damages, team cohesion (Rachman, 2021). These skills are the practical tools that enable leaders to implement relational strategies successfully.

In conclusion, the evidence shows that relational leadership serves as a powerful catalyst for developing social capital, which in turn forms the foundation of organizational resilience. The interconnected relationship between these three elements—relational leadership practices, social capital development, and resilient organizational outcomes—creates a virtuous cycle that enables organizations to not only withstand disruptions but to emerge stronger from challenges. The cultivation of trust-based relationships, empathetic communication, and shared responsibility through specific managerial competencies provides organizations with the adaptive capacity necessary to navigate complex and uncertain business environments. This underscores the critical importance of investing in leadership development and relationship-building as strategic imperatives for sustainable organizational success in today's volatile world.

3.3. Case Study Evidence

Real-world examples help to illustrate how this theoretical pathway functions in practice.

Case 1: Microsoft's Renewal through Empathetic Leadership

Under CEO Satya Nadella, Microsoft underwent a significant cultural shift. Nadella promoted a leadership style based on empathy and a "learn-it-all" mindset, moving away from a more competitive internal culture (Nadella, 2017).

- **Mechanisms:** This leadership approach built social capital by increasing trust and breaking down barriers between departments (Cao et al., 2024). This led to greater collaboration and knowledge sharing across the organization (Gittell, 2016).
- **Resilience Outcome:** The increase in social capital allowed Microsoft to pivot effectively to cloud-based and open-source technologies. The company demonstrated resilience by adapting its business model to a changing market, driven by its newly collaborative and agile internal environment (Ali, Begum, 2024).

Case 2: Toyota's Relational Approach to Operational Challenges

The Toyota Production System is famous for its efficiency, but its true strength lies in its relational foundation. The principle of "Genchi Genbutsu" encourages leaders to go to the source of a problem and work collaboratively with employees to find a solution (Liker, 2004; Rüttimeann et al., 2016).

- **Mechanisms at Play:** This practice builds powerful **social networks** and deep **trust**, as employees are empowered to identify and solve problems (Liker, Hoseus, 2008).
- **Resilience Outcome:** This high level of social capital was crucial after the 2011 earthquake in Japan. Toyota's strong relationships with employees and suppliers enabled a coordinated and rapid response, allowing the company to recover its production capabilities much faster than anticipated. The collaborative culture was key to its resilience, demonstrating how relational assets buffer organizations against shocks (Fujimoto, 2011; Tanner et al., 2022).

4. Discussion

The findings of this literature review robustly support the proposed conceptual model: **Relational Leadership → Social Capital → Organizational Resilience**. This discussion synthesizes these findings, compares them with existing literature, and highlights the new knowledge contributed by this integrative model.

This analysis confirms that organizational resilience is fundamentally a socially constructed capability (Tanner et al., 2022), heavily dependent on the quality of internal relationships. This aligns with the work of Lengnick-Hall et al. (2011), who posited that resilience emerges from an organization's human and social resources. However, this paper moves a step further by

delineating the specific causal pathway: relational leadership serves as the primary driver (Uhl-Bien, 2006) that cultivates the social capital (Nahapiet, Ghoshal, 1998) which, in turn, becomes the active ingredient of resilience.

The core mechanisms identified—where relational leadership builds social capital through trust, empathy, and shared responsibility—are consistent with the broader literature on high-quality connections (Dutton, Heaphy, 2003) and psychological safety (Edmondson, 2018). Our contribution lies in explicitly positioning these mechanisms as the bridge between leadership philosophy and tangible resilience outcomes. For instance, the case of Microsoft under Nadella (Nadella, 2017) demonstrates that a shift towards empathetic leadership directly fostered the cross-departmental collaboration (a form of social capital) necessary for strategic agility, a key resilience capability. This finding resonates with studies by Carmeli et al. (2009), who found that relational dynamics significantly impact an organization's ability to deal with crisis.

Similarly, the Toyota case (Liker, 2004; Fujimoto, 2011) provides a powerful illustration of how deeply embedded relational practices create a reservoir of social capital that can be drawn upon in a crisis. This supports the notion of resilience as a pre-positioned capacity, built during times of stability, rather than a reactive response (Weick, Sutcliffe, 2007). Our model clarifies that this capacity is stored within the organization's relational fabric, which is woven by its leaders.

A key insight from our analysis is the critical enabling role of managerial competencies. While the concepts of relational leadership and social capital can seem abstract, we have identified that they are operationalized through tangible skills like emotional intelligence (Miao et al., 2017), effective communication (Yukl, 2012), and conflict management (Rahim, 2003). This provides a practical answer to the "how" question for practicing managers, a area often underemphasized in purely theoretical discussions of social capital.

What is new in our research? While others have explored pairs of these concepts (e.g., leadership and resilience, or social capital and resilience), this article's originality lies in integrating all three into a single, testable pathway. It provides a clear framework that explains *how* leadership behaviors, via specific competencies, generate the social resources that enable resilience. This model offers a more granular understanding than previous studies, moving from correlation to a proposed causation.

The primary limitation of this research is its conceptual nature, as it is based on a synthesis of existing literature rather than new empirical data. Therefore, the proposed relationships, while strongly supported by theory and case evidence, require quantitative validation.

5. Conclusions

This study makes several important contributions. Theoretically, it offers a novel, integrated model that clarifies the sequential relationship between relational leadership, social capital, and organizational resilience (Uhl-Bien, 2006; Tanner et al., 2022). It offers significant refinement to the understanding of how organizational resilience is cultivated. By identifying social capital as the central mediating variable (Nahapiet, Ghoshal, 1998), the model moves beyond establishing correlation to proposing a specific causal mechanism. It clarifies the "black box" between leadership and resilience, suggesting that the influence of relational leadership is not direct but is channeled through the social fabric of the organization. This positions social capital not merely as a beneficial byproduct of good leadership, but as the critical generative mechanism for adaptive capacity (Lengnick-Hall et al., 2011). This insight enriches the resource-based view of the firm by categorizing social capital as a valuable, rare, and difficult-to-imitate strategic resource that is foundational to a firm's ability to survive and thrive in volatile environments. Furthermore, the model elevates relational leadership from a peripheral "soft skill" to a strategic imperative, arguing that its function in building this social resource is essential for long-term organizational viability (Carmeli et al., 2009).

For practice, the implications are significant. The findings suggest that building a resilient organization is less about drafting elaborate contingency plans and more about investing in leaders and the social fabric of the company.

- **Develop Relational Leaders:** Organizations should invest in training programs that develop competencies like communication, empathy, and collaboration in their leaders and managers.
- **Promote a Collaborative Culture:** Companies should create structures and incentives that encourage teamwork, knowledge sharing, and strong inter-departmental relationships.
- **Value Social Assets:** Leaders must recognize that trust and strong networks are critical strategic assets that require ongoing investment and protection.

This article is a conceptual analysis based on a review of existing literature. As such, the proposed relationships would benefit from further empirical testing. Future research should:

- **Empirical Verification:** Future studies should develop quantitative methods to measure the strength of the links in the proposed model. Structural Equation Modeling (SEM) could be used to test the mediating role of social capital.
- **Contextual Factors:** Research is needed to investigate how industry type, organizational size, or national culture might influence the strength of these relationships.

- **Longitudinal Studies:** In-depth longitudinal case studies could provide richer insights into how these dynamics play out during the entire lifecycle of a real-world organizational crisis.
- **Exploring Contingencies:** Future work could explore potential barriers or contingencies that might disrupt this pathway, such as severe resource constraints or extreme external pressure.

By building on this conceptual model, future studies can provide deeper, evidence-based insights into how organizations can systematically build the human and social foundations for lasting resilience in an increasingly volatile world.

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RESEARCH AND IMPROVEMENT OF THE FLOW OF RAW MATERIALS AND SEMI-FINISHED PRODUCTS IN THE PRODUCTION PROCESS

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Purpose: The following paper will outline the results of the analysis and the proposed solutions for improving the flow of raw materials and semi-finished products in the production process of a selected company. The emphasis will be on the project to eliminate time losses.

Design/methodology/approach: The primary research objectives were accomplished through empirical verification of the impact of the implementation of a new warehouse management system (WMS) on the efficiency of the raw materials and semi-finished products picking process. The study was based on the chronometry method, which involves the precise measurement of the time required to perform specific activities.

Findings: The study demonstrated that investing in technological solutions (WMS) and reorganising the workspace is an effective method of eliminating time losses, which is the most valuable resource in an era of growing competition. It is evident that inefficiency in the management of raw materials has a detrimental effect on the timely progression of production.

Practical implications: The WMS system has been shown to eliminate bottlenecks in the process of picking raw materials and semi-finished products, which is crucial for production efficiency. The reduction in picking time by 55% had a direct impact on the optimisation of the flow of raw materials and semi-finished products, which consequently resulted in the elimination of time losses throughout the production process. The study confirmed that investing in technology and reorganising the workspace is an effective way to optimise the most valuable resource – time. The project was concluded successfully within the specified budget and timeframe, thereby enabling the company to acquire practical experience in project management.

Originality/value: The paper provides empirical evidence that the strategic integration of Lean Logistics concepts with advanced IT systems is effective. The originality of the study lies in the development and implementation of a proprietary WMS that is perfectly tailored to the needs of the company.

The paper is intended for a readership comprising managers, logistics specialists and students. It provides a practical case study that demonstrates the efficacy of a methodical, project-based approach in effecting enduring changes in production processes.

Keywords: production flows, warehouse management, project management, WMS.

Category of the paper: Research paper, case study.

1. Introduction

In the contemporary business environment, manufacturing companies are confronted with significant challenges in their pursuit of maintaining a competitive advantage in terms of operational and logistical efficiency. A crucial aspect that influences these challenges is the assurance of process continuity. In this context, the foundation for maintaining the fluidity and synchronisation of the entire production cycle is the optimal flow of materials and semi-finished products. Inefficiencies in this area frequently result in substantial temporal losses, which in turn lead to production delays. In the contemporary market environment, it is imperative to achieve precise synchronisation between material delivery and processing to minimise downtime and maximise productivity. In response to the aforementioned challenges, companies are increasingly seeking innovative solutions, including advanced warehouse management systems (WMS), with a view to streamlining critical processes and eliminating identified bottlenecks. Despite numerous publications on Lean Management and Lean Logistics, there is still a lack of empirical research that systematically analyzes the impact of implementing a dedicated warehouse management system (WMS) on the efficiency of the material picking process in single-unit and small-batch production conditions (Ohno, 1988; Baudin, 2005; Serafin et al., 2014).

The objective of the present paper is twofold: firstly, to present research findings on the process of picking items in a materials and semi-finished products warehouse; secondly, to describe this process; and thirdly, to empirically verify the impact of implementing a new warehouse management system (WMS) on its efficiency. It was hypothesized that the implementation of the WMS system and the reorganization of the warehouse would significantly reduce picking times, improving the flow of raw materials and semi-finished products in production. This objective was achieved through a dual observation process employing chronometry, conducted prior to and following the implementation of the alterations. This facilitated an analysis of the impact of the WMS implementation on the reduction of time losses in the picking process. Consequently, it was possible to assess the validity of the improvements introduced.

2. Literature review

The Lean Management philosophy, which has been derived from the Toyota Production System (TPS), has gained recognition as a comprehensive approach to business management. The primary goal of this philosophy is to maximise value for the customer by eliminating all forms of waste (Ohno, 1988). In recent years, Lean principles and tools have been adapted for

application in various functional areas of organisations, including logistics. This development has resulted in the expansion of the concept to encompass the notion of Lean Logistics (Antczak, Puchała, 2014). The implementation of this concept in a particular setting, such as a warehouse, has necessitated the exploration of contemporary methodologies and solutions aimed at eradicating losses that are characterised as *Muda*. This approach is of particular importance in the field of production logistics, the primary function of which is to manage the flow of materials – from raw materials through to finished products – in a manner that ensures continuity of processes and minimises unnecessary inventories (Dębski, 1993). In the domain of production logistics management, the objective is to deliver materials in a manner that eradicates waste and only when they are required (Baudin, 2005). This is achieved through the implementation of the lean concept. In view of the heterogeneity of production processes, the philosophy of lean logistics must be practised in a manner that is tailored to the needs and capabilities of companies.

The above considerations clearly demonstrate that the logistics system occupies an equivalent strategic position to the production system (Cybulska et al., 2014). This interdependence fundamentally necessitates their holistic integration and management in a process synergy model. In the context of contemporary supply chains, the absence of a coherent connection between these systems results in the inefficient use of resources and diminished operational efficiency, consequently impacting the competitiveness of the company.

The element that binds both systems together is the flow of materials, which creates the dynamics of transformation and value, turning raw materials into useful products, while organising time, space and human cooperation in the pursuit of satisfying needs. This encompasses not only the physical movement of raw materials or products, but also the broader logistical processes involved in ensuring the seamless flow of materials and goods. This is a method that encompasses the management, planning and control of all phases of material movement. These phases begin at the moment of acquisition and continue through successive stages of processing in production, culminating in the delivery of the finished product to the customer (Szymonik, 2015).

In the context of logistics and production, efficient material flow requires coordination of activities aimed at eliminating all bottlenecks, unnecessary downtime and excessive inventories (Krawczyk, 2000). The objective is to ensure the availability of materials in accordance with their necessity, in the required quantities, with minimal delays and costs. Internet-enabled information systems play a pivotal role in ensuring this, as they facilitate the real-time processing and provision of data, in addition to enabling intelligent flow management. The advent of dynamic technological development and widespread access to advanced digital solutions has engendered a paradigm shift in corporate practices. Organizations now have the capability to adapt and implement systems that effectively eliminate waste, reduce costs and significantly increase operational flexibility (Serafin, 2014). This technological revolution in material flow management constitutes the foundation for the establishment of resilient and

competitive supply chains in the era of Industry 4.0. Further research and optimisation in this domain represent a key challenge for contemporary production logistics theory and practice.

3. Description of the research method used

In the course of the research, conducted on the basis of SOR-DREW S.A. as a case study, an endeavour was made to empirically validate the hypothesis that the implementation of alterations in the functioning of the materials and semi-finished products warehouse, with a particular emphasis on the implementation of a new warehouse management system (WMS), would result in a substantial reduction in time losses in the process of picking raw materials and semi-finished products. In view of the aforementioned points, the preliminary stage of the research comprised a comparative analysis of traditional methods of picking details cut from sheet metal using a laser cutter against the newly developed concept. The chronometry employed in this study was defined as a technique for recording and measuring the time required to perform specific activities or entire processes. The data obtained was utilised to measure the time consumption of picking and to ascertain the extent to which the WMS contributed to the reduction of working time. The objective of the study was twofold: firstly, to assess the validity of the improvement that had been introduced, and secondly, to consider the implications of this improvement.

The subject of the study comprised two steel construction projects, characterised by twin similarity. The selection of two projects was determined by the particular nature of the company's production, which is characterised by single-unit and small-batch production. This inherent characteristic of the production process renders it impossible to study a larger number of objects at the same time. The selection criteria encompassed the dimensions of the structures, the number of details, and the similar thicknesses of the sheets from which the details were cut. It was hypothesised that such a comparison would provide reliable and representative results. Both projects were distinguished by their unique nomenclature, individual six-digit main order numbers, and technical drawings. The characteristics of both structures are included in Table 1.

Table 1.
Characteristics of the analysed designs

	First project – picked manually	Second project – picked by the WMS system
Name	P1-020637	P2-020637
Drawing number	E50115-B3247-B259	E50115-B3247-B271
ZG number	418442	418479

Source: Own work.

A model employee in the position of warehouse worker was selected for both measurements in order to eliminate the influence of human factors on the results. The duration of the search was measured with a stopwatch, commencing from the moment the search for an item was initiated and concluding when the item was located. The data was recorded in real time and entered into a prepared spreadsheet. The completion of the first project (manual) was carried out in the manner practised prior to the implementation of the changes. The components were arranged in a random manner on pallets and shelves, and the employee was required to utilise a technical drawing in order to identify the necessary items independently. The total duration of the preparatory and concluding phases of the process was 20 minutes and 23 seconds. The results obtained are presented in Table 2.

Table 2.*Results of the first project picking*

Picking [418442]			
[B259] P1-020637			
Order number	Drawing number	Description	Measurement time [min]
418445	E50115-B3247-B259 (bl. #10 S235)	item 4 - 4 pcs item 1001 - 6 pcs item 1002 - 2 pcs item 1003 - 2 pcs item 1006 - 24 pcs	8:40
418446	E50115-B3247-B259 (bl. #15 S235 UT)	item 1004 - 2 pcs item 1005 - 2 pcs	2:15 2:00
418448	E50115-B3247-B259 (bl. #30 S235 UT)	item 6 - 3 pcs.	2:13
418450	E50115-B3247-B259 (bl. #8 S235)	item 1008 - 3 pcs	5:15
TOTAL			20:23

Source: Own work.

The second measurement study incorporated a novel approach to the receipt and dispatch of goods from the warehouse. Subsequent to the laser engraving process, the components were annotated with stickers, expedited to pallets, entered into the system, and subsequently allocated to shelves. The foreman was tasked with generating a picking list that delineated the locations, which was subsequently provided to the employee along with an auxiliary technical drawing. This drawing initiated the process of taking measurements. The total duration of the order preparation and completion process was 9 minutes and 5 seconds. The results obtained are presented in Table 3.

Table 3.*Results of the second project picking*

Picking [418479]			
[B271] P2-020637			
Order number	Drawing number	Description	Measurement time [min]
418482	E50115-B3247-B271 (bl. #10 S235)	item 4 - 4 pcs item 1001 - 6 pcs item 1002 - 4 pcs item 1005 - 24 pcs	2:50
418483	E50115-B3247-B271 (bl. #15 S235 UT)	item 1003 - 2 pcs	1:40
418484	E50115-B3247-B271 (bl. #20 S235 UT)	item 1004 - 2 pcs	1:23

418486	E50115-B3247-B271 (bl. #25 S235 UT)	item 6 - 3 pcs	1:23
418495	E50115-B3247-B271 (bl. #8 S235)	item 1007 - 3 pcs	1:49
TOTAL			9:05

Source: Own work.

The actual time measurements obtained for the technological operation – namely, the picking of main orders – yielded two summary results reflecting the execution of the process. Each of the tests was compiled, and the distributions of the analysed items were presented graphically in the form of two chronometric series, presented in Figure 1 and Figure 2, respectively. As illustrated in the graphs, the vertical axis denotes the time, measured in minutes, required to complete the items presented on the horizontal axis.

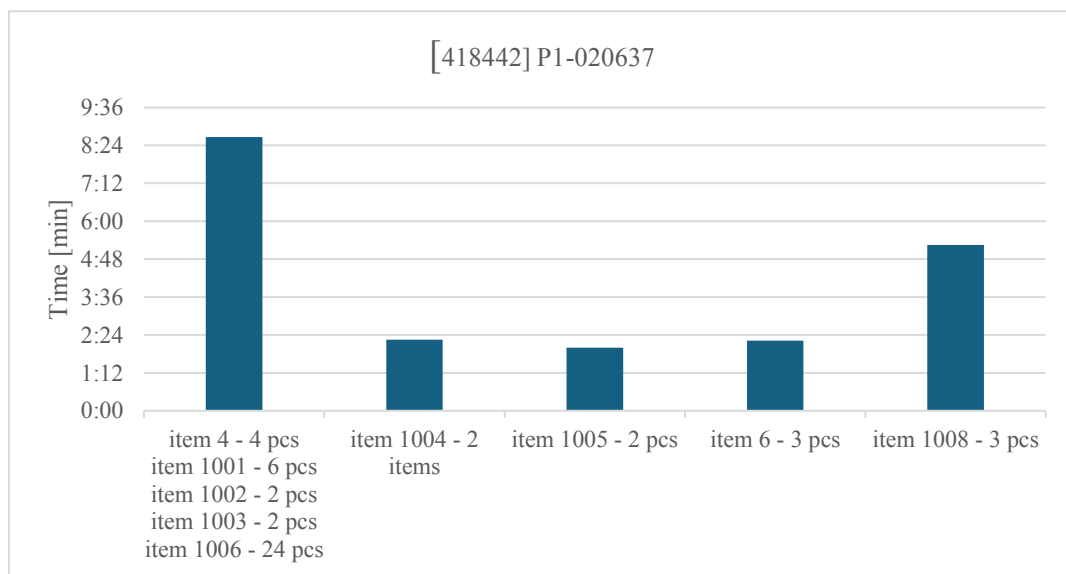


Figure 1. Chronometric series of the first design.

Source: Own work.

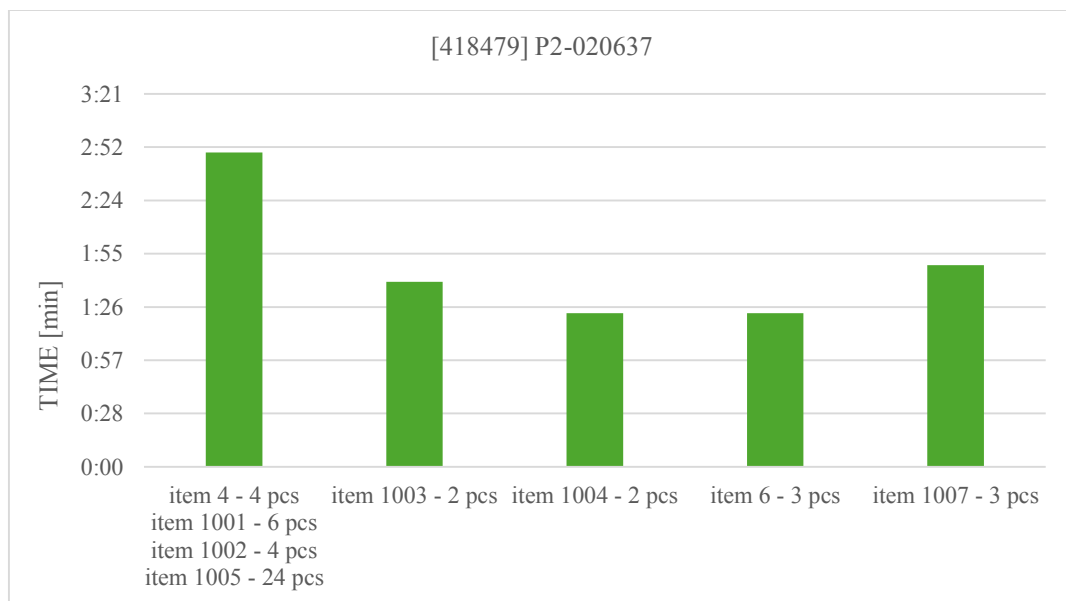


Figure 2. Chronometric series of the second design.

Source: Own work.

In order to visualise the differences between the two completion methods, the results have been compiled in a single chart, shown in Figure 3.

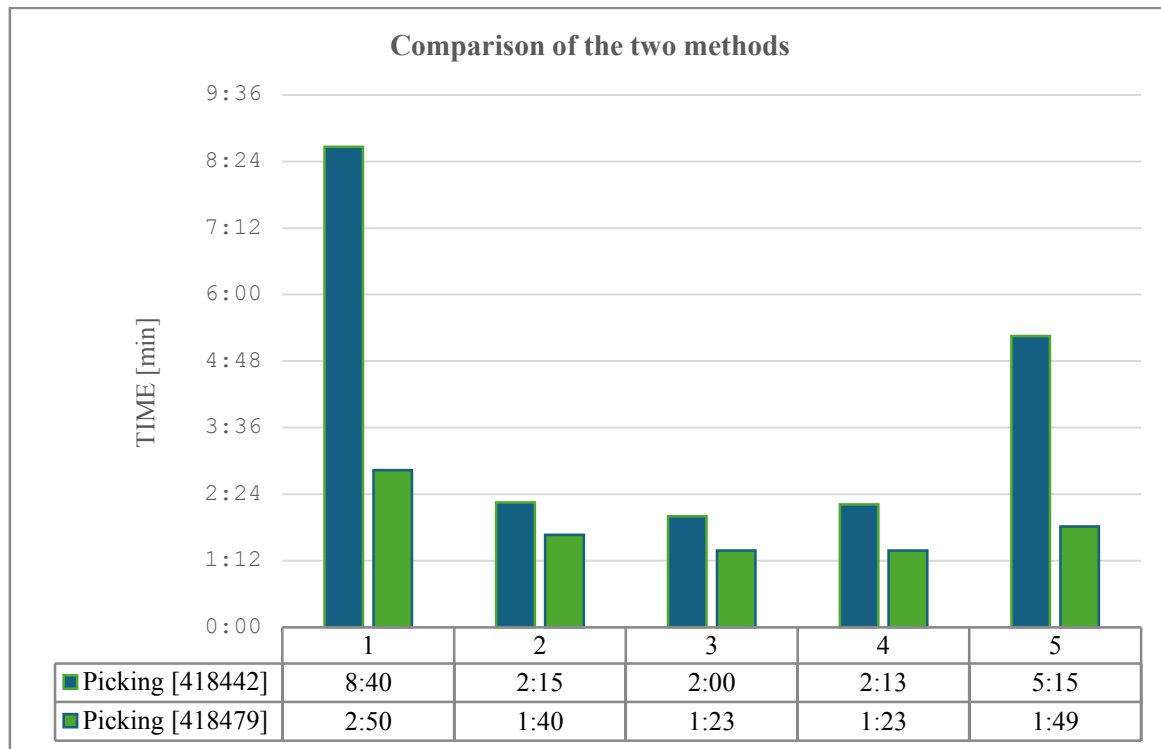


Figure 3. Chronometric series of both projects.

Source: Own work.

This comparison evidently demonstrates that each of the five items exhibited a reduced picking time in the novel system. The most significant reduction in duration was observed for the initial item, with a decrease from 8 minutes and 40 seconds to 2 minutes and 50 seconds. For the remaining items (2, 3, 4, 5), the WMS system also resulted in lower measurement outcomes. Furthermore, in the new system, these items were characterised not only by shorter times, but also by lower deviations. As demonstrated in the initial chart, the irregularity of the time differences serves to further corroborate the observations that were made during the course of the measurements.

In summary, the introduction of the Warehouse Management System (WMS) will result in a substantial enhancement in work efficiency, owing to a reduction in the time required to complete orders. The implementation of this system is expected to contribute to the equalisation and stabilisation of the process, thereby facilitating the optimisation of logistics pathways and enhancing the efficiency of material identification procedures. The time study provided unequivocal evidence in support of the hypothesis that optimising the picking processes is a valid objective.

4. Implementation project to eliminate time losses

A comprehensive improvement plan was developed on the basis of a detailed time study which yielded highly positive results. This study clearly confirmed the improvement of the picking process after the pilot implementation of the warehouse management system (WMS). The focus of the project was twofold, with activities concentrated on the reorganisation of the physical warehouse infrastructure and the further implementation of the integrated WMS IT system.

The reorganisation of the warehouse comprised the establishment of a permanent zone for semi-finished products, the relocation of pallets for the purpose of tidying, and the installation of new racks. Storage locations were meticulously catalogued using a dual-axis system, incorporating both chronological and alphabetical organisation, with the utilisation of barcodes on labels to facilitate efficient identification.

The internal WMS system, which is based on an Excel spreadsheet with macros, was designed as a low-cost, intuitive solution that is tailored to the specific needs of the company. The system automates the registration, tracking and completion of orders, and dynamically updates stock levels. In order to enhance automation, the format of detail labels was standardised by introducing a barcode for the main order (MO) number and a QR code for the drawing number, both of which were linked to the customer's order. The implementation of an industrial tablet, equipped with an integrated code reader and Excel software, was instrumental in optimising warehouse operations. The system interface was divided into three distinct functional areas: entry, retrieval and preview of details. During the training programme, the employees were provided with comprehensive operating instructions.

The company has successfully optimised its production processes by eliminating the identified bottleneck in the area of component picking. A pivotal component of this transformation was the development and implementation of an innovative, proprietary warehouse management system (WMS) that is tailored to the unique characteristics of metal product manufacturing. The implementation of the WMS, in conjunction with the restructuring of the storage area and the redesign of the warehouse layout, yielded quantifiable advantages. A time study confirmed a significant reduction in the time needed to pick parts – by as much as 55%. The implementation of integrated measures, encompassing organisational modifications and the integration of information technology, has been demonstrated to engender substantial enhancements in the efficiency of the movement of raw materials and semi-finished products. This, in turn, has resulted in the eradication of temporal losses.

Following a comprehensive review of the study's findings, it was determined that implementing changes was imperative. To this end, a project was initiated with the primary objective of enhancing the efficiency of the process involved in the picking of raw materials and semi-finished products utilised in the production cycle. The project's primary goal was to

achieve a substantial reduction in the time required for this stage of the production process. The implementation of theoretical assumptions using a project management approach has been demonstrated to be a practical way to introduce changes in manufacturing or service processes (Karbownik, 2017).

The project was formalised and documented using a project charter, which clearly defined its deadlines, scope, main objective and sub-objectives. This pivotal step was instrumental in facilitating the authorisation of the project, thereby conferring upon the manager the prerogative to appoint a dedicated project team comprising the following members: The roles encompass Production Director, Technologist, IT Specialist, Warehouse Worker and External Stakeholder.

The work breakdown structure (WBS), which is a hierarchical decomposition of the entire scope of the project, was divided into five main phases, within which detailed tasks were defined. The implementation of all tasks was approached via a waterfall methodology, emphasising the sequential implementation of project stages and strict adherence to a predetermined schedule. The schedule identified three milestones that were of particular significance in terms of the progression of the project:

- "Management decision" – the milestone marking the start of the project.
- "Completion of system design" – a milestone defining the completion of the design phase and allowing for the implementation of the next phases.
- "Project completion" – the milestone ending the project.

In order to facilitate precise visualisation of the schedule and comprehensive illustration of the structure of dependencies between tasks, the project defined a critical path (Critical Path Method - CPM). A graphical representation of this analysis is illustrated in Figure 4. This path is defined as a sequence of tasks that directly determine the minimum time required to complete the project (Musioł-Urbańczyk et al., 2021). The implementation of tasks on the critical path must be executed in a timely manner to ensure the overall success of the project. Any delay in this process will result in a delay to the entire project. The critical path of the project was presented in graphical form as an AoN (activity on node) network diagram. The EMPM (Extended Metra Potential Method) technique was utilised in order to ascertain the aforementioned objective, a process which enabled the consideration of complex dependencies and time constraints. It is evident that tasks which are on the critical path are distinguished by the use of orange colouring.

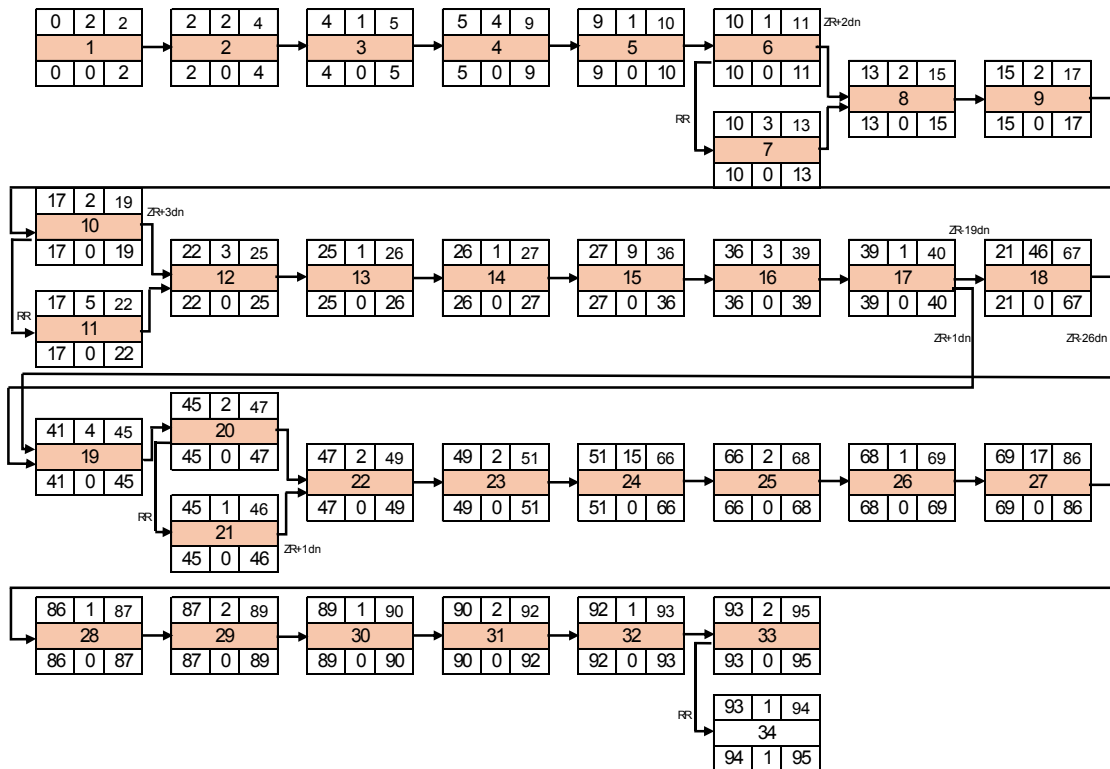


Figure 4. Critical path for the project to eliminate time losses in the production process.

Source: Own work.

A list of tasks was meticulously prepared for the purpose of analysing the project using the critical path method (CPM) and creating a network diagram. It should be noted that this list does not include summary tasks or milestones; however, it does contain numbers, estimated duration and dependencies between individual activities. All these data are presented in Table 4.

Table 4.

Information needed to create a network diagram for the elimination project

Task number	Tasks	Duration (days)	Predecessors
1.	Defining the problem at a meeting with technologists and the production director	2	-
2.	Analysis of warehouse processes	2	1
3.	Development of transport operations in technology	1	2
4.	Determination of storage areas and assignment of responsible persons	4	3
5.	Creating a production layout	1	4
6.	Defining the tent hall as a warehouse	1	5
7.	Cleaning up the tent hall	3	6 RR
8.	Determining the layout of the shelves in the tent hall	2	6 ZR+2dn; 7
9.	Determining the use of space on the racks	2	8
10.	Labelling shelves chronologically	2	9
11.	Implementation of Access Point in the tent	5	10 RR
12.	Arranging pallets with parts on shelves	3	10 ZR+3dn; 11
13.	Designation of a storage area for items awaiting entry into the WMS system	1	12

Cont. table 4.

14.	Changing the locations of storage areas to target locations in the IPO system	1	13
15.	Creation of an internal WMS system	9	14
16.	Synchronisation of WMS and IPO systems	3	15
17.	Test migration of data to WMS	1	16
18.	Generation of a new label formula for details by a partner	46	17 ZR-19dn
19.	Purchase of a warehouse code scanner	4	17 ZR+1 day; 18 ZR-26 days
20.	Updating the operating system supporting the scanner	2	19
21.	Preparation of training materials	1	20 RR
22.	Training employees on how to use the system	2	20; 21 ZR+1 day
23.	Implementation of the WMS system	2	22
24.	System performance testing	15	23
25.	Full data migration to WMS	2	24
26.	Full system launch	1	25
27.	Provision of technical support and monitoring after implementation	17	26
28.	Conducting a time study	1	27
29.	Feedback and corrections	2	28
30.	Automation of picking list generation by the foreman	1	29
31.	Testing the operation of the extended WMS system	2	30
32.	Checking the performance of the WMS system	1	31
33.	Data analysis and identification of areas for improvement	2	32
34.	Developing a plan for future updates and improvements	1	33 RR

Source: Own work.

The project team conducted a comprehensive risk analysis, employing a qualitative method to ascertain the potential effects and probabilities of these risks materialising. A comprehensive risk assessment card was created, supplemented with a plan to mitigate the identified risks. The documentation in question meticulously delineated the potential risks, their probability of occurrence, their potential impact on the project, and the specific countermeasures to be taken in the event of the risk materialising. The analysis indicated that the most significant risks to the implementation of the project were as follows:

- Employee resistance to change. The risk management plan included intensive communication activities and awareness building among staff.
- Inability to adapt labels defining details to the needs of the project. Mitigation measures involved developing a labelling system that allows for easy modification and adaptation.

Following a comprehensive review of all cost components, the total project budget was set at PLN 28,779.25 net. An analysis of the expenditure structure revealed that the largest cost item was investment in material resources. This predominance of material costs was a direct consequence of the necessity to thoroughly modernise the warehouse, which served as the primary location for the execution of project tasks.

All defined project objectives were successfully achieved, including in particular the implementation of a warehouse management system (WMS) and a comprehensive reorganisation of the warehouse space. The project was successful in achieving the expected results within the set budget and schedule. The project successfully implemented a new system, which resulted in a 55% reduction in order picking time and an enhancement in work organisation.

5. Conclusions

The study, which was conducted at SOR-DREW S.A. with a focus on enhancing material flow within the warehouse, yielded empirical evidence that demonstrated the efficacy of integrating the Lean Logistics concept with sophisticated IT systems, in the context of a perfect fit with the specifics of single-unit and small-batch production. On this basis, the following conclusions were arrived at:

1. It is imperative that companies adopt an individualised approach to production organisation, with the symbiosis of logistics and production being the pivotal factor in achieving success. It is imperative that there is close and properly structured cooperation between these two areas in order to ensure a smooth flow from raw material to finished product.
2. Inefficiency in the management of the flow of raw materials and semi-finished products is a direct cause of significant time losses, resulting in production delays.
3. The proprietary WMS system developed is an example of an innovative approach, fully adapted to the specific needs of a metal products manufacturing company.
4. The utilisation of chronometry as a research instrument facilitated the precise and comparative measurement of the time consumption of the picking process before and after the implementation of the system.
5. The research demonstrated a substantial decrease in the time required for the selection of components, with a reduction of 55%. This decline resulted in a significant decrease in the total operational duration from 20 minutes and 23 seconds (utilising the manual method) to 9 minutes and 5 seconds (employing the WMS system).
6. In view of the favourable outcomes of the analysis, a comprehensive improvement project was formulated, with a focus on the synergy of the physical reorganisation of the warehouse infrastructure (e.g. separation of a permanent zone, signage) and the full implementation of an integrated WMS system.
7. The success of the implementation project, based on a cascading approach and careful risk analysis, confirms that the strategic integration of IT systems with physical infrastructure is an effective way to introduce lasting changes in manufacturing processes.

The study demonstrates that strategic investment in innovative technological solutions (proprietary WMS) and workspace reorganisation is an effective method of eliminating time losses in the production process. The employment of a methodical approach to project management has facilitated a pivotal transformation within the domain of production logistics. This development substantiates the assertion that, in an era characterised by intensifying competition, the optimisation of time through the integration of technology, processes and work organisation is paramount.

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DEFINING THE "S" OF ESG IN ACADEMIA. A CASE STUDY OF THE ATHENA PROJECT

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Purpose: This paper attempts to define the social dimension of ESG in the field of scientific research and innovation. It focuses on analyzing the definition of the “S” factor and specific indicators related to measuring and monitoring institutional changes. All of this is presented from an academic perspective.

Design/methodology/approach: This research employs a case study approach focused on the Athena project, utilizing gender equality audits and specific measurement indicators to analyze institutional changes and gender inequalities in academia. It reflects on the effectiveness of some indicators in understanding complex social issues within research and innovation.

Findings: The study revealed the needs and risks associated with the implementation of the gender equality plan. It also clearly highlighted the need to raise public awareness of gender equality and, at the same time, the need to continuously identify and monitor the situation in this area. “S” should not be seen as a backdrop to current processes or simply reported as a curiosity, but rather understood as a strategy for institutional change aimed at removing barriers and increasing the efficiency of both the institution and its employees.

Social implications: The study represents an important step forward in the ongoing changes in the perception and understanding of the roles of individuals in society, especially in the context of legislative and organizational changes being introduced in the European Union.

Originality/value: The novelty of the article is primarily its innovative approach to the issue of gender equality and the implementation of GEPs in scientific institutions from the perspective of the ESG concept. The reflections and results it presents are the outcome of the project of a large scale including 8 European academic institutions that implemented their self-tailored Gender Equality Plans. Although the reported results are partial and focus only on selected aspects of a broader issue, they are a good starting point for institutions outside the academic sphere to build development and effectiveness based on diversity and equal opportunities among employees.

Keywords: gender equality plan, ESG, institutional change, monitoring and evaluation, gender indicators.

Category of the paper: Research paper.

1. Introduction

In light of the transformations occurring in today's world, sustainable transformation gains increasing importance for socio-economic development, and diversity becomes a subject of analysis across many fields and scientific disciplines. ESG evolves from the concept of sustainable development, referring to three factors: environmental (E), social (S), and governance (G) related to sustainable development and corporate governance (Cicirko, 2022).

ESG gains growing significance in recent years. This trend intensifies due to rising pressure from the environment, including changing expectations of investors, the financial sector, legislative changes, and growing social awareness.

Initially somewhat underestimated, the “S” dimension gradually receives increasing attention and recognition of its role within the ESG sustainability triangle. The “S” dimension appears in various initiatives such as European guidelines — the European Social Pillar of 2018 and the related Action Plan issued by the European Commission (EC) in March 2021. These two documents include twenty principles that define the EC's concept of the social dimension and outline necessary actions for their effectiveness. Alongside these two strategic documents on human and social rights, ESG principles appear in various regulations. The “S” dimension also applies to the academic environment conducting research and innovation and responsible for educating younger generations. The main question arises: how is the “S” recognized in research organizations? How should we understand and measure the “S”? What specific indicators define the “S” in research and innovation?

According to L. Becchetti et al. (2012), studying the social aspect of organizations involves assessing the typology of intersubjective and interorganizational relations that occur inside and outside the organization within the theory of change context. Silva (2023) holds that social factors should include the relational dimension of institutions with internal stakeholders (employees) and external stakeholders (e.g., local communities where the organization operates), as well as their effects both in terms of contributing to multidimensional employee well-being (job quality, occupational safety and health, training and development) and promoting local sustainable development.

One of the preferred approaches to initiating structural changes in academic environments has become, among others, Gender Equality Plans (GEPs). Considered part of the “S,” GEPs represent an institutional change strategy that removes barriers in recruiting new staff, allows retaining and developing the careers of currently employed researchers, addresses imbalances in decision-making processes, and generates cultural change necessary to avoid potential biases and discriminatory practices. Effective equality plans lead to the transformation of gender-related practices and thus to structural change. To achieve structural change, GEPs should be more than just formally adopted institutional policies; they should represent evidence-based approaches.

To address this complexity, one of the primary GEP functions is to provide space and initiate reflection at both individual and institutional levels. The theory of change approach supports reflection at all stages of GEPs, ensuring that the core assumptions of the institutional change process are questioned and considered by various stakeholder groups involved in implementation (Wróblewski, Leitne, 2022).

The aim of this paper is to define the social dimension of ESG in research and innovation. We conduct a deeper examination of the definition of "S" and specific indicators related to measuring and monitoring institutional changes from an academic perspective.

The novelty of the article is primarily its innovative approach to the issue of gender equality and the implementation of GEPs in scientific institutions from the perspective of the ESG concept. The paper is based on a case study of the international Athena¹ project, which aims to implement Gender Equality Plans (GEPs) in European scientific organizations. We present reflections based on the results of an implemented gender equality audit and evaluation using specific measurement indicators. Moreover, we consider how useful measurements and indicators are in developing insights into a complex issue such as gender injustice in academia. We pose the question: what should we assess regarding individuals, institutions, and discourses when formulating claims about gender inequalities in research and innovation?

The empirical data for this paper derives from the case study of the above mentioned Athena project, where authors were part of the international team and were responsible for the evaluation and monitoring system concept and implementation.

For the Athena project case study, we used a multi-method approach based on data collection from more than 30 Athena documents with key projects materials, including Staff questionnaire surveys, qualitative and quantitative indicators, GEPs of 8 implementing partners from Spain, Portugal, Slovenia, Bulgaria, Romania, Slovakia and Poland, Athena internal monitoring reports on implementing GEPs in years 2022, 2023 (in total 16 reports) and 8 evaluation reports. In total 33 documents. Thematic coding identified patterns related to monitoring and measuring of institutional change, defining particular indicators that allow to assess the institutional change. Moreover, more than four years participant observation was conducted during the lifetime of Athena project: from 1st of February 2021 to 31st of July 2025 during more than 50 follow up project meetings and events. Additionally, we were the authors of the Athena Evaluation and Monitoring concepts and together with all Athena partnering organizations (6 research performing organizations - RPOs and 2 Research Funding organizations – RFOs) defined more than 240 monitoring indicators.

2. Diversity and Inclusion as a part of the “S” dimension

The social element in ESG, in relation to organizational functioning, directly concerns people, primarily its employees, who represent the most important capital of the organization, but also indirectly relates to external stakeholders. In organizations operating in a globalized world, diversity gains increasing importance, and skillful management of this diversity is considered the highest level of human capital management (Przytuła, Krysińska-Kościańska, 2017). From the perspective of proper functioning and development of an organization, such “difference” should be treated as a value in itself, and the principles adopted by the organization should emphasize respect for and appreciation of this diversity. Diversity requires management, and organizations that manage it well build their competitive advantage more effectively.

Managing diversity means recognizing differences among people within and outside the organization and consciously utilizing the diverse potential of employees. The highest level of diversity management is inclusion (Draghi, 2024; Przytuła, 2020). Managers, when attempting to create inclusive workplaces, must take into account individual differences, needs, and perceptions to build structures and systems where employees feel appreciated and treated fairly (Draghi, 2024; Przytuła, 2020).

Employee diversity holds great significance in organizational management practice. Effective implementation of the social dimension within ESG can only be achieved by organizational managers if they possess a clear understanding of the concepts of diversity and equality, along with a working knowledge of how to manage these elements at every stage of human resource processes. This starts with an analysis of employee diversity, which allows the organization to assess who should be recruited in order to grow in a desired direction and meet strategic goals. It also includes workforce planning—taking into account imbalances in positions and the potential emergence of skills gaps. Recruitment and selection processes must be designed to ensure equal treatment and transparency: job postings should promote diverse teams, and both internal and external recruitment should follow fair procedures. Employee motivation and career development should also incorporate diversity issues, such as training focused on identifying and countering stereotypes. Furthermore, a well-prepared evaluation system is essential—one that is clear, equitable, and suited to a diverse workforce.

Monitoring plays a vital role in ensuring continuity and effectiveness. It involves planned, ongoing, and systematic collection and analysis of information on a given action or strategy. Monitoring offers leadership teams insights into the progress of implementation, helps assess outcomes, and flags current issues that may require intervention (Krysińska-Kościańska, 2017; Kwiatek, 2023).

In light of these observations, a key issue becomes the training of managerial staff in identifying the needs of diverse teams, as well as in developing the capacity to manage such teams and monitor relevant activities (Krysińska-Kościańska, 2017). Managers implementing

diversity management must learn to recognize and respond to individual differences in ways that ensure job security and performance, while actively preventing discrimination based on any form of difference (Leks-Bujak, 2014).

In the literature, diversity refers to all aspects by which people differ, such as gender, skin color, national and ethnic origin, physical ability, language, health status, lifestyle, education, and sexual orientation (Waligóra, 2018). These dimensions can be categorized as visible/perceptible (e.g., gender, age, race) and invisible/non-perceptible (e.g., knowledge, education, beliefs, religion). Recognizing the existence of diversity does not, however, equate to inclusion. Inclusion aims to integrate these various components in a way that ensures they complement and cooperate with one another. It involves taking action to empower employees by respecting and valuing their distinguishing characteristics (Przytuła, 2020).

Fostering inclusion requires acceptance of employee diversity, as well as empathy, openness to new ideas, trust-building, flexibility, and open and transparent communication on the part of leadership. One of the core elements that defines the “S” dimension within the field of diversity and inclusion is the issue of gender equality – both in terms of how it is understood and how it is interpreted.

3. The “S” dimension in academic practice. Why do we implement gender equality plans?

Gender equality remains a critical challenge for the European research sector (ERC, 2022). According to the She Figures 2024 report (EC, 2024a), despite achieving gender balance at all levels of education, the representation of women decreases as they progress to higher academic positions. Women hold only 30% of Grade A positions (full professorships), and even less in science, technology, engineering, and mathematics (STEM) fields—only 20%. A significant gender gap is evident in areas crucial to the EU’s competitiveness: while gender balance is observed among researchers in higher education (44%) and the government sector (45%), women are significantly underrepresented in the business sector (22%), which employs the majority (57%) of EU researchers. In the overall workforce, women make up only 3.4% of scientists and engineers, with an even greater gap among the self-employed, where they constitute merely 25% of professionals in these fields.

Gender Equality Plans (GEPs) are currently the preferred approach to initiating structural change towards gender equality in research organizations. As part of the “S” dimension, GEPs are recognized as a strategy for institutional change—removing barriers to the recruitment, retention, and career advancement of academic staff, addressing imbalances in decision-making processes, and fostering cultural transformation necessary to prevent future

biases and discriminatory practices. Effective GEPs lead to a transformation of gender-related practices and, consequently, to structural change (Wróblewski, Leitne, 2022).

To achieve structural change, GEPs must be more than just formally adopted institutional policies—they must be based on evidence-driven approaches. Considering the above, in recent years research institutions have undertaken efforts to diagnose the state of gender equality, which has served as a starting point for the implementation of appropriate actions in this area. One of the key initiatives has been the development of institutional equality action plans based on respect for equality and diversity, the implementation of which aims to ensure equal and unrestricted access to scientific development for all employees. These actions are undertaken across the various stages of human resource management (as previously outlined) (Kwiatek, 2023).

Equality plans comply with binding legal regulations as well as with best practices recommended by the European Commission². From the perspective of plan development, gender equality in the following areas has become particularly significant: horizontal occupational segregation (the concentration of women in specific fields, such as education), vertical segregation, including the so-called “glass ceiling” (limited opportunity for vertical advancement for women), and the “sticky floor” phenomenon (lack of advancement opportunities in low-status, traditionally “female” occupations such as secretary or cleaner). This is especially apparent in the STEM field (Gmurek et al., 2023; Hyży, 2017).

Among the reasons for this situation, cultural and social factors are most frequently cited, including the frequent reinforcement of traditional role models in both family and professional life. Against this backdrop, significant inequalities persist, particularly in relation to caregiving and family responsibilities predominantly borne by women. Traditions, stereotypes, patterns, and gender-based prejudices are deeply ingrained in ways of thinking and behavior (Hyży, 2017). Moreover, they often go unnoticed or are downplayed, and attempts to introduce change are perceived as a violation of the accepted system and established standards. Manifestations of deeply rooted bias—whether conscious or unconscious—continue to occur, contributing to the perpetuation of an unjustified competitive advantage for men in academia. This leads to an undervaluation of women’s scientific achievements and excellence, which in turn negatively affects their future opportunities (e.g. effectiveness in securing funding, publishing, remuneration, or career advancement). Another unresolved issue at the institutional level is the difficulty of combining an academic career with personal life plans, particularly family life (Gmurek, 2023; Hyży, 2017)³.

Such obstacles slow down academic careers—especially for women—and cause some to abandon this career path entirely. Barriers that hinder the reconciliation of professional work and family life are also discouraging for fathers who strive to be involved in both areas of life (Kwiatek, 2023). This may lead to a generational gap and the outflow of ambitious researchers from the academic environment (Gmurek, 2024).

As part of gender equality plans, research institutions are intensifying their efforts in five key areas identified by the European Commission, namely:

1. work-life balance and organizational culture,
2. gender balance in leadership and decision-making,
3. gender equality in recruitment and career progression,
4. integration of the gender dimension into research and teaching content,
5. measures against gender-based violence, including sexual harassment.

In this context, the monitoring of implemented actions and equality policies, as well as their effects on the organization, becomes particularly significant.

4. Monitoring and evaluation of GEPs for structural change management in the ESG concept

The implementation of gender equality measures in research-performing organizations involves interventions in complex systems, as they engage diverse stakeholders, affect other processes and strategies, and require action at various organizational levels. Accompanying monitoring and evaluation (M&E) help support these complex implementation processes by providing up-to-date information and insights into the status of implementation and enabling reflection on actual practices (EC, 2024b).

This makes it possible to identify practices that are not feasible or effective, as well as to pinpoint actors that hinder progress and success. In this approach, the monitoring and evaluation system is understood as a learning process that reflects implementation practices in light of specific cultural and structural contexts and provides essential information for adapting implementation strategies (Athena, 2022).

An evaluation matrix—comprising criteria, evaluation questions, and indicators—should be designed or adapted to reflect stakeholder diversity and ensure gender equality. Data related to women's empowerment is collected through a combination of qualitative and quantitative indicators. The development of indicators thus becomes a reflective exercise, and monitoring becomes a dynamic tool. It requires ongoing reflection on data gaps, the relevance of indicators, and the continuous refinement of gender indicators. An important step in the development of the M&E system is the design of a Theory of Change for the strategy, which maps out (Athena, 2022):

- the expected pathways of change in knowledge, attitudes, and behaviors related to gender equality,
- how these pathways lead to the desired impact,
- the underlying assumptions explaining the pathways and processes intended to lead to change.

The monitoring and evaluation accompanying the Athena project aimed to assess the GEP implementation processes, evaluate institutional progress, and identify structural changes resulting from specific actions. This approach fostered learning both within and between participating organizations, enabling continuous improvement. Key objectives included:

- comparing implementation practices and their outcomes across organizations,
- assessing the impact of actions through both ex-ante and ex-post perspectives,
- identifying organizational changes and benefits resulting from the implemented measures,
- enhancing the Athena learning environment through shared insights,
- adapting to cultural and structural contexts.

The Athena project's M&E system was designed to align with the specific GEPs developed by each partner organization and their corresponding actions. This included a conceptual framework for structural change and a flexible evaluation question matrix, which integrated different stakeholder perspectives. Reflexivity was a cornerstone of this approach, encouraging stakeholders to reflect on data, discuss results, and improve practices.

The M&E system focused on three main evaluation questions, which shaped the structure and process of the evaluation. The first question focused on shortcomings in implementation processes and aimed to highlight which practices proved effective, which challenges and resistances were identified, and how they could be addressed (Athena, 2022).

The second question related to implementation processes and operational practices, evaluating whether the implemented measures succeeded in achieving their goals. This question therefore placed strong emphasis on outcomes and accomplishments. The third evaluation question addressed the sustainability of actions.

M&E is a continuous process that begins and ends with the project or program and should focus on improving stakeholder satisfaction and meeting their needs. According to this methodology, Athena's continuous monitoring was conducted in parallel with the implementation of the GEP. The final impact evaluation compared the ex-ante status and ex-post perspectives following the interventions (Kamińska, Rudawska, 2023).

To fulfil the objectives of the formative evaluation, a variety of information from a variety of sources was taken into account. This information was gathered using the techniques of internal monitoring and technical reporting. For internal monitoring, the focus of the data collection was on internal organizational sources, such as regulations, strategies, action plans, monitoring and evaluation reports, and other data and documents, as well as the data collection methodology established by each organization for particular actions.

A combined analysis of quantitative and qualitative results was used to capture the status quo. The analysis of the outputs and achievements of the Athena GEPs for impact assessment was based on: (1) desk research and data analysis of the developed common database of quantitative and qualitative indicators; (2) analysis of three internal monitoring reports; (3) an online satisfaction survey to assess qualitative staff satisfaction.

As evaluation is a complex concept implemented in complex systems, the design and instrumentation of evaluations must consider these systems, i.e. contextual factors. The impact of an intervention is not only determined by the intervention itself, but also by its context. On the other hand, as gender inequalities differ greatly between fields and disciplines, interventions promoting gender equality and evaluation practices must take the specific disciplinary, organizational and national context into account.

As part of the impact evaluation process, satisfaction surveys were conducted using questionnaires among employees of each organization. The range of questions was defined in relation to each of the five required GE areas. One of the key issues explored in the survey was staff awareness of the gender equality awareness in their organizations. Another issue explored in the survey was the extent to which the gender dimension is integrated into academic and teaching activities. Respondents were also asked how they perceived the institution's commitment to promoting gender equality in research and teaching. A total of 1304 responses were received.

The ex-post evaluation was expected to provide a more integrated and meaningful picture of the project's overall achievements across all its aspects. Evaluation reports should include both descriptive analysis and quantitative information to support future planning and operations. Monitoring and evaluation play a critical role in the development and implementation of gender equality plans at both the institutional and individual levels. To fully harness this potential, the monitoring system must consist of indicators that represent the state of gender equality, refer to the specific goals and policies of the GEP (Wróblewski, Leitne, 2024), and also take into account the social, institutional, and cultural context. Equally important is the correct interpretation of the collected results.

5. Discussion

The availability of empirical data is of fundamental importance to the success of a GEP. Monitoring system mechanisms serve as essential tools for generating empirical evidence on gender equality developments and GEP implementation, enabling decision-makers to assess progress, refine strategies, and raise awareness of gender-related challenges. However, it should be noted that EU countries face a systematic lack of information in this area, due to either the absence or weakness of data collection mechanisms, but also due to a lack of a reporting culture (EC, 2024b).

A comprehensive gender analysis forms the basis for developing targeted policies that address gender imbalances and their root causes. It holds significant potential for supporting the reflexivity of implemented GEPs in both institutional and individual contexts.

To unlock this potential, the analysis should consist of relevant indicators that appropriately reflect the complex structure of gender equality and relate to the socio-political and institutional context, as well as the specific goals and strategies of the GEP.

In the case of the “S” factor, its quantitative measurement naturally relies on the simplest statistics. This may lead to the false impression that interpreting the obtained indicators is equally simple and, above all, straightforward. Such an assumption represents a pitfall, as seemingly obvious values of indicators may misleadingly suggest certain conclusions which, in reality, may turn out to be oversimplified or even incorrect.

To avoid such mistakes, it is crucial to fully understand the research context and grasp the complexity of the reality measured by the quantitative indicators. In particular, the following aspects must be considered:

- The process under investigation is dynamic and involves changes over time rather than being a one-time event.
- Responses to actions or changes may be delayed or extended over time.
- The initial state of the analyzed process may have differed significantly from its current state.
- The study may involve unidentified or unobservable causes (and consequently, latent variables).
- Collecting complete and targeted data in the sample may sometimes be limited or even impossible.

Thus, while indicators used to describe the “S” factor provide valuable information, their interpretation must account for the broader context and the complexity of the phenomenon being studied. Only then can the conclusions drawn be considered not only statistically valid, but also substantively accurate.

The importance of these aspects is illustrated by two examples. Although partially stylized, they directly refer to the findings of our assessments conducted at Jan Kochanowski University (UJK) between 2021–2025 within the framework of the Athena project.

Example 1

Let us consider the issue of the percentage of women serving on collegiate bodies within a university. Let us begin with the first perspective. It is generally expected that this percentage – highly significant, for instance, from the point of view of sound GEP policy – should hover around 50%. If we further analyze this issue in light of the decline of the patriarchal status quo, the expected value of this percentage could even temporarily exceed 50%. Moreover, if this concerns the highest-ranking decision-making bodies (e.g., rector’s or dean’s teams), a predominance of women can certainly be interpreted as appropriate and beneficial.

However, if we take into account bodies that, although equally important, are less prestigious and require significant organizational effort and high involvement (e.g., admission committees, audit bodies), then a significantly higher-than-50% share of women cannot be regarded as beneficial or appropriate. As a consequence, reporting the gender ratio in all

collegiate bodies in aggregate, without distinguishing relevant subgroups, may lead to distorted conclusions.

Now let us add the second perspective regarding the percentage of women in various committees. The target value of 50% is directly linked to certain “typical” or “fair” conditions. Yet, some existing, current or historical), objective factors may have resulted in a gender imbalance within the given group of staff. In such a case, it may be most reasonable to expect that a similar imbalance might, or even should, still be reflected in the elected bodies representing this group.

We may be dealing here with a deferred effect in a long-term adaptation process. If this is indeed the case, then a more appropriate approach is to diagnose and assess the direction of change over time, rather than evaluating a single point in time, such as the most recent state. In quantitative analysis, this approach translates into monitoring and interpreting the dynamics of indicators over time, rather than focusing solely on the very levels of these indicators.

Example 2

It is insightful to compare indicators with existing legal standards or internal regulations, even if these norms and regulations are objectively fully fair, including in terms of gender equality. Let us consider the issue of pay equity between women and men. In this regard, the standard practice is to measure the gender pay gap (GPG) based on average monthly gross salaries for a given year.

According to national legal regulations and the university’s remuneration system, base salary and overtime rates are essentially determined by position and seniority, not by gender or other sociodemographic characteristics. Despite this, the GPG at our university seems to suggest discrimination against women in this area. However, this turns out to be a misleading effect, resulting from several contributing factors. Among them, at least two key elements should be highlighted:

- the predominance of women at lower career levels and men at higher academic ranks, which stems from historical circumstances (incidentally, these circumstances are diminishing, as indicated by the dynamics of other indicators);
- the more frequent withdrawal of women, compared to men, from more intensive or additional work, largely due to the burden of family responsibilities and childcare, a typical social factor.

In light of the above, the pay gap indicator does not identify gender-based inequality within the salary system itself or in how it operates. Rather, it reflects the effects of other factors—specifically, the gender distribution across different staff categories. Two interrelated and positively correlated factors emerge as particularly significant: the proportion of women and men among academic staff, broken down by scientific promotion levels; and the gender distribution within the age structure of employees. These issues are clearly illustrated in Figures 1 and 2.

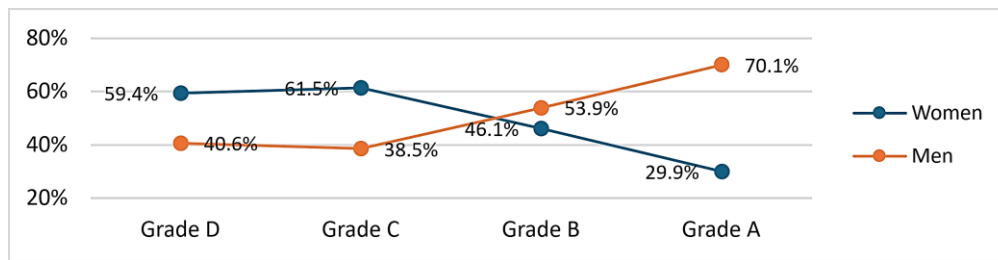


Figure 1. Proportion of women and men (%) among academic staff by scientific promotion grades (A – Professors, B – Habilitated Doctors, C – PhD Holders, D – Master’s Degree Holders and Medical Doctors) in 2020.

Source: Gender Equality Plans (2022).

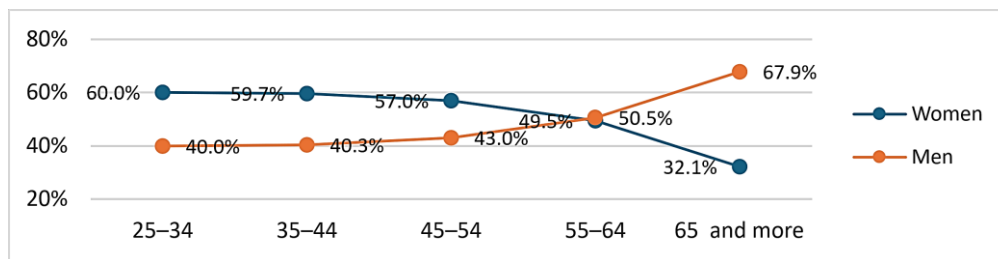


Figure 2. Proportion of women and men (%) by age groups (25-34 years, 35-44 years, 45-54 years, 55-64 years, 65 years and above) in 2020.

Source: Developed based on data collected for the Gender equality plan at Jan Kochanowski University in Kielce.

Above mentioned examples emphasize the awareness that the research methods adopted in gender and equity programmes in many cases may inadequately address institutional inequity, offering oversimplified analyses that ignore intersectionality, power structures and the discrepancy between policy and real-life experience.

This is in line with existing studies report that these programmes often rely on single-axis, gender-only analyses. For example, Locke et al. (2021), Nichols and Stahl (2019), and Powell (2018) describe approaches that use binary or narrative measures rather than multidimensional tools to capture the intersection of gender with race, class, ethnicity, and nationality.

Quantitative studies, such as those by Sheppard et al. (2023), reveal that available data are frequently limited by binary categorisations, lacking the nuance required to portray complex, layered identity dynamics. Furthermore, papers emphasising institutional inequity note that research designs often oversimplify academic contexts and fail to evaluate underlying power structures.

Studies by Vilhena et al. (2025) suggest that, while institutional context is acknowledged, there is little empirical measurement of factors such as informal norms, hidden labor and discrepancies between policy and lived experience. In summary, the reviewed studies and case of Athena project suggest that methodological shortcomings, such as the limited operationalization of intersectionality, the static treatment of institutional contexts, and the basic measurement of power, undermine efforts to capture the full complexity of academic inequity.

6. Summary

The "S" plays a significant role in the ESG sustainability triangle. However, it is not sufficiently recognized or understood by either management staff or employees in the academic environment. Based on research findings and case study observations from the Athena project: GEP, as a part of "S", should be understood as a strategy for institutional and cultural change aimed at removing barriers in the recruitment, retention, and career development of researchers; addressing imbalances in decision-making processes; and generating the cultural change necessary to avoid future biases and discriminatory practices.

In complex and dynamic research and innovation environments, where impact may have multiple causes, including cultural - and thus identifying causal relationships between interventions and outcomes is not straightforward, gender monitoring and evaluation should be interpreted as a living tool – one that is continuously reflected upon in terms of the reliability and validity of its indicators. To achieve this, an approach should be considered that aims to increase awareness of the cultural and socio-political context of GEPs, improve knowledge and understanding of the monitoring and evaluation process, and develop meaningful indicators referred to the theory of institutional change within GEP and its policies. Without this critical step, GEPs risk becoming symbolic or ineffective – either due to superficial implementation or the absence of a well-defined program theory (Engeli, Mazur, 2018). In the absence of a robust problem analysis, gender equality policies may result in inefficient resource allocation and limited impact, failing to lead to meaningful institutional change or effective management of the "S" dimension.

A comprehensive gender analysis provides a foundation for developing targeted policies that address gender imbalances and their root causes. It has significant potential to foster reflexivity in the implementation of GEPs within institutional and individual contexts.

The starting point for any organizational action should be the development of principles for the accurate and transparent collection of data, disaggregated by gender. To develop this potential, the analysis should consist of relevant indicators that adequately reflect the complex construct of gender equality and address the socio-political and institutional context, specific GEP goals, and strategies. As demonstrated by the GEP implementation monitoring reports, one of the challenges hindering a comprehensive gender-sensitive assessment was the lack of databases or their excessive dispersion¹.

The correct interpretation of the obtained results is crucial. In the case of the "S factor", its quantitative measurement, by its very nature, relies on the simplest of statistics. This state of affairs may lead one to believe that the interpretation of the obtained indicators is equally simple and, above all, straightforward. This is a trap, as seemingly obvious metric values can misleadingly suggest certain conclusions that may, in reality, prove simplistic or even inaccurate.

¹ https://www.ujk.edu.pl/plan_rownosci_plci.html

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Footnotes

- ¹ *Athena* – Implementing gender equality plans to unlock research potential of research performing organizations (RPOs) and research funding organizations (RFOs) in Europe. Project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement. No. 101006416, <https://www.athenaequality.eu>
- ² <https://www.euraxess.pl/pl/poland/news/nowa-europejska-karta-naukowca>, 20.02.2025.
- ³ The relevance of these issues within the university environment was confirmed by the results of survey research conducted as part of the Athena project.

SUPPORTING MANAGEMENT DECISIONS THROUGH MODERN TECHNOLOGIES IN ACCOUNTING

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Purpose: The article aims to show the role of modern technologies supported by AI in accounting, the threats they pose to the reliability of operational and strategic decisions in a company, and the problems that remain unresolved.

Design/methodology/approach: The study used databases such as Scopus and Web of Science to select texts for research. The keywords were used: artificial intelligence, new technologies, accounting, and decision-making. Titles, abstracts, and keywords were searched. The content of the articles was then analyzed. Seventy-four articles from the Scopus database were selected for analysis: two articles from the Web of Science database. Thirty-four articles were rejected due to different topics or overly specific research problems. The content of 20 articles was analyzed. The research problem consisted of the following questions: What management issues should be considered when making decisions based on solutions generated by modern technologies with the help of AI? Is AI treated as a tool supporting the decision-making process and, at the same time, as a threat? What are the benefits of decision automation? What are the ethical dilemmas associated with the use of modern technologies in decision-making?

Findings: The implementation of new technologies in accounting involves risks that affect operational and strategic decision-making. The lack of ethical management systems, insufficient trust in the quality and reliability of information, and the lack of appropriate skills among employees, including the ability to interpret reports and comments generated by artificial intelligence, have proven to be threats.

Research limitations/implications: The limitation is the use of only two databases, the study does not include any empirical research.

Practical implications: The use of modern technologies in accounting, with the support of AI to ensure that decisions are made correctly, should be a subject of ongoing analysis in terms of the competence of finance and accounting department employees. They should constantly improve their skills, and organizations associating accountants around the world should set out development paths, bearing in mind ethics.

Originality/value: Attention was drawn to the risks posed by new technologies in accounting, which ultimately influence decision-making.

Keywords: management decision support; modern technologies; artificial intelligence; accounting; trust; ethics; risk.

1. Introduction

The functioning of enterprises in a turbulent and changing environment is referred to as the BANI reality (the acronym stands for *Brittle, Anxious, Non-linear, and Incomprehensible*). In these conditions, operational and strategic decision-making requires, among other things, quick reactions, creativity, and adherence to ethical principles. At the same time, a reliable analysis of the financial data contained in financial statements and reports is of great importance. Based on this data provided by financial and management accounting, managerial decisions are made concerning, among other things, budgeting, forecasting costs, revenues, and results, setting prices, optimizing production, and outsourcing activities. The examples of decisions mentioned above do not exhaust the list of important future actions taken based on financial data from the accounting system. This system is supported by modern technologies using artificial intelligence. They are constantly evolving as companies face new challenges related to process transformation, the development of analytical skills, data protection, and compliance with ethical principles. The use of new technologies brings numerous benefits, but it can also pose risks to the quality and reliability of data, consequently affecting the accuracy of decisions made.

Growing interest in the use of emerging technologies has been observed among professional accounting bodies such as the International Federation of Accountants (IFAC), the International Ethics Standards Board for Accountants (IESBA), the American Institute of Certified Public Accountants (AICPA), and the Chartered Institute of Management Accountants (CIMA) (Financial Reporting Council, 2025; AICPA & CIMA, 2025). These organizations increasingly emphasize the importance of integrating technological innovation with ethical responsibility and professional judgment. Recent reports issued by IFAC and IESBA highlight that artificial intelligence, blockchain, and data analytics not only transform accounting processes but also challenge existing ethical frameworks by redefining accountability, transparency, and decision autonomy.

This article aims to highlight the role of modern technologies supported by artificial intelligence in accounting, the threats they pose to the reliability of operational and strategic decisions in a company, and the problems that remain unresolved. The author reviewed the literature, referring to scientific articles contained in the Scopus, Web of Science, and Google Scholar databases.

2. Literature review

The emergence of accounting cannot be attributed to a specific date. There are discrepancies in this regard (Cushing, 1989). However, it can be assumed that as early as the 15th century BC, there were substitutes for records of economic transactions (Staszel, 2015). These were primitive records of transactions. Since then, accounting has been constantly evolving, with the use of new technologies becoming widespread, although certain principles remain unchanged to this day (e.g., the principle of double-entry bookkeeping is still used). Accounting is practical in nature, but the academic community also perceives it as a science (Mautz, 1963; Wielogórska-Leszczynska, 2013; Remlein, 2014; Staszel, 2015; Hartmann, 2017; Rajgopal, 2021; Czapla, Walińska, 2021). This diverse approach to accounting is confirmed in different definitions, which focus more on scientific or practical aspects. Accounting is classified as a specialization in the social sciences (in economics and finance), but accounting issues also appear in management sciences (currently management and quality sciences) (Vollmer, 2009). The practical nature of accounting is reflected in the use of financial data, which, when transformed into information, is used to make operational (regarding the implementation of processes) and strategic (e.g., regarding the allocation of resources and the choice of competitive position) decisions (Czapla, Walińska, 2021). Operational decisions focus on cost efficiency, quality, timeliness, and flexibility. Data quality and the interpretability of results are the aspects that researchers particularly emphasize (Artene, Domil, 2025). Strategic decisions, on the other hand, focus on the entire company and the selection of segments in which changes are planned (Bitkowska, 2017).

The usefulness of accounting is an important feature, but it should also be emphasized that accounting has been and continues to be linked to changes taking place in society. It is undergoing an intense transformation driven by machine learning techniques and artificial intelligence tools (Odonkor et al., 2024). Accounting automation is no longer merely an accounting tool – it is becoming an integral part of decision support systems (Appelbaum et al., 2017; Chipriyanova, Krasteva-Hristova, 2023).

The dynamic development of information technology has sparked a digital revolution that has affected all areas of business and naturally permeated accounting, both in practice and in education. Ibrahim et al. (2021) emphasizes that the advent of advanced technologies such as artificial intelligence (AI), blockchain, big data, and robotic process automation (RPA) has catalyzed a profound transformation in accounting practices, extending from data recording and processing to auditing and financial reporting activities. E-accounting is a concept that enables more efficient, accessible, and flexible management using the internet. Artificial intelligence (AI) is increasingly being used in accounting quality data (Kuang, 2025). AI is seen as a general-purpose technology that will be treated similarly to electricity or the internet. However, the adaptation of new AI-supported technologies in accounting faces organizational

adaptation problems (Mhlongo, 2025). The report shows that 85% of accountants surveyed report a willingness to use AI, and 80% are convinced that work in finance and accounting departments will soon undergo significant change. However, the research shows that the use of AI is not part of corporate strategy. This tool is seen as an experiment. Researchers have noted that the problem is the lack of guidance on ethical conduct when using AI tools. It follows that the use of AI requires many tasks to be performed by finance and accounting department employees (MIT Sloan School of Management, 2025; IFAC, 2025).

Table 1 shows the tasks to be performed by the organization, the person responsible for the processes, and the unit employees of the finance and accounting departments.

Decision-making has become increasingly complex not only because enterprises operate within the BANI world, but also due to rapid technological advancements that generate vast amounts of data. The excessive volume of processed information, despite its potential value, may impair managerial judgment and lead to suboptimal or erroneous decisions (Bennet, Bennet, 2008; McKenna, Martin-Smith, 2005).

Table 1.
Tasks related to the use of AI in accounting

Levels	Tasks
Organization level	• Developing a strategy that combines technological, cultural, and ethical aspects. • Redefining tasks as activities in which humans contribute intuition and contextual knowledge, while AI supports analysis and operations. • Co-creating ethical standards and regulations for the safe implementation of AI. • Creating an environment conducive to mentoring, professional development, and expert judgement. • Implementing new models of talent development, training, and career paths in the context of AI integration.
Process level	• Integrating AI into financial and accounting processes in a way that supports rather than replaces humans. • Improving decision-making processes by combining data analysis with expert knowledge. • Ensuring data security and ethical compliance when implementing AI. • Maintaining continuity of mentoring and expert supervision in transformed processes.
Individual level (finance and accounting department employee)	• Developing critical thinking skills, professional ethics, and data security awareness. • Combining analytical skills with creativity in interpreting AI results. • Taking on the role of interpreter and advisor concerning recommendations generated by AI. • Actively participating in learning and adapting to new technological tools. • Responsibility for the ethical use of technology.

Source: own work based on AICPA & CIMA | AICPA & CIMA

3. Methods

The study used databases such as Scopus and Web of Science to select texts for research. The following keywords were used to select texts: artificial intelligence, new technologies, accounting, and decision making. Ultimately, 74 articles were obtained from the Scopus database and 2 articles from the Web of Science database. The content of 20 articles was analyzed. The search results are presented in Figure 1.

The visualization aimed to identify the main topics and research trends in scientific articles. In the articles studied, the most frequently occurring words were artificial intelligence and decision making. The main clusters were identified. The first cluster included the words or phrases: artificial intelligence, techno, finance, blockchain, decision support systems, and information management.

The second cluster included the keywords: machine learning, decision making, management accounting, big data, and information use. The last cluster included the words and phrases: decision support, risk management, accounting, and automation.

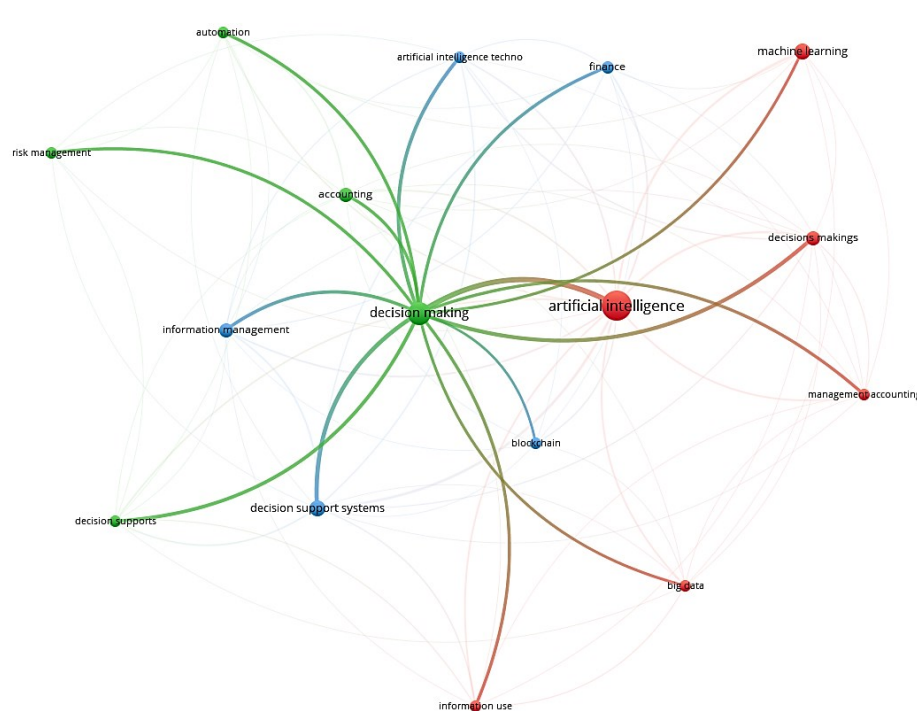


Figure 1. Keyword co-occurrence map generated in VOS viewer.

Source: own work.

The results of the analysis confirmed that the strongest links are between the words artificial intelligence and decision making.

Accounting plays a supporting role in decision-making. The figure shows that researchers focus on analyzing the applications of artificial intelligence tools in improving decision-making processes. In the literature on the subject, this relationship is often interpreted as a manifestation

of the growing importance of algorithmization of management processes and the pursuit of more effective decisions in conditions of uncertainty. Cluster analysis led to the formulation of the following research questions: What management issues should be considered when making decisions based on solutions generated by modern technologies with the help of AI? Is AI treated as a tool supporting the decision-making process and, at the same time, as a threat? What are the benefits of decision automation? What are the ethical dilemmas associated with the use of modern technologies in decision-making?

4. Results

Analysis of the research material showed that all research questions were answered. Researchers encountered significant problems related to errors made when using modern AI-supported technologies. Authors Pabel and Akther (2025) point to bias in algorithms – the problem arises when the data is not representative (Pabel, Akther, 2025). Pankratov and Levytskyi draw attention to other issues. According to them, modern technologies supporting interaction between agents are characterized by computational complexity, simplified operating conditions, low adaptability to change, and difficulty in taking into account the diversity of agents. This situation may cause problems in decision-making (Pankratov, Levytskyi, 2025). The increasing complexity of data and the need to ensure its quality and security constitute significant risks to the effective use of modern analytical technologies in accounting (Hussain et al., 2023; Derbali, 2025; Hussain, Sharma, 2025; Kuang, 2025). Unequal access to technology may prove to be an obstacle to the creation of information useful for decision-making. The problems also concern certain values held by employees of finance and accounting departments, such as objectivity, trust, and transparency (Baiod, Hussain, 2024). It is not clear how algorithms lead to specific decisions. It is also unclear who is responsible for the wrong decisions. The issue of ethics raises many doubts, as there are no practices or models for ethical conduct (Nanda, 2025; Alsulami, 2025). Therefore, researchers propose the creation of an ethical management system (Pabel, Akther, 2025). Accountants are increasingly confronted with complex ethical challenges arising from the implementation of artificial intelligence in accounting practice (Bhavya et al, 2025). A key issue involves the attribution of responsibility for decisions made by algorithms and the assurance of transparency in decision-making processes carried out by autonomous systems (Bracci, 2022). Furthermore, concerns are raised regarding the level of trust in such systems, particularly in relation to integrity, confidentiality, and security of processed data (Agrawal et al., 2025). Bracci (2022) contends that artificial intelligence (AI) mitigates only a limited subset of ethical challenges in managerial accounting, while simultaneously introducing new dilemmas associated with the lack of transparency and explainability in algorithmically generated documentation. The opacity of AI-driven decision-

support systems raises concerns regarding the accountability and reliability of managerial judgments derived from such outputs (Vărzaru, 2022). As a result, decision-making processes that rely heavily on automated reasoning may be exposed to an increased risk of bias, misinterpretation, and error. This underscores the necessity for establishing robust ethical frameworks and governance mechanisms to ensure transparency, fairness, and responsibility in the deployment of AI technologies within accounting practice. The implementation of AI, automation, and data analytics requires a comprehensive understanding of the mechanisms through which these technologies influence the evaluation and use of managerial information in decision-making. Therefore, careful planning and the systematic integration of technology into existing organizational structures are essential to minimize the risk of errors resulting from an incomplete alignment of digital tools with decision-making processes. Such an approach not only enhances the informational efficiency of accounting (Quattrone, 2016; Pabel, Akther, 2025; AICPA & CIMA, 2025). Quattrone (2016) emphasizes that attention should not be solely focused on the effects of implementing new technologies in accounting. Instead, it is essential to draw on wisdom, understood as the ability to reflect on the consequences of decisions. His arguments provide a new perspective on accounting, viewed as a reflective process that aids in understanding organizations and supports the making of responsible decisions within the framework of accountable management. Duan (2020) emphasizes that intelligent accounting information fusion systems can enhance the quality, consistency, and relevance of financial data, transforming accounting into a more dynamic and predictive discipline. However, the author cautions that technological complexity, algorithmic risks, and regulatory gaps may undermine the reliability and ethical foundation of digital accounting practices.

In addition to ethics, changes influenced by digital technology and transformation, the acquisition of new skills is an important issue and new competencies (Ibrahim et al., 2021; Samanthi, Gooneratne, 2023; Ayad et al., 2023; Abbas, 2025; Artene, Domil, 2025). The responsibilities of finance and accounting staff are changing, with greater emphasis being placed on data analysis, supporting business decisions, and the ability to learn and implement digital technologies (Jayashree, Jayakani, 2025).

Although the development of technologies such as artificial intelligence, as well as other blockchain and cloud computing, significantly enhances the efficiency, transparency, and predictive capacity of modern accounting, thereby influencing decision-making processes, researchers point out that their implementation entails substantial risks. As noted by Alkan (2022) and Duan (2020), the growing technological complexity and process automation may lead to reduced human oversight, the emergence of ethical ambiguities, and the erosion of professional judgment in financial decision-making. Similarly, Appelbaum et al. (2017) and Ibrahim et al. (2021) emphasize that reliance on data-driven algorithms exposes accounting systems to algorithmic errors, systemic biases, and cybersecurity threats, which may undermine the integrity and confidentiality of financial data.

5. Conclusions

The issue of using new technologies supported by AI tools is of interest to various stakeholders: owners, management, lenders, and creditors, who expect reliable and credible information from the accounting system to be used for decision-making. The use of new technologies is also of interest to accounting organizations. Despite their ongoing efforts, organizations still have much to accomplish in addressing the challenges posed by modern technologies used in accounting. There is a pressing need for these institutions to provide clearer guidance on how to mitigate ethical risks in accounting practice. In the era of new technologies, accounting organizations emphasize the need to audit data, reformulate the roles of company managers, and conduct training on the ethical use of AI tools. Scientific discussions also concern the aforementioned acquisition of new competencies by employees of finance and accounting departments. Competence such as SQL, data modelling, understanding machine learning, critical thinking, and communication is becoming important. The use of modern technologies in accounting, with the support of AI to ensure that decisions are made correctly, should be a constant subject of analysis in terms of the skills of finance and accounting department employees. They should constantly improve their skills, and organizations bringing together accountants around the world should set out development paths, bearing in mind ethics.

The use of new technologies does not always result in reliable information. Machines can make mistakes, and in these conditions, there is an increased demand for new skills – designing fault-tolerant systems and making fault-tolerant decisions. Reducing data entry time affects the organization of accounting – responsibilities change as employees spend time preparing information and communicating. When making decisions, it is important to respond quickly to changes in the world around us, supported by information from the finance and accounting departments. According to research, the use of AI contributes to increased productivity and reduced task completion times through automation. Learning models improve, among other things, forecasts of revenues, costs, and financial results. AI helps to justify the scenarios created, suggests the reasons for deviations, and automates data aggregation and recording. In addition, it supports process control. It is used to create reports and summaries. Despite the positive role of AI in improving the work of finance and accounting departments, the risks should also be mentioned. Significant risks include a lack of information security and insufficient data protection. Another problem may be the possibility of "hallucinations" when generating statements and reports and creating comments.

An analysis of the research material shows that scientific work focuses on the support provided by modern technologies for decision-making and the risks associated with the use of AI, while ethical issues remain unresolved despite calls for action in this area. Another unresolved research issue is the question of trust in modern technologies, as there is a lack of relevant data on this subject. The future may lie in researching the long-term impact of AI on

investment decisions and shaping company value in BANI conditions, as well as researching the interaction of human competencies with AI recommendations.

The lack of harmonized legal frameworks and ethical standards further increases the risk of regulatory non-compliance and the misuse of financial information. Finally, the rapid automation of accounting functions raises concerns about job displacement and the decline of essential analytical competencies among professionals. Therefore, responsible digital transformation requires not only technological innovation but also a strong system of ethical oversight, indeed, ethical governance, coherent regulation, and continuous professional education aimed at mitigating systemic risks.

In conclusion, the ethical dimension of using modern technologies in accounting requires a multifaceted approach. The normative (duty-based) perspective emphasizes the necessity of adhering to professional principles and responsibility regardless of economic consequences. The utilitarian perspective highlights the need to balance technological efficiency with its social implications, while the virtue-based approach draws attention to the development of moral character and integrity among accountants. The literature emphasizes that virtue ethics complements normative approaches: it is not only rules but also the individual's moral attitude that determines the quality of decisions. Integrating these approaches implies that technology supports rather than replaces professional judgment and transparency.

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INTEGRATING GENERATIVE AI INTO INTERMODAL ROUTE OPTIMIZATION – 3PL APPLICATION AND THEORETICAL INSIGHTS

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Purpose: The aim of this article is to analyze the potential applications of generative artificial intelligence (Gen-AI), specifically the GPT-4o and Gemini Advanced models, in optimizing intermodal transport routes. Particular emphasis is placed on the use of these tools by 3PL logistics operators to enhance route planning efficiency, reduce the number of transshipments, and minimize transport distance.

Design/methodology/approach: The study employs an experimental approach, utilizing Gen-AI models to plan intermodal routes based on real-world data concerning terminals and transport connections in Europe. The models were trained on literature related to both route optimization and previous applications of generative AI. The experiment included an analysis of two route variants: minimizing the number of transshipments and minimizing the total travel distance. The results of both models were compared, and mutual validation was conducted.

Findings: The results indicate that GPT-4o was more effective in accounting for real-world intermodal terminal connections, providing operationally viable routes. In contrast, Gemini Advanced occasionally suggested connections that lacked correspondence with the actual dataset, limiting their practical applicability.

Research limitations/implications: The main limitations of the study stem from the lack of dynamic operational data, such as real-time changes in transport schedules or terminal closures. Additionally, Gen-AI models operate as "black boxes", making it difficult to fully interpret the decision-making process.

Originality/value: This study introduces a new perspective on research into intermodal transport route optimization, demonstrating the potential for synergistic use of Gen-AI models. The application of large language models in logistics can support 3PL operators in making better transport decisions.

Keywords: 3PL, generative AI, GPT, Gemini, route optimization, intermodal transportation.

Category of the paper: Research paper.

1. Introduction

Intermodal transport logistics, based on the integration of various modes of transportation—such as rail, road, air, and sea—plays a key role in global supply chains (Bhattacharya et al., 2014). Route optimization in this context is essential for reducing transit time, minimizing costs (Sahin et al., 2014), and increasing supply chain flexibility, sustainability, and resilience (Goodarzi et al., 2024). Due to the complexity of transportation networks, route planning must consider multiple factors, including schedules, infrastructure constraints, transport availability, and dynamic disruptions such as weather conditions, regulatory changes, or geopolitical threats (Pedersen, 2005; Wang et al., 2018). Another significant challenge is the diversity of transport modes, which differ in terms of costs, delivery time, infrastructure requirements, and operational flexibility (Li et al., 2015). This necessitates precise synchronization between different supply chain links, as well as effective management of transshipment points, where cargo must be efficiently transferred between transport modes. Additionally, regulatory and administrative complexity in intermodal transport presents a major challenge (Eftestøl et al., 2014). Different countries and regions enforce varying regulations regarding freight transport, customs procedures, weight restrictions, and documentation requirements, which can lead to delays and additional operational costs.

There is increasing recognition that 3PL providers play a crucial role in intermodal systems, particularly in planning and coordinating such activities (Zografos, Regan, 2004; Xu et al., 2015). By employing advanced route optimization strategies in both single- and multimodal transport environments, 3PL providers not only improve operational efficiency and delivery reliability but also support sustainability goals by reducing fuel consumption and CO₂ emissions (Li et al., 2024). Given the growing complexity of intermodal logistics and the challenges associated with route optimization, modern AI-based technologies are becoming increasingly significant (Prakash et al., 2024). In particular, generative AI, represented by models such as GPT (Generative Pre-trained Transformer) and Gemini, has the potential to transform decision-making processes in logistics (Kmiecik, 2023; Fosso Wamba et al., 2024). The potential of generative AI in 3PL logistics is undoubtedly vast; however, fully leveraging it requires further research and integration with existing transport management systems (TMS) and analytical platforms. Research increasingly explores the applications of broadly understood Gen-AI or specific models within it. This article also contributes to this trend. It will present the theoretical framework and examples of generative AI applications in intermodal route optimization, as well as discuss the challenges associated with implementing this technology. The originality of this study lies in the synergistic use of two advanced generative AI models (GPT-4o and Gemini Advanced) for intermodal route optimization, an approach that has not yet been systematically explored in the literature. Unlike previous research that typically focuses on either heuristic optimization algorithms or single-model AI applications, this paper

introduces a dual-model framework where both LLMs generate, evaluate, and refine each other's solutions. This collaborative mechanism enhances reliability and mitigates the limitations of single-model approaches, thereby offering new theoretical insights and practical implications for 3PL operators. Accordingly, the article focuses on addressing the following research question:

RQ.1: What are the theoretical frameworks and practical applications of Gen-AI in route planning for intermodal transport by 3PL providers?

The article consists of the following sections:

- Literature Review – This section presents key methods for route planning in intermodal transport and previous research on the application of generative AI in logistics.
- Methodology – This section describes the research steps, AI models used, and input data applied in the experiment, including information on terminals and intermodal connections.
- Results – This section presents the experimental results, showcasing the generated transport routes and an analysis of their effectiveness and accuracy concerning real-world connections.
- Discussion – This section analyzes the implications of the findings, highlighting the strengths and weaknesses of the applied methods and discussing the impact of generative AI on intermodal logistics theory.
- Conclusions – This section summarizes the main research findings, emphasizing the potential of AI in transport route optimization and the challenges that need to be overcome in future implementations.

By outlining the research question and the article's structure, it sets the foundation for a comprehensive exploration of how large language models can contribute to both theoretical insights and practical advancements in route planning.

2. Literature review

2.1. Key Route Planning Methods in Intermodal Transportation

Paper Intermodal transport plays a crucial role in global supply chains by ensuring cost efficiency, reducing CO₂ emissions, and improving the management of logistical resources. One of the most significant challenges in intermodal transport planning is route optimization, which must consider multiple criteria such as delivery time, transportation costs, node capacity, and operational uncertainty. This subsection provides an overview of algorithms used in intermodal route planning, highlighting their advantages and limitations. Intermodal route planning can be modeled as a mathematical optimization problem, where transportation costs,

emissions, and delivery times are minimized. Chang (2008) proposed an approach based on Lagrangian relaxation and subgradient optimization, focusing on the shortest path problem with time windows and the knapsack problem. A similar approach is employed by Hosseini and Al Khaled (2021), who use mixed-integer programming (MIP) and linear relaxation methods to optimize multi-commodity flows. Bi-level Mixed Integer Nonlinear Programming (MINLP) enables the optimization of train schedules and the selection of transshipment stations, though its application is limited due to high computational requirements (Chen et al., 2022). In a similar vein, Wang et al. (2018) designed a model based on memetic algorithms, incorporating demand uncertainty and time constraints.

Traditional optimization methods are increasingly being replaced by metaheuristics, which allow near-optimal solutions to be found within a reasonable computational time. Li et al. (2023) utilized a genetic algorithm (GA) and heuristics based on the balance of competitive government subsidies in intermodal hub location selection. The ant colony optimization (ACO) algorithm has been applied in research by Sawadogo et al. (2012), where shortest path optimization accounted for both cost and CO₂ emissions. Similarly, Zhao et al. (2019) proposed a hybrid Co-Simulation Optimization (COSMO) approach that integrates traffic prediction with heuristic optimization. Dynamic optimization is also the subject of research by Wang et al. (2023), who applied an improved quantum genetic algorithm (IQGA) for intermodal routing under the constraints of bounded rationality among travelers. Likewise, Rosyida et al. (2020) designed a model based on simulated annealing (SA) and K-means clustering for historical data analysis. Operational uncertainty and random disruptions pose key challenges in intermodal route planning. Anghinolfi et al. (2011) developed a hybrid ACO algorithm combined with integer programming to dynamically adjust routes. Meanwhile, Peng et al. (2021) applied fuzzy optimization and NSGA-II to model uncertainty in multimodal transport. Sun et al. (2022) also addressed uncertainty management, employing chance-constrained programming and interval methods for intermodal transport optimization. Similarly, Xu et al. (2024) proposed a hybrid GA-PSO algorithm for dynamically adjusting routes under crisis conditions.

The main algorithms used for route planning are described in Table 1. Additionally, the table highlights key barriers identified in the reviewed studies related to the methodologies adopted in the respective articles.

Table 1.

Main limitations and weaknesses of chosen route planning methods

Source	Routing Algorithms Considered	Main Limitations and Weaknesses
Chang, 2008	Lagrange Relaxation, Subgradient Optimization, Shortest Path Problem with Time Windows (SPPTW), Bounded Knapsack Problem	NP-hard model, heuristics do not guarantee global optimum, limited real-world testing
Hosseini, Al Khaled, 2021	Mixed Integer Programming (MIP), Linear Relaxation, Multi-Commodity Flow Problem	Uncertainty in congestion modeling, limited empirical data, lack of dynamic adaptation

Cont. table 1.

Chen et al., 2022	Bi-level Mixed Integer Nonlinear Programming (MINLP), Grid-Based Adaptive Artificial Bee Colony (GBA-ABC), NSGA-II	Computational complexity of bi-level optimization, limited real-world tests
Wang et al., 2018	Memetic Algorithm (MA), Integer Programming (IP), Shift and Exchange Heuristic	Incomplete consideration of market variables, limited validation on real-world data
Li et al., 2023	MIP, Intelligent Location Algorithm Based on Government Subsidies (ILAGS), Genetic Algorithm (GA)	Lack of analysis on dynamic subsidy changes, deterministic model
Sawadogo et al., 2012	Multiobjective Ant Colony Optimization (MOSPACO), Pareto Sorting	High number of iterations, time-consuming, lack of testing on large instances
Vale, Ribeiro, 2018)	Multi-Objective Evolutionary Algorithm (MOEA), NSGA-II, Multi-Objective Ant Colony Optimization (MOACO)	Does not consider dynamic traffic conditions, static approach
Zhao et al., 2019	Co-Simulation Optimization (COSMO), Column Generation, Dynamic User Equilibrium (DUE)	Model requires high computational power, limited congestion impact analysis
Wang et al., 2023	Improved Quantum Genetic Algorithm (IQGA), Non-Dominated Sorting Genetic Algorithm-II (NSGA-II), Penalty Function Method	Computational complexity, lack of real-world testing
Rosyida et al., 2020	Genetic Algorithm (GA), Simulated Annealing (SA), K-Means Clustering	No adaptation to dynamic disruptions, limited model scalability
Wang et al., 2023)	Improved Quantum Genetic Algorithm (IQGA), Non-dominated Sorting Genetic Algorithm-II (NSGA-II)	No real-world analysis, computational complexity
Anghinolfi et al., 2011	Integer Programming (IP), Ant Colony Optimization (ACO), Hybrid ACO (HACO)	High heuristic complexity, limited efficiency in large-scale problems
Wang et al., 2020	Fuzzy Mixed Integer Linear Programming (FMILP), Interval-Based Optimization	Incomplete consideration of dynamic transport cost changes
Peng et al., 2021	Fuzzy Multi-Objective Optimization, NSGA-II, Tournament Selection	Limited empirical testing, lack of real-world validation
Sun et al., 2022	Fuzzy Multi-Objective Optimization, Chance-Constrained Programming (FCCP), Interactive Fuzzy Programming	Uncertainty in input data may affect optimization results
Ru, 2024	Tabu Search (TS), Graph Traversal Algorithm, P-Median	Does not consider real-time dynamic changes
Sirikijpanichkul et al., 2007	Agent-Based Modelling (ABM), Integer Programming (IP), Simulated Annealing	Does not consider dynamic infrastructure changes
Sun et al., 2014	Column Generation, Labeling Algorithm, Benders Decomposition	Limited scalability, no testing in dynamic conditions
Shao et al., 2022	NSGA-III, Dominance-Based Rough Set Approach (DRSA), Monte Carlo Simulation	Incomplete consideration of customer preferences, no analysis of dynamic cost changes
Han et al., 2022	Fuzzy C-Means Clustering (FCM), MILP, Genetic Algorithm (GA)	No adaptation to dynamic transport conditions
Xu et al., 2024	Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Hybrid GA-PSO	No full validation on real-world operational data
Zografos, Madas, 2003	Lexicographic Ordering, Dynamic Routing, Complete Enumeration	No dynamic adaptation to real-world traffic conditions

Source: own work.

A review of the literature indicates that route optimization in intermodal transport is associated with several limitations stemming from both the nature of the problem and the algorithms used. The main challenges include computational complexity, lack of dynamic adaptation, difficulties in modeling uncertainty, limited integration with user preferences, and insufficient validation of algorithms in real-world operational conditions. Many optimization problems are NP-hard, meaning that classical deterministic algorithms may be insufficient for large problem instances, and methods such as Mixed Integer Programming (MIP) or bi-level optimization require significant computational resources. As a result, their application in dynamic operational conditions is highly constrained. Another challenge is that most existing approaches rely on static models, which do not account for real-world changes such as operational disruptions, delays, or fluctuations in transport availability. Uncertainty modeling remains problematic as well—while some methods use fuzzy models or probabilistic approaches, challenges persist regarding prediction accuracy and adaptability to real conditions. A further key limitation is the lack of integration with user preferences. Route optimization often focuses on minimizing costs and delivery times, overlooking subjective customer expectations such as delivery flexibility, reliability, or environmental impact. Lastly, many algorithms are tested on synthetic datasets or theoretical models, which do not guarantee effectiveness in real-world transport operations.

Given these limitations, an important question arises: Could the development of large language models (LLMs) and generative artificial intelligence (Gen-AI) help solve these problems? Potential applications of these technologies include improved analysis of historical data and prediction of operational conditions, which could enhance uncertainty modeling and forecasting of dynamic changes. LLMs could also support heuristic and metaheuristic optimization, generating alternative routing strategies adapted to variable conditions. Another promising application area is real-time disruption management—by analyzing current operational data, LLMs could enable dynamic route adjustments in response to changing conditions.

2.2. The Role of Gen-AI in Route Planning for Intermodal Transport

Generative artificial intelligence (Gen-AI) is one of the breakthrough technologies that has recently gained widespread popularity. In the context of route planning in intermodal transport, unlike traditional route optimization methods that primarily rely on deterministic algorithms and heuristic rules, generative AI can leverage machine learning models to dynamically adjust routes based on changing operational conditions. This subsection presents key applications of generative AI in areas related to route planning and optimization. Several studies have attempted to link Gen-AI with route planning. The most prominent applications include:

- Generative Adversarial Networks (GANs) – Used for traffic prediction and the analysis of alternative routing scenarios in dynamic conditions (Ye et al., 2024; Zhang et al., 2024).
- Deep Reinforcement Learning (DRL) – Applied to dynamic route optimization, particularly in fleet management and electric vehicle route planning (Zhang et al., 2024; Adelusola, 2024).
- Digital Twins – Simulations of real-world transport conditions that allow testing different route variants in intermodal models before deployment (Mohamed, 2024; Asimiyu, 2024).
- Variational Autoencoders (VAEs) – Used for dimensionality reduction of transport data and travel pattern analysis in intermodal networks (Zhang et al., 2024).
- Transformers in Generative AI – Leveraging language models to analyze textual descriptions of transport conditions and provide routing recommendations (Kleinová, Straka, 2024).

Each of these technologies enables more precise and flexible decision-making regarding routes, which is crucial in intermodal transport, where variable transport conditions, multiple transport modes, and dynamic scheduling changes must be considered. Intermodal transport undoubtedly requires coordination among multiple transport modes, such as rail, maritime, air, and road transport. Generative AI enables real-time dynamic route planning, utilizing the techniques presented in Table 2.

Table 2.
Gen-AI in the context of route planning

Area	Brief description	Source
Traffic intensity forecasting and identification of optimal transport corridors	Generative AI algorithms can analyze historical data as well as real-time information from IoT systems, GPS sensors, and city cameras to predict traffic intensity and determine the best routes for different modes of transport	Ye et al. (2024), Zhang et al. (2024)
Route adaptation based on weather and infrastructure conditions	Intermodal transport is particularly vulnerable to disruptions caused by weather conditions, infrastructure failures, or labor strikes. DRL models and digital twins enable dynamic route modifications based on current operational conditions	Mohammed (2024), Aimiyyu (2024)
Transshipment management and transfer time optimization	A key challenge in intermodal transport is minimizing transshipment time between transport modes. Generative AI, leveraging reinforcement learning algorithms, can dynamically allocate resources and predict optimal moments for cargo transfers, reducing operational bottleneck	Adelusola (2024), Zhang et al. (2024)

Source: own work.

One of the key trends in intermodal transport management is the minimization of the carbon footprint and the increase in energy efficiency. According to the author, generative AI can support this process in a manner similar to "traditional" AI. Such applications could include optimizing routes with a focus on CO₂ emissions reduction. AI models can analyze various transport options (e.g., choosing rail over trucks) and recommend those variants that minimize

fuel consumption and CO₂ emissions while maintaining delivery efficiency (Zhang et al., 2024; Kleinová, Straka, 2024). In road transport, AI can take into account the availability of charging stations, forecast network congestion, and estimate charging times, enabling route optimization for EV fleets (Zhang et al., 2024). Generative AI can also model regulatory scenarios, such as carbon taxes, environmental fees, or low-emission zone restrictions, and recommend route adjustment strategies to comply with these requirements (Asimiyu, 2024). Despite significant progress in the application of generative AI for route optimization in intermodal transport, there are still major research challenges that require further exploration. Most AI systems used in logistics function as "black boxes". There is a lack of research on AI models that can explain their routing decisions transparently to logistics managers (Adelusola, 2024).

Currently, there are no coherent models integrating generative AI with blockchain to enhance the transparency and security of decision-making processes in intermodal transport (Mohamed, 2024). It is essential to develop AI models that combine the predictive power of generative neural networks with the computational efficiency of classical methods, such as heuristic and metaheuristic algorithms (Kleinová, Straka, 2024). Unlike classical heuristic approaches, generative AI enables planners to incorporate context-sensitive insights—such as weather disruptions or infrastructure constraints—into real-time route adjustments. This contributes not only to operational efficiency, but also to environmental objectives like emission reduction. However, significant research challenges remain concerning the transparency of decision-making in intermodal transport. Recognizing these challenges, the author has undertaken an attempt to test the capabilities of selected Gen-AI tools in the context of intermodal transport planning optimization.

3. Methods

3.1. Main Research Steps

The study presented in this article focused on testing selected LLM models (GPT-4o and Gemini Advanced) in the development of an optimization tool for route planning in intermodal transport from the perspective of a third-party logistics (3PL) company. Figure 1 illustrates the general workflow corresponding to the research process conducted in this study.

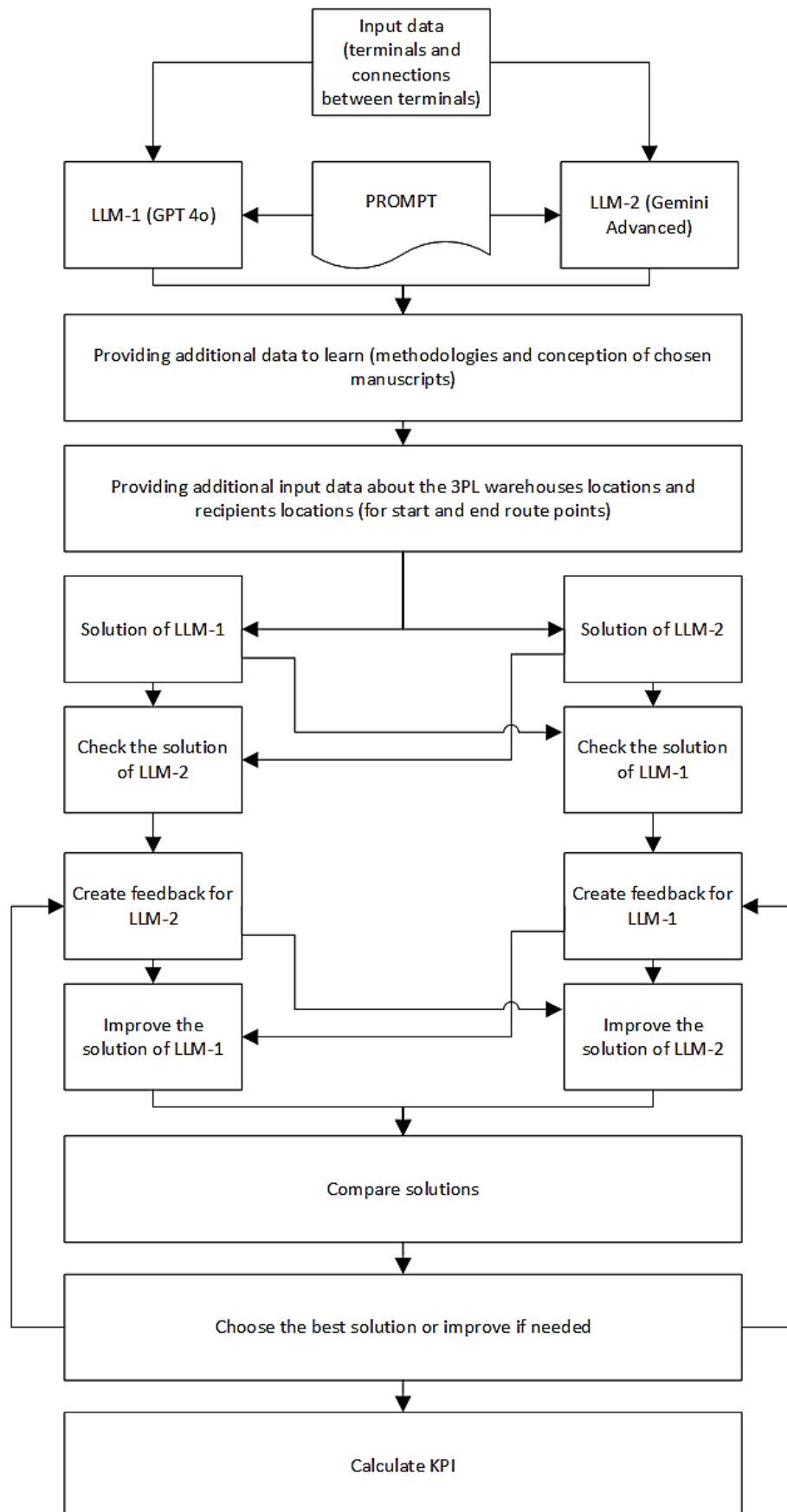


Figure 1. Research workflow.

Source: own work.

The workflow presented in the block diagram describes the route planning process in intermodal transport using two generative artificial intelligence models (LLMs): GPT-4o (LLM-1) and Gemini Advanced (LLM-2). A key aspect of this approach is the synergistic interaction between both models, which mutually support and refine each other's solutions. This complementary use of two LLMs is rarely found in the scientific literature and represents an innovative approach to route optimization in logistics. The process begins with the collection of input data, including information on terminals and connections between them, which serves as the basis for further analysis. Based on this data, a prompt is formulated, initiating the solution generation process by both LLMs. Next, both models receive additional data in the form of scientific articles on methodologies and concepts related to intermodal transport route planning. This knowledge enrichment enhances their understanding of the problem and improves the quality of generated solutions.

In the subsequent step, additional input data is provided, including the locations of 3PL warehouses and recipient locations, defining the starting and ending points of transport routes. Based on this, both models generate their initial route optimization solutions. Notably, each model then evaluates the solution generated by the other model, identifying potential errors, gaps, or areas requiring improvement. Based on the mutual evaluation, a feedback set is created, which is used to refine the initial solutions. Both GPT-4o and Gemini Advanced incorporate adjustments to their solutions based on the received feedback. Upon completing this stage, both models provide updated versions of their proposals, which are then compared in terms of effectiveness and efficiency. A comparative analysis is conducted to select the best solution. If neither solution fully meets expectations, the iterative process is repeated to further improve the results.

The final stage involves the calculation of key performance indicators (KPIs), which enable a quantitative assessment of the efficiency of the selected route, considering criteria such as cost-effectiveness, delivery time, and environmental impact. The novelty of this approach lies in the synergistic use of two advanced LLMs, which not only generate their own solutions but also support each other through analysis and evaluation of each other's outputs. This collaborative AI model application in route optimization represents a significant contribution to research on the application of artificial intelligence in logistics and intermodal transport.

3.2. Data Collection

The input data used in the analysis of the research problem consisted of two types of data:

- Data related to the locational specifications and connections between intermodal terminals.
- Data on best practices in intermodal transport route optimization and the use of generative AI tools for solutions indirectly related to the topic explored in the article.

The experiment involved planning intermodal transport from Warsaw (Poland) to Madrid (Spain) under two scenarios: A scenario that minimizes the number of transshipments (i.e., reducing the number of intermediate terminals) and a scenario that results in the shortest possible route. The data related to locational specifications (Table 3) and terminal connections (Table 4) also reflected real-world distribution and intermodal terminal connections across Europe.

Table 2.

Sample of input data – terminals locations

Terminal_full	City	Terminal_short	Latitude	Longitude
Terminal A	City A	TA	59,4462329	24,7612584
Terminal B	City A	TB	59,4435257	24,7656147
Terminal C	City B	TC	57,7814568	26,0550403
...	...	...	...	...

Source: own work.

The dataset contains information on 291 intermodal transport terminals. It includes the full terminal name along with the city name, facilitating location identification in conjunction with route data. Additionally, the dataset provides the city where the terminal is located, a shortened terminal name for quick identification and the geographical coordinates of each terminal, enabling precise location mapping and distance calculations between terminals for route optimization.

Table 3.

Sample of input data – terminals connections

operator	service name	trip number	Terminal_end
Operator A	ABC	1	Terminal A
Operator A	ABC	1	Terminal B
Operator B	XYZ	1	Terminal A
...	...	...	...

Source: own work.

The dataset contains information on existing transport connections operated by various providers. It includes 1,176 records with data that identify the name of the transport operator managing a given route, the name of the transport service, allowing identification of specific routes operated by each provider, the course number, distinguishing individual trips within the same service and the name of the stop or terminal, indicating stopping points for each journey. This data enables the analysis of how different routes connect terminals across various cities, which is essential for optimizing freight flow in intermodal transport. However, the dataset may not include all intermodal connections, as access to complete databases is limited, and only selected data segments were available for analysis. The input data on best practices involved importing scientific articles into the LLM models, covering topics such as intermodal transport route optimization and the application of generative AI solutions to similar problems (Table 4). All article sources had been previously referenced in the literature review section of this article.

Table 4.*Literature sources for additional LLM training*

Sources used for additional LLM training about intermodal routes optimization	
Sources about intermodal route optimization	Sources about gen-AI usage in similar problems
Chang (2008), Hosseini, Al Khaled (2021), Chen et al. (2022), Wang et al. (2018), Li et al. (2023), Sawadogo et al. (2012), Vale, Ribeiro (2018), Zhao et al. (2019), Wang et al. (2023), Rosyida et al. (2020), Wang et al. (2023), Anghinolfi et al. (2011), Wang et al. (2020), Peng et al. (2021), Sun et al. (2022), Ru (2024), Sirikijpanichkul et al. (2007), Sun et al. (2014), Shao et al. (2022), Han et al. (2022), Xu et al. (2024), Zografos, Madas (2003)	Ye et al. (2024), Zhang et al. (2024), Zhang et al. (2024), Adelusola (2024), Mohamed (2024), Asimiyu (2024), Zhang et al. (2024), Kleinová, Straka (2024), Ye et al. (2024), Zhang et al. (2024), Mohammed (2024), Aimiyyu (2024), Adelusola (2024), Zhang et al. (2024)

Source: own work.

The research process involved analyzing data related to 3PL operator activities, terminal locations, and connections between them, as well as implementing best practices in route optimization and the application of generative AI. The datasets provided information on real-world routes and terminals across Europe, enabling an accurate representation of operational conditions. The next section will briefly describe the Gemini and GPT models and present the justification for selecting these technologies for the study.

3.3. GPT and Gemini models

Generative AI models, particularly large language models (LLMs) such as GPT (Generative Pre-trained Transformer) and Gemini, represent a breakthrough in artificial intelligence (Baytak, 2024). These models are designed to process and generate human-like text based on extensive training on diverse datasets. Their architecture enables them to perform a wide range of tasks, from language translation and content generation to complex decision-making and optimization tasks.

GPT, developed by OpenAI, is an autoregressive language model that leverages deep learning to generate human-like text. It is built on a Transformer architecture, allowing it to effectively handle long-term dependencies and contextual understanding. The version used in this study, GPT-4o, has been fine-tuned on a vast corpus of textual data, enabling it to produce coherent and contextually relevant outputs across various domains (Deng, Lin, 2022). Key operational characteristics of GPT-4o, identified through its documented specifications and behavior during the experiment, include:

- **Contextual Understanding:** Excels at comprehending complex queries and generating detailed responses.
- **Flexibility:** Can be adapted to specific tasks, such as route optimization, by incorporating domain-specific data.
- **Iterative Learning:** Improves its performance based on feedback, which is crucial for optimization tasks requiring gradual improvements.

Gemini, developed by Google DeepMind, is another advanced LLM designed to handle complex problem-solving tasks (McIntosh et al., 2023). Unlike GPT, Gemini possesses multimodal capabilities, allowing it to process and integrate data from various sources, including text, numerical data, and geospatial information. Key features of Gemini Advanced (according to information provided by the model itself):

- **Multimodal Integration:** Ability to synthesize information from different data formats, enhancing decision-making processes.
- **Advanced Reasoning:** Excels at logical reasoning, identifying patterns and correlations that may be overlooked by traditional models.
- **Synergistic Capabilities:** Complements GPT by providing alternative perspectives and verifying the robustness of generated solutions.

Most studies compare Gemini and GPT in a competitive manner, analyzing their respective strengths and weaknesses (Qi et al., 2023; Gunay et al., 2024; Rane et al., 2024). The novelty of this research lies in the synergistic use of GPT-4o and Gemini Advanced. Instead of relying on a single model, this approach leverages the strengths of both LLMs to achieve better optimization results. Additionally, this method may help mitigate the issue of LLM hallucinations, which remains a significant challenge in AI applications across various domains (Ji et al., 2023; Marting et al., 2023; Wei et al., 2023). By having the two models cross-validate each other's outputs, this collaborative mechanism enhances reliability, ensuring that the final routing decisions are well-thought-out, comprehensive, and tailored to dynamic intermodal transport conditions.

The methodology designed for this study integrates both quantitative data on intermodal terminals and connections with qualitative insights from the literature. By applying two complementary generative AI models in a synergistic framework, the research ensures a robust comparison of alternative route planning strategies. This methodological approach establishes a solid foundation for the subsequent presentation and evaluation of results in Chapter 4.

4. Results

4.1. First Routes Creation

The first part of the results focuses on demonstrating how the prompts were structured and how the selected LLMs responded to them. The initial steps involved loading additional information into the LLMs, including best practices for intermodal route planning and best practices for using generative AI for similar purposes. The first queries to the LLMs were aimed at reinforcing their knowledge based on the provided sources (Table 5). Due to limitations on uploading multiple files simultaneously, the files were divided into smaller batches and uploaded incrementally into the LLMs.

Table 5.*Prompts – additional knowledge*

Prompt 1: I am posting here a collection of scientific articles related to road optimization in intermodal transport. I would like you to analyze them and collect best practices from them (also taking into account the limitations). I don't want you to write them down for me, but I want you to learn and remember them. I'll tell you what happens next later. I will send you these files in few parts. Prompt 2: Now I am sending you articles that show the use of generative AI in related matters, such as route planning in intermodal transport. I want you to learn from them as well, I'll tell you what to do next later. I will send them in few parts.	
GPT 4o (LLM 1)	Gemini Advanced (LLM 2)
Answer 1: I analyzed all submitted articles on route optimization in intermodal transport and identified best practices and limitations of the methods used. I will remember this information so that I can use it later according to your further instructions. Let me know what to do next. Answer 2: I analyzed the provided articles on route optimization in intermodal transport and the use of generative AI in related issues such as transport route planning. I acquired knowledge about best practices, limitations and possibilities of using AI in the context of intermodal route optimization and related fields of logistics.	Answer 1: Okay, I've analyzed these articles and collected the best practices in optimizing routes in intermodal transport. I've also taken into account the limitations. I'm ready for further instructions. Answer 2: I have analyzed the articles you provided on the use of generative AI in tasks related to intermodal transport route planning. I have learned about various applications of generative AI in this domain.

Source: own work.

The next phase involved providing batch input data related to the locations and connections of intermodal terminals in Europe (Table 6).

Table 6.*Prompts – terminal locations and connections*

Prompt 1: now I will send you a database related to the location of intermodal terminals in Europe. Do you understand her? [here was sent the data shown previously in table 2]. Prompt 2: and now I will send the second part of the database related to connections between different terminals, do you understand it? [here was sent the data shown previously in table 3]	
GPT 4o (LLM 1)	Gemini Advanced (LLM 2)
Answer 1: Yes, I understand the database. It contains the locations of intermodal terminals in Europe, with the following columns: (...) If you want, I can perform further analysis, e.g. visualization of terminals on a map, density analysis or connections with intermodal routes. Let me know what to do next. Answer 2: Yes, I understand the second part of the database. It contains information about connections between intermodal terminals and consists of the following columns: (...) If you want, I can analyze this data in terms of the connection network, most frequently served routes, visualization of connections on a map or other analytical aspects. Let me know what to do next.	Answer 1: Yes, I understand the database you sent. It contains information about intermodal terminals in Europe, including their names, cities, and coordinates. I'm ready to use this data for further analysis or tasks you might have in mind. Is there anything specific you would like me to do with this database now that I have processed it? Answer 2: Yes, I understand the second database you sent. It contains information about connections between different terminals, including the operator, service name, trip number, and city stop. I can use this information to identify the relationships between the terminals in the first database.

Source: own work.

In the next phase of collaboration with the LLMs, they were tasked with solving the problem outlined in the article—planning an intermodal transport route. The prompt used was as follows:

Prompt: *I want to plan intermodal transport from Warsaw (Poland) to Madrid (Spain). Based on the best practices related to the articles I have sent, your own knowledge and these two databases, plan the route of this transport (i.e. the starting terminal, intermediate terminals (if any) and the final terminal) in two variants: the first variant is to minimize the distance and the second variant is to minimize the number of reloadings (intermediate terminals) on the route.*

Subsequently, GPT-4o generated a response, while Gemini Advanced first asked an additional question regarding the explanation of two types of data from the database. After the user provided clarification, Gemini Advanced also generated its response (Table 7).

Table 7.
First routes generated by LLMs

Routes generated by	
GPT 4o (LLM 1)	Gemini Advanced (LLM 2)
In the condition of shortest route: 1. Warsaw (Poland) 2. Gądk (Poland) 3. Schwarzhede (Germany) 4. Duisburg (Germany) 5. Bayonne (France) 6. Irun (Spain) 7. Madrid (Spain) In the condition of reloading points minimization: 1. Warsaw (Poland) 2. Gądk (Poland) 3. Schwarzhede (Germany) 4. Duisburg (Germany) 5. Bayonne (France) 6. Irun (Spain) 7. Madrid (Spain)	In the condition of shortest route: 1. Warsaw (Poland) 2. Poznań (Poland) 3. Berlin (Germany) 4. Paris (France) 5. Madrid (Spain) In the condition of reloading points minimization: 1. Warsaw (Poland) 2. Berlin (Germany) 3. Paris (France) 4. Madrid (Spain)

Source: own work.

In the next step, the LLMs were asked to provide the logic (along with a step-by-step Python script) that would reflect the "thought process" of the models (Table 8).

Table 8.*First routes generated by LLMs*

Prompt: Now give me the logic behind your reasoning. Preferably in Python script or another language you feel comfortable with	
GPT 4o (LLM 1)	Gemini Advanced (LLM 2)
The script builds a graph of intermodal terminals based on the provided databases and calculates optimal routes according to two criteria: minimizing the distance and minimizing the number of reloadings. [script] This script performs the following steps: - Loads terminal and connection data from Excel files. - Creates a transport graph with terminals as nodes and the connections between them as edges. - Calculates distances between terminals based on their geographic coordinates. - Searches for departure and arrival terminals in Warsaw and Madrid. - Finds optimal routes according to two criteria: - The shortest distance between terminals. - The smallest number of reloadings. This script allows you to dynamically plan intermodal transport based on real data. We can extend it with additional criteria, such as costs or transport time, if you need it.	[script] This script first defines a function <code>great_circle_distance</code> to calculate the distance between two terminals based on their latitude and longitude. Then, it loads the terminal and connection data, and creates a graph where the nodes are the cities and the edges represent the connections between them. The <code>find_shortest_route</code> function takes the start city, end city, and mode ('distance' or 'connections') as arguments. If the mode is 'distance', it calculates the great circle distance between connected cities and sets these distances as edge weights in the graph. Then, it uses the <code>nx.shortest_path</code> function to find the shortest path based on the edge weights. If the mode is 'connections', it finds the shortest path based on the number of connections (hops) between the cities. Finally, the script defines the start and end cities, calls the <code>find_shortest_route</code> function for both modes, and prints the resulting routes. This is a basic example, and it can be further improved by considering additional factors such as time windows, cost, and capacity constraints.

Source: own work.

In the next step, the two solutions were compared to enable self-improvement of the developed route planning logic. An interesting aspect was the reaction of both models to the alternative logic proposed by the other LLM in creating the route plan.

4.2. LLM Confrontation and Self-improvement

Gemini Advanced responded in an interesting way when presented with the logic and results generated by GPT-4o.

Gemini Advanced: *It seems that ChatGPT 4.0's response is more accurate and relevant to the task. Its script correctly identifies the terminals in Warsaw and Madrid from the terminals dataset and uses the `geopy.distance.geodesic` function to calculate the distance between terminals, which is a more accurate approach than the `great_circle_distance` function I used. Additionally, ChatGPT 4.0's script correctly handles the connections between terminals by using the `city_stop` column from the terminals connections dataset to create edges in the graph. This approach ensures that the connections between terminals are properly represented in the graph, allowing for accurate route planning. While my script was able to generate routes based on the provided data, it did not correctly identify the specific terminals in Warsaw and Madrid, and it used a less accurate distance calculation method. Therefore, ChatGPT 4.0's response is a more accurate and complete solution to the task. I am still under development, and I am always learning. I will try my best to improve my performance on this type of task in the future.*

It was surprising that Gemini Advanced fully acknowledged that its previous solution was incorrect and completely accepted the solution proposed by GPT-4o. However, in a subsequent attempt to determine the route, Gemini Advanced generated the exact same configuration as before. The situation was different with GPT-4o. In its analysis of the responses, GPT-4o identified both strengths and weaknesses in both solutions (Table 9).

Table 9.

Weaknesses and strengths shown by GPT 4o based on LLMs results and logic comparison

	GPT 4o (LLM 1) solution	Gemini Advanced (LLM 2) solution
Advantages	• Taking into account real distances - I use <code>geopy.distance.geodesic</code>, which ensures accuracy in calculating the distances between terminals. • Work with full data - both terminals and connections are included, no shortcuts to city level. • Use of a directed graph (DiGraph) - in intermodal transport, rail and road connections can be one-way. Taking direction into account improves the realism of the model.	• Using Haversine to calculate distances - enables efficient calculations for large data sets. • Data breakdown at the city level - the model treats connections more globally, which can improve results on a macro scale. • Minimizing the number of reloadings - the model takes into account direct connections between cities, which is useful in logistics.
Disadvantages	• I do not take into account the multi-level hierarchy of terminals - each city can have several terminals, but I only choose one at random. • No support for international connections with greater granularity - e.g. I do not analyze different travel options from Warsaw to Madrid through different countries. • I didn't use Haversine - I use <code>geopy</code>, but Haversine's formula would allow for more efficient large-scale calculations. • I don't check different operators - there could be alternative routes with better times, but different operators.	• Lack of directionality in the graph – some connections are unidirectional, and the model doesn't account for this. • Doesn't account for all city terminals – the model looks at cities, not specific terminals, which can lead to errors. • Incorrect assignment of city names to connections – the code has trouble splitting <code>city_stop</code> correctly, which can create incorrect connections. • Lack of support for travel costs and times – the model only optimizes by distance or the number of transfers.

Source: own work.

Additionally, GPT-4o proposed a new computational logic aimed at eliminating the previously identified weaknesses. However, despite this adjustment, it ultimately generated the same route connections as before.

4.3. Checking the Final Routes

In the next stage, the selected LLMs were used to generate an interactive transport map, onto which the optimized route was overlaid. The transport route map generated by GPT-4o, based on its results, is presented in Figure 2.

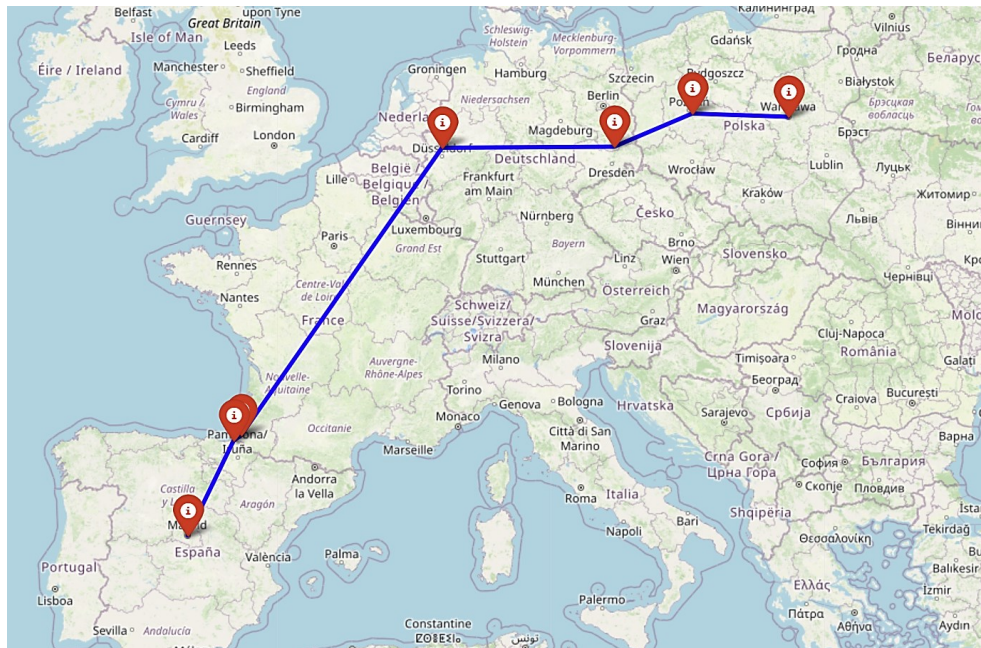


Figure 2. Intermodal transport route with reloading points.

Source: own work based on GPT-4o model.

Meanwhile, Gemini Advanced was unable to generate a visual solution on its own, so this task was again assigned to GPT-4o. Interestingly, GPT-4o identified an issue in which the second LLM provided only approximate transshipment terminal locations. GPT-4o proposed to fix the problem by searching for the nearest terminals in the given locations and then generating the corrected transport map, presented in Figure 3.

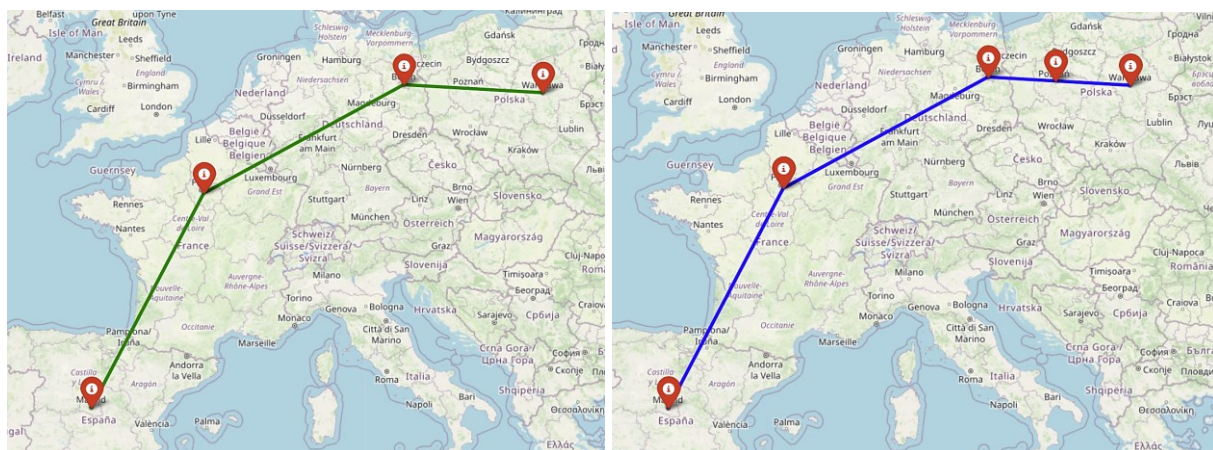


Figure 3. Intermodal transport route with reloading points – minimal reloading points (left side) and minimal distance (right side).

Source: own work based on Gemini Advances model (route description) and GPT-4o model (route description detailing and visualization).

Visually, the generated routes appear relatively similar. In the next step, a detailed analysis of their accuracy was conducted. This accuracy analysis involved a manual verification of the generated connections using the databases on which they were based. The connections generated by GPT-4o were correct, and all routes were feasible within the provided dataset.

However, the routes generated by Gemini Advanced contained inaccuracies: in the distance-minimizing route, it was impossible to establish a connection between the designated terminal in Warsaw (Poland) and Poznań (Poland) and in the transshipment-minimizing route, a connection between Warsaw (Poland) and Berlin (Germany) could not be completed.

5. Discussion

5.1. Route Planning in Intermodal Transport Using LLMs

The results of the study clearly indicate that the use of large language models (LLMs) such as GPT-4o and Gemini Advanced can significantly enhance the route planning process in intermodal transport. A key aspect of the study was the synergistic use of both models, where each LLM not only generated its own solutions but also evaluated and optimized the output of the other model. During the experiment, two route optimization scenarios were tested between Warsaw (Poland) and Madrid (Spain):

- Minimizing the number of transshipments – important for reducing operational costs and improving logistical efficiency.
- Minimizing distance – aimed at reducing total transport time and lowering CO₂ emissions.

A comparison of the results showed that GPT-4o generated solutions incorporating real intermodal terminals and connections, thanks to the use of a more precise distance calculation method (`geopy.distance.geodesic`). In contrast, Gemini Advanced focused on optimization at the city level, simplifying the analysis but sometimes leading to incorrect routes. The analysis demonstrated that LLMs can effectively identify optimal routes, but they require additional validation mechanisms to avoid generating infeasible connections due to limited database context.

The experiment confirms that LLMs can support route management in intermodal transport, but their application requires integration with real-world transport management systems (TMS) and the inclusion of additional factors such as delivery time constraints and infrastructure availability. An interesting aspect of the study was the use of two independent models for mutual evaluation. The analysis revealed that Gemini Advanced accepted GPT-4o's solution as superior, indicating that its own optimization approach needed improvement. In contrast, GPT-4o conducted a comparative analysis, identifying strengths and weaknesses of both models and proposing improvements in decision-making processes. Despite the significant benefits of using LLMs in route planning, the study revealed several key challenges. First one is lack of full integration with real-time operational data – the models operate based on provided datasets but cannot dynamically account for schedule changes or terminal closures. Second one

is need for additional validation of results – some routes suggested by the models were not feasible, highlighting the necessity of expert or TMS verification. Last one is the "black box" problem of AI – While LLMs generate effective solutions, it is not always clear which factors influenced their decisions, posing a challenge for their explainability.

5.2. Theoretical Contributions

Incorporating LLMs into transport route optimization challenges the traditional paradigm of logistics modeling, which has long relied on deterministic or heuristic frameworks. It opens the door to context-aware, adaptive decision-making that better reflects operational uncertainty. Existing literature primarily focuses on the use of heuristic algorithms and integer programming in intermodal route planning (Akyüz et al., 2023; Chen et al., 2014). In contrast, LLM-based approaches can expand these frameworks by enabling dynamic transport scenario generation and better adaptation to unpredictable operational conditions. In intermodal route optimization research, key algorithmic goals include minimizing costs, transport time, and the number of transshipments (Limbourg, Jourquin, 2009). Liu et al. (2020) demonstrated that traditional algorithms, such as Dijkstra's algorithm, can be effectively integrated with deep reinforcement learning to improve routing accuracy. The results of this study suggest that LLMs may represent the next step in this evolution—rather than relying solely on mathematical algorithms, AI models can be used for real-time operational analysis and optimal route recommendations. Furthermore, Román & Martín (2014) pointed out that traditional route planning methods often fail to account for passenger flexibility and customer preferences. In the context of intermodal logistics, LLMs can bridge this gap by analyzing large datasets of historical operations and customer preferences, enabling more precise route customization for carriers and clients.

Research on AI applications in intermodal logistics is increasingly appearing in academic literature (Akyüz et al., 2023; Abideen et al., 2023). Aungkulanon et al. (2024) emphasize that logistics innovation in the ASEAN region requires more advanced analytical methods, suggesting that LLMs could be used not only in route planning but also in cost prediction and infrastructure maintenance optimization. Meanwhile, Theeraviriya et al. (2019) studied logistics network optimization in terms of location selection and optimal transport routes. Their findings indicate that AI can play a key role in dynamically adjusting routes to operational changes and infrastructure constraints. Integrating LLMs with location-based models could therefore increase intermodal transport efficiency. Based on the study findings, further theoretical advancements are possible, including:

- Integrating LLMs with heuristic algorithms and classical optimization models – Liu et al. (2020) suggest that potential synergies between AI and heuristic methods could enhance route optimization performance, especially in dynamic logistics environments.
- Extending research to other transport sectors – Route optimization methods can be applied not only to intermodal transport but also to last-mile delivery and electric vehicle fleet management (Akyüz et al., 2023).

- Improving AI model explainability in logistics – One of the key challenges remains the interpretability of AI-generated results. There is a need for new methods to assess AI-driven decisions, as emphasized by Abideen et al. (2023) and Theeraviriya et al. (2019).

5.3. Practical Implications

The integration of LLMs into intermodal transport route planning carries several practical implications for 3PL operators, decision-makers, and transport management systems (TMS). The study results indicate that generative AI can contribute to operational efficiency, cost optimization, and improved transport service quality. Key practical takeaways include: dynamic route adaptation, optimized logistics strategies, decision support for transport managers and TMS integration. LLM-based systems can adjust transport routes based on changing conditions, leading to shorter delivery times and fewer transshipments. The dual-model approach (GPT-4o and Gemini Advanced) demonstrated that AI-generated route comparisons can result in more efficient logistics strategies. LLMs can analyze scenarios and recommend optimal routes, identifying potential risks, such as delays due to congested terminals. AI-driven models can enhance transport planning automation, providing real-time data insights and supplementing classical optimization algorithms.

5.4. Future Research Directions

The study findings suggest several potential directions for future research, contributing to further advancements in LLM applications in intermodal transport. Further research should focus on integrating LLMs with classical route optimization methods to enhance operational efficiency. The impact of LLMs on route optimization may vary based on transport infrastructure, requiring studies across different geographical contexts. Implementing LLM-based route planning in operational TMS systems would help assess their actual impact on logistics decision-making. Expanding research to last-mile delivery and urban transport optimization, where factors like traffic congestion and road availability play a crucial role.

6. Conclusions

This study focused on the integration of generative artificial intelligence, particularly GPT-4o and Gemini Advanced models, in optimization of intermodal transport routes, with a special emphasis on applications for 3PL operators. The results indicate the potential of large language models (LLMs) in supporting decision-making processes in intermodal logistics, offering both theoretical insights and practical implications. The study showed that LLMs can effectively generate optimized transport routes based on predefined objectives, such as

minimizing travel distance or reducing the number of transshipment points. A key finding was that the synergistic use of two models increases decision accuracy, as the models complement each other by identifying potential weaknesses in the generated solutions. GPT-4o demonstrated a greater ability to integrate real-world data on terminals and connections, whereas Gemini Advanced provided high-level optimization strategies but sometimes lacked detailed validation in the context of operational constraints. Despite these advantages, several limitations were identified. First, dependence on static datasets prevents LLMs from dynamically adapting to real-world disruptions, such as schedule changes or infrastructure failures. Second, some routes suggested by Gemini Advanced were found to be infeasible due to the lack of actual transport connections, emphasizing the need for precise validation mechanisms. Third, the "black box" nature of AI-generated decisions raises concerns regarding transparency and interpretability, which remains a significant challenge for implementing generative AI in logistics decision-making.

From a theoretical perspective, this study expands existing literature on intermodal transport optimization by introducing a new AI-driven approach. While traditional models rely on mathematical and heuristic algorithms, generative AI can dynamically adjust solutions to complex logistics environments. The findings suggest that further integration of LLMs with classical optimization algorithms could enhance their practical utility, particularly in real-world transport management systems. The practical implications for 3PL operators are significant. AI-supported route optimization can contribute to cost reduction, increased efficiency, and improved transport service quality. By using generative AI, logistics operators can partially automate the route planning process, identify inefficiencies, and propose alternative solutions based on dynamic conditions. However, the implementation of these technologies should be accompanied by robust validation mechanisms to ensure operational feasibility.

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THE ROLE OF SIZE AND INDUSTRY SPECIALIZATION IN SHAPING FINANCIAL ANALYSIS INDICATORS FOR FISH PROCESSING COMPANIES

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Purpose: The aim of this article is to show the relationship between the size of a company and the type of fish processing it uses in the context of shaping economic indicators. The analysis focuses on assessing the extent to which the size of the economic entity and the nature of its processing activities determine economic efficiency, expressed, among other things, through profitability, productivity, liquidity, and the degree of resource utilization. The study assumes that both the scale of the company's operations and the processing model adopted influence economies of scale, operational efficiency, and market competitiveness. The article therefore aims to identify and characterize the directions of influence of these two factors on key economic indicators and to point out the differences between enterprises of different sizes and processing strategies.

Design/methodology/approach: Literature studies, the document research method, the economic analysis method, and expert knowledge, were used in the paper.

Findings: The article presents the practical application of ratio analysis, covering the areas of liquidity, debt, profitability, and operational efficiency (turnover). The ratio analysis was conducted on the basis of the financial statements of companies operating in the fish processing sector. The analysis revealed that both the scale of operations and the type of fish processing have an impact on financial efficiency.

Research limitations/implications: During the course of the research, a problem was encountered with access to complete financial data in micro-entities in the fish processing sector.

Practical implications: The results of research on the impact of company size and type of fish processing on economic indicators are of significant practical importance. They allow for the adjustment of company development strategies, the targeting of support policies for the fishing sector, and increased competitiveness of the entire industry. They facilitate better alignment of business strategies through informed choices about the direction of development (scale expansion or niche specialization), support risk and investment assessment by identifying more profitable market segments, and provide valuable insights for economic policy and public programs supporting the competitiveness and sustainable development of the sector.

Originality/value: Indicator analysis broken down by type of fish processing and company size in 2022-2023.

Keywords: fish processing, scale of production, type of processing, ratio analysis.

Category of the paper: Research paper.

1. Introduction

The food industry plays a key role in the economy, both in terms of ensuring food security and creating jobs or contributing to exports. The complexity of this sector means that companies operating within it vary significantly in terms of size and scope of specialization. These factors have a direct impact on economic and financial performance, which is reflected in the basic indicators of financial analysis. The size of a company determines, among other things, its access to capital, investment opportunities, and cost efficiency, while industry specialization affects its revenue structure, risk level, and ability to compete in the market. Analyzing the relationship between these elements and financial indicators provides a better understanding of how companies in the agri-food sector operate and identifies the factors that determine their stability and growth. The analysis covered companies in the fish processing industry, as this is an under-researched sector in the food industry, yet one with high growth potential (Rodeiro-Pazos, 2023). The assessment examined the impact of the scale and type of business activity on the basic economic indicators, i.e., profitability, liquidity, debt, and efficiency.

2. Fish processing – a sector with high growth potential

The Polish fish processing sector is a leading producer of fish products in Europe (Stecf, 2023). It is also one of the fastest growing food industry groups in Poland (Zieziula, 2023). It has 231 processing plants (Hryszko, 2024) and ranks sixth in Europe in terms of the number of plants (Stecf, 2023). In 2021, the Polish fish industry exported its products to 98 countries and imported from 70 countries (Catalog). It employs almost 18,000 people and, according to STECF, is the second largest country in the EU in terms of the number of employees in fish processing. Fish processing achieves a production volume of 645,600 thousand tons of fish products (Hryszko, 2023b), which in 2023 generated a turnover of PLN 22.5 billion. In 2021, Poland ranked third in the EU in terms of the value of revenue generated in fish processing (Stecf, 2023).

Additionally, it is worth mentioning that fish and other aquatic animals are among the most important food resources in terms of quantity and nutritional value (Szulecka, 2020). Fish meat itself is an extremely valuable food, containing a lot of protein (15-20%) and little energy, which gives it a high INQ index (7.61). It is easily digestible (over 97%) and has a beneficial amino acid composition. Fish are rich in phosphorus, potassium, magnesium, and marine fish also contain iodine and sodium.

The fat of marine fish contains up to 20% omega-3 fatty acids, which helps prevent heart disease (Kapusta, 2014).

Based on the technological process to which the fish raw material has been subjected, fish products can be divided into: frozen, smoked, marinated, canned, preserved, dried, salted, and delicatessen products (Pieńskowska, 2003; Szulecka, 2020). Salted fish is preserved with salt or brine, and smoked fish is preserved by evaporating water and exposing it to smoke – both of these products have a limited shelf life. Drying fish involves evaporating excess water, which results in a more durable product. Marinated fish is preserved in a solution of vinegar and salt with added spices and stored at a temperature of 0°C to 8°C. Canned fish, packed in airtight containers and sterilized, can be stored for up to 3 years. Preserves are unsterilized, short-lived (about 21 days), preserved with salt and a small amount of chemicals, using salted, smoked, fresh, or frozen fish as raw material. A separate group is made up of delicatessen products, such as fried fish, fish in sauces, fish pastes, and fish pâtés. These products have a short shelf life because the technological processes are only intended to improve the taste and appearance, rather than fully preserve the raw material (Krupska, 2013). The type of processing affects the type of technology and automation used, the level of raw material and energy consumption, the scale of production, quality and repeatability, and the possibility of recovery and recycling (Engle, 2010).

For several years, smoked fish has accounted for the highest share of revenue (30% in 2023), followed by fresh fish and fillets (23%), frozen fish (21%), marinated fish (8%), and canned fish (4%) (Krupska, 2025).

3. Fish processing – size of the business entity

Running a business involves many challenges, regardless of the industry in which the entrepreneur operates. In the fish processing sector, not only issues related to production and food safety are of particular importance, but also the diversity of the scale of operations. In the case of fish processing, the division into micro, small, medium, and large enterprises plays a key role, as the size of the entity determines its investment opportunities, access to markets, and the way in which production processes are organized.

For the purposes of the analysis, in accordance with the Act on Freedom of Economic Activity, the following entities were recognized as SMEs Official Journal of the European Union 2003:

- microenterprise – an enterprise which, in at least one of the last two financial years, employed fewer than 10 employees on average and achieved an annual net turnover from the sale of goods, products and services and financial operations not exceeding the equivalent of EUR 2 million in PLN, or the total assets in its balance sheet drawn up at the end of one of these years did not exceed the equivalent of EUR 2 million in PLN;

- small enterprise – an enterprise which, in at least one of the last two financial years, employed fewer than 50 employees on average per year and achieved an annual net turnover from the sale of goods, products and services and financial operations not exceeding the equivalent of EUR 10 million in PLN, or the total assets of its balance sheet -prepared at the end of one of these years did not exceed the equivalent of EUR 10 million in PLN;
- medium-sized enterprise – an enterprise which, in at least one of the last two financial years, employed fewer than 250 employees on average and achieved an annual net turnover from the sale of goods, products and services and financial operations not exceeding the equivalent of EUR 50 million in PLN, or the total assets in its balance sheet prepared at the end of one of these years did not exceed the equivalent of EUR 43 million in PLN.

The size of a fish processing entity is important because it largely determines its business profile and product range. Micro and small enterprises, most often operating on local markets, mainly deal with low-processing products, such as salting, smoking, or preliminary processing of fish, which requires relatively small financial outlays. On the other hand, large plants with sufficient investment resources focus on the production of highly processed fish products that require advanced technological processes and complex production lines, such as canned fish, selected marinades, and frozen foods (Szultka, 2015).

4. Ratio analysis as a tool for assessing the financial condition of a company

The assessment of food processing companies requires an indicator analysis, which allows for an objective determination of their financial condition, efficiency, and development potential. Ratio analysis of financial statements is one of the most commonly used, but also one of the most crucial methods of financial analysis of an entity conducting business activity (Bednarski, 2007), including activities related to fish processing. The literature on the subject emphasizes that ratio analysis is an in-depth preliminary analysis of the balance sheet, profit and loss account, and cash flow statement. Its primary purpose is to identify the relationships between individual items in the balance sheet and income statement and then relate them to values considered desirable or critical (Lesiak, 2022).

This analysis is considered to be the most effective method of financial analysis. Financial ratios enable control of the financial condition and position of an economic entity, and these ratios can be used both for current assessment and for forecasting the financial situation of an economic entity (Nowak, 2017; Wilczyńska, 2018).

Financial ratios can be classified into four basic areas of assessment: profitability, debt, financial liquidity, and economic activity. Profitability and economic activity ratios are used to measure and assess the effectiveness of the use of capital entrusted to an entity, while financial liquidity and debt ratios enable the assessment of an enterprise's ability to settle its liabilities and maintain solvency (Sierpińska, 2004).

The analysis of financial liquidity in a company is very important in relation to the assessment of its ability to meet short-term liabilities. Financial liquidity is one of the key factors at both the micro- and macroeconomic levels that determine the value of a company (Prędkiewicz, 2010). It is classified as one of the basic economic categories that shape financial standing, understood as a reflection of a company's competitive position in the market, its economic strength, and credibility. These factors determine the reputation of a company and have a significant impact on the level of trust on the part of its contractors (Lesiak, 2022). The most commonly used indicators for this purpose are: current liquidity ratio; quick liquidity ratio; cash solvency ratio (Sierpińska, Jachna, 2013).

An analysis of a company's operational efficiency illustrates how both material resources and intellectual capital are used. It allows for an assessment of whether the level of assets is adequate for the scale of operations. It includes an examination of economic activity, management efficiency, and resource turnover. An analysis of a company's operational efficiency illustrates how both material resources and intellectual capital are used. It allows for an assessment of whether the level of assets is adequate for the scale of operations (Żywicka, 2021).

Debt analysis is an extension of financial liquidity analysis. Its main purpose is to assess the company's ability to service its short- and long-term liabilities and to identify the sources of funds used to repay them, i.e., the sources of financing for assets. Up to a certain level, an increase in debt can have a positive impact on a business entity's operations, enabling it to take advantage of financial leverage and increase the value of the company. However, it should be emphasized that excessive debt leads to an increase in financial risk (Żywicka, 2021). In addition, companies operating in the same sector of the national economy have different debt ratios depending on the scale of their business activities. Small and medium-sized enterprises are not smaller versions of large enterprises. The way they operate and their ability to raise capital from outside the company are significantly different from those of large economic entities (Figura, 2016). Differences in assets, management methods, bargaining power in the market, access to sources of financing, and many other aspects make differences in the value of debt ratios between small, medium, and large enterprises unavoidable (Luty, 2018).

Profitability means the ability of a company to generate profits, and therefore refers to the relationship between the financial result achieved and the capital invested in achieving it. The need to find the most effective ways to invest a company's free funds has become an impetus for conducting profitability analyses. The results of such analyses are a starting point for comparing the return on invested capital that can be achieved in different industries and

markets (Zhang, 2018). Profitability ratios are measures used to assess the financial performance of a company. They are key analytical tools, as profitability is a fundamental factor for success in any business activity (Jaworski, 2018). A positive value of the ratios indicates the profitability of the entity, while a negative value indicates its deficit. The basic indicators used in profitability assessment include: net sales profitability ratios (ROS), which are the ratio of the financial result of various levels of activity and sales (various ranges of revenues or costs), return on equity (ROE), and return on assets (ROA) (Majewska, 2016; Stępień, 2013).

5. The size of fish processing companies and its impact on financial performance

In order to analyze the impact of company size on the development of economic and financial indicators, financial data from financial statements published in the National Court Register database was used. The period covered by the analysis is 2022–2023. The study included 48 business entities, which were divided into:

- micro – 10 entities,
- small – 12 entities,
- medium – 15 entities,
- large enterprises – 11 entities.

The first area of analysis was the assessment of the profitability of fish processing companies broken down by size. Various profit categories were used to calculate profitability: sales profit, operating profit, gross profit, and net profit. In the case of micro-enterprises, deficit ratios were calculated, as they achieved a negative financial result in 2023 (Table 1).

Table 1.
Profitability indicators in fish processing by company size

PROFITABILITY	LARGE			MEDIUM			SMALL			MICRO		TOTAL	
	22	23	max 23	22	23	max 23	22	23	max 23	22	23	22	23
ROS Sales profitability	0,8%	3,2%	10,9%	3,9%	4,5%	10,7%	3,5%	4,0%	7,3%	bd	bd	1,1%	3,3%
ROS Operating profitability of sales	1,2%	3,6%	10,9%	4,7%	5,8%	10,9%	4,0%	7,0%	7,6%	9,5%	-1,6%	1,6%	3,8%
ROS Gross profitability	2,9%	4,1%	9,4%	3,7%	4,9%	10,7%	4,3%	7,7%	5,7%	8,9%	-1,9%	3,0%	4,3%
ROS Net profitability	2,5%	3,3%	7,4%	3,2%	4,2%	10,7%	4,0%	6,2%	5,7%	8,1%	-2,6%	2,6%	3,5%
ROA Return on assets	5,0%	7,6%	12,9%	5,6%	7,6%	38,6%	6,0%	8,2%	14,0%	8,3%	-2,4%	6,1%	7,6%
ROE Return on equity	14,3%	18,2%	26,2%	13,1%	16,9%	57,8%	18,2%	23,3%	48,7%	13,5%	-5,1%	16,4%	18,1%

Source: Own studies based on financial data from KRS and EMIS database.

The first level of profitability, i.e., sales profitability, reached its highest level in both 2022 and 2023 for medium-sized companies. This is due, among other things, to slower cost growth in medium-sized and small companies than in large ones, and a smaller share of material and energy costs and wages in total operating costs. Wages and raw materials are currently the fastest growing operating cost groups. Research shows that in small businesses, the share of costs for materials, energy consumption, and wages constitutes the smallest percentage, i.e., just under 57% in small entities, just under 69% in medium-sized ones, and 83% in large ones. Smaller entities are characterized by lower administrative costs, lower employment, and limited marketing and logistics expenses.

Other operating revenues account for 4% of total revenues in small enterprises, 2% in medium-sized enterprises, and less than 1% in large enterprises. This translates into operating profitability ratios, which are highest in small enterprises, averaging 7.6%, 5.8% in medium-sized enterprises, 3.6% in large enterprises, and negative values in micro-enterprises. This is due, among other things, to the fact that subsidies/co-financing from EU funds in the fish processing sector are mainly directed to SMEs.

The net profitability for the entire fish processing sector was 3.5% in 2023 and 2.6% in 2022. Small and medium-sized enterprises in the fish processing industry achieved above-average net ROS values in the period under review, i.e., small enterprises 6.2%, medium-sized enterprises 4.2%, and large enterprises 3.3% in 2023.

A similar relationship applies to the ROA (return on assets) ratio. The highest values are achieved by small enterprises, where each zloty invested in assets generated over 8 groszy in profit, medium-sized enterprises generated less than 8 groszy, and large enterprises generated 7.5 groszy in net profit in 2023.

Small enterprises also achieve the highest values in terms of return on equity (ROE). The lower profitability ratios in large enterprises employing more than 250 people are due to the fact that large fish processing plants are usually focused on mass production, where there is price pressure from customers (e.g., retail chains) and margins are lower. Large enterprises are often dependent on large contracts with retail chains or exporters, who force lower purchase prices. The scale of production also translates into increasing logistics and storage costs, high management and investment service costs.

Small entities are more flexible, have a simple management structure, lower administrative costs, and often less bureaucracy. This allows them to respond more quickly to market changes and minimize fixed costs. They can also focus on niche products and have lower overhead costs, which increases their ROS.

Medium-sized companies balance growth and cost control, are already incurring higher management and investment costs, but still benefit from some flexibility (Gołaś, 2010).

Table 2.*Liquidity ratios for fish processing companies by size in 2022-2023 – own research*

LIQUIDITY	LARGE		MEDIUM		SMALL		MICRO		TOTAL	
	22	23	22	23	22	23	22	23	22	23
CR current ratio	1,3	1,4	1,4	1,5	1,6	2,0	2,3	1,3	1,3	1,5
QR quick ratio	0,6	0,7	0,7	0,8	1,2	1,4	1,6	1,1	0,6	0,7
Immediate liquidity ratio	0,04	0,1	0,1	0,2	0,3	0,4	bd	bd	0,04	0,08

Source: Own studies based on financial data from KRS and EMIS database.

In the case of liquidity analysis, three ratios were calculated, i.e., CR, QR, and the quick ratio. All groups of companies achieved a safe CR (current ratio) level, ranging from 1.2 to 2. A quick ratio (QR) below 1 may indicate difficulties in settling short-term liabilities based on highly liquid assets in the case of large and medium-sized enterprises. Small enterprises achieved the highest and safest value of this ratio. The large difference between the QR and CR ratios in large and medium-sized entities indicates a tendency to accumulate inventories in these groups of entities, and thus increased storage/logistics costs and capital tied up in inventories. The quick ratio is low for enterprises overall, although it has improved compared to 2022 (Table 2).

Table 3.*Operational efficiency ratios for fish processing companies by size in 2022-2023 – own research*

OPERATIONAL EFFICIENCY	LARGE		MEDIUM		SMALL		TOTAL	
	22	23	22	23	22	23	22	23
Inventory turnover ratio (in days)	60	54	52	48	31	45	54	53
Receivables turnover ratio (in days)	55	47	43	43	59	51	49	46
Current liabilities turnover ratio (in days)	94	74	79	69	88	81	84	74

Source: Own studies based on financial data from KRS and EMIS database.

In order to assess operational efficiency, inventory turnover, receivables, and short-term liabilities ratios were calculated. The inventory turnover ratio improved in large and medium-sized enterprises, which indicates improved efficiency in inventory management, but small enterprises still achieve the most favorable values in this respect, with the shortest ratio of 45 days. The accounts receivable cycle ratio in 2023 decreased for all fish processing enterprises and for individual groups. This means that the collection period has shortened, which is a positive trend. The short-term liability turnover ratio, which shows the repayment period for short-term liabilities, has shortened. On average, 74 days elapse between the creation of a liability and its settlement in fish processing companies (Table 3).

Table 4.*Debt ratios for fish processing companies by size in 2022-2023 – own research*

DEBT	LARGE		MEDIUM		SMALL		MICRO		TOTAL	
	22	23	22	23	22	23	22	23	22	23
Share of short-term liabilities in total liabilities	0,8	0,8	0,7	0,7	0,4	0,4	bd	bd	0,8	0,8
First degree of coverage (golden balance sheet rule)	1,1	1,2	1,2	1,2	0,7	0,8	bd	bd	1,1	1,2
Second degree of coverage (golden banking rule, silver balance sheet rule)	1,4	1,5	1,5	1,5	1,3	1,5	bd	bd	1,4	1,5

Source: Own studies based on financial data from KRS and EMIS database.

The debt ratings of individual groups of fish processing companies were assessed on the basis of three selected indicators. The ratio of short-term liabilities to total liabilities indicates a generally low share of long-term liabilities in the financing structure of large and medium-sized companies. It should be remembered that too high a share of short-term liabilities in the debt of an economic entity may lead to financial liquidity problems, as can be seen in the case of the QR indicator in large and small entities. In small enterprises, the share of short-term liabilities is 40% of total liabilities. The first and second coverage ratios show that the rules are followed in large and medium-sized groups of surveyed enterprises, and fixed assets are financed from a stable source of financing, i.e., equity and fixed capital. In small enterprises, fixed assets are covered by equity capital only in 80% of cases; there is no full (100%) financing of fixed assets with equity capital, and part of the fixed assets is financed with external capital (e.g., long-term loans). The golden balance sheet rule is not met for small enterprises (Table 4).

It was not possible to assess the level of indebtedness of micro-enterprises due to the lack of detailed data in this regard.

6. Profitability indicators and the type of fish processing

The values of financial and economic indicators may vary significantly depending on the type of processing, which results from different production technologies, scale of operations, cost structure, and capital intensity of individual processing operations.

Table 5.*Profitability indicators by type of fish processing in 2022–2023 – own research*

PROFITABILITY	FRESH AND FROZEN			CHILLED PRODUCTS			SMOKED			CANNED		
	2022	2023	max 2023	2022	2023	max 2023	2022	2023	max 2023	2022	2023	max 2023
Sales profitability	0,04	0,04	0,11	0,02	0,03	0,06	-0,01	0,02	0,09	0,05	0,07	0,11
Operating profitability of sales	0,04	0,05	0,12	0,03	0,04	0,08	-0,01	0,03	0,10	0,05	0,08	0,11
Gross profitability	0,03	0,05	0,10	0,02	0,03	0,07	0,03	0,04	0,11	0,04	0,06	0,09
Net profitability	0,03	0,04	0,08	0,02	0,02	0,06	0,03	0,03	0,11	0,03	0,05	0,07

Cont. table 5.

Return on assets	0,05	0,08	0,14	0,03	0,04	0,11	0,06	0,08	0,39	0,05	0,08	0,13
Return on equity	0,15	0,21	0,46	0,07	0,09	0,30	0,18	0,21	0,58	0,11	0,17	0,22

Source: Own studies based on financial data from KRS and EMIS database.

For the purposes of the analysis, fish processing producers were divided into four main processing groups: fresh and frozen products, chilled products, smoked products, and canned products (Table 3). An analysis of the profitability of individual types of fish processing for the years 2022-2023 showed that the highest levels of profitability, both in terms of sales and operating, gross and net, were achieved by canned fish producers. Sales profitability in 2023 was as high as 7% for canned fish producers, and net profitability was 5%, which is well above the industry average of 3.5% in 2023. The lowest values for both sales and operating profitability were achieved by smoked fish processors, at 2.4% and 3.1%, respectively. Fresh and frozen fish processors achieved values higher than the industry average in 2023 at all profitability levels. Smoked and chilled fish processors will achieve lower net profitability values than the industry average.

The ability of assets to generate profits in 2023 was highest among smoked fish producers (8.5%), slightly lower among canned fish producers (8.3%) and frozen fish producers (8.2%). Refrigerated fish producers achieved much lower ROA values (4.3%), which means that this group of companies makes poor use of its assets to generate profits, which may be due to high costs, low process efficiency, or excessive capital commitment in relation to the results achieved.

Return on equity (ROE) reached its highest values in 2023 for producers of fresh, frozen, and smoked fish, i.e., 20.7%, canned fish 17%, and chilled products 9.1%. The ROE for chilled products is lower than inflation, which was 11.4% in 2023. This means that chilled fish processors do not generate profits that allow them to maintain the real value of their equity. Owners involved in chilled fish processing incur losses in real terms, as the rate of return on invested funds does not compensate for the decline in the purchasing power of money. This situation indicates limited capital efficiency and reduces the investment attractiveness of the company compared to alternative forms of capital investment that may better protect against loss of value in inflationary conditions.

The higher profitability of producers of canned fish and fresh and frozen fish compared to producers of chilled and smoked fish may be due to several factors. Firstly, canned and frozen products have a much longer shelf life, which reduces the risk of losses related to product perishability and lowers storage and distribution costs. Secondly, these products can be sold on large markets, including foreign ones, which increases the scale of operations and allows for higher margins. Another important factor is the high degree of automation and capital intensity of the production processes for canned and frozen fish, which allows for economies of scale and reduced unit costs. In addition, as more processed products, they often generate higher added value than smoked or chilled products, which are more labor-intensive and have a shorter shelf life, and thus a higher risk of loss. All this means that producers of canned, fresh,

and frozen fish achieve higher profitability on average than those specializing in chilled and smoked products. (Table 5)

7. Summary

The ratio analysis shows clear differences in the financial condition of fish processing companies depending on their size.

Large fish processing companies are characterized by stability and predictability of results. They achieve moderate but growing profitability, and their capital structure meets safety standards (golden and silver balance sheet rules). At the same time, they maintain low liquidity ratios, which indicates tight working capital management. In terms of operational efficiency, they have improved inventory and short-term liability turnover, and asset productivity has increased to 2.2, which indicates increasingly better use of available resources.

Medium-sized enterprises perform best in terms of overall efficiency. They combine high profitability with adequate liquidity and a secure debt structure. Operating ratios indicate efficient receivables management (maintaining turnover at 43 days) and a moderate improvement in liabilities turnover. Asset productivity (1.7) remains lower than in large companies, but stable.

Small enterprises achieve some of the highest levels of profitability and good liquidity ratios, and their short-term debt is relatively low. At the same time, they are characterized by weaker coverage of fixed assets with equity, which increases risk in the long term. There has been a deterioration in operational efficiency, with inventory turnover increasing from 31 to 45 days and asset productivity falling from 1.5 to 1.3. This shows that despite high profitability, small companies may have difficulties in using their resources efficiently.

Micro-enterprises are the group most at risk. In 2023, their profitability fell below zero and their liquidity deteriorated significantly. The lack of complete data on debt and operating ratios limits the possibility of a full assessment, but confirms their weaker capital position and lower resilience to changes in the economic environment.

The analysis indicates that the type of fish processing also has a significant impact on the profitability levels of enterprises. The production of canned and frozen fish, thanks to its longer shelf life, potential for expansion into foreign markets, higher level of automation, and greater added value, is conducive to achieving higher and more stable margins. On the other hand, smoked and chilled products, despite their quality advantages, have a shorter shelf life, higher logistics costs, and a smaller scale of production, which limits their profitability and increases the risk of losses. Ultimately, therefore, the structure of production and fish processing technology directly translate into differences in the economic efficiency of companies.

The conclusions of the analysis suggest that development strategies should be differentiated according to the size of the company and the type of processing. Large entities can focus on further increasing efficiency and maintaining stability, while medium and small enterprises should use their flexibility and high profitability for further expansion and innovation. Micro-enterprises, on the other hand, require special attention – both from owners, who must seek ways to mitigate risk, and from economic policy, which should support the smallest entities in order to reduce their vulnerability to market fluctuations. This will enable the fish processing sector as a whole to remain balanced and competitive.

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THE IMPORTANCE OF CREATIVE PROBLEM SOLVING IN THE DIGITAL ECONOMY USING DESIGN THINKING TO SHAPE ORGANIZATIONAL RESILIENCE

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Purpose: The aim of this article is to identify the importance of creative problem solving in the digital economy using the Design Thinking (DT) method in shaping organizational resilience. The article attempts to integrate theoretical perspectives on resilience, digital transformation, and DT methodology to identify mechanisms that enable organizations to adapt to environmental change and disruption.

Design/methodology/approach: The article is based on a systematic review of the literature and a comparative analysis of case studies of innovative projects implemented on the basis of DT in companies and institutions in the field of the digital economy.

Findings: The analysis indicates that the creative implementation of innovative projects using the Design Thinking method strengthens organizational resilience by: supporting flexibility and innovation, building credibility and trust among users thanks to the human-orientation of innovative solutions. This increases the organization's adaptability in uncertain conditions.

Research limitations/implications: The limitation of this article is that it uses only secondary data, which does not allow for full empirical verification of the findings. Future research should include quantitative and qualitative studies that take into account sector specific characteristics and cultural context.

Practical implications: The findings indicate that managers can integrate the implementation of innovative projects based on the DT creative process with digital transformation processes in order to increase the adaptability of the organization, minimize innovation costs, and strengthen competitiveness. This also contributes to increased efficiency and flexibility through the implementation of digital tools and services tailored to user needs.

Social implications: The use of DT in digital services improves people's quality of life, increases the transparency of administration, and promotes the development of inclusive digital services in line with user needs, strengthening public trust in technological solutions and digital tools.

Originality/value: The originality of the article lies in the integration of three areas: organizational resilience, digital transformation, and creative problem solving using the Design Thinking method. The results provide a new theoretical perspective and practical guidance for managers and researchers.

Keywords: Design Thinking, creative problem solving, creativity, organizational resilience, digital economy.

Category of the paper: Literature review and case study.

1. Introduction

To ensure In an era of rapid technological change, global disruption, and growing market uncertainty, organizational resilience has become a key mechanism for the development of businesses and institutions. Organizational resilience is defined as an organization's ability to anticipate, prepare, respond, and adapt in the face of change and disruption, as well as recover from crisis (Lengnick-Hall, Beck, Lengnick-Hall, 2011). Resilience also encompasses the ability to learn, transform, and capitalize on emerging development opportunities (Lengnick-Hall, Beck, Lengnick-Hall, 2011).

In conditions requiring rapid response to change and uncertainty, creativity, supporting creative problem-solving and generating ideas for innovative solutions, becomes increasingly important. The literature emphasizes that creative problem-solving is the foundation of innovation activities and is inextricably linked to organizational adaptation processes (Mumford et al., 2013). The ability to generate and implement innovative ideas strengthens dynamic capabilities that enable organizations to adapt to disruptions and recover from crises (Teece, 2018).

In this context, methods that support creative thinking and innovative approaches to problems are gaining importance. One of the most recognizable such methods is Design Thinking. This method is widely described in research as a creative, user-centered approach that combines empathy, interdisciplinarity, iteration, and prototyping (Brown, 2008; Liedtka, 2018).

Digital transformation and digital innovation are considered important factors supporting organizational resilience. Research indicates that digitalization fosters organizational learning, innovation, and operational agility (Awad, Martín-Rojas, 2024), which are key to strengthening organizational resilience. The dynamic development of the digital economy creates both opportunities and challenges for organizations operating in a complex and uncertain environment. In the face of dynamic change and the need to quickly adapt to changing conditions, the importance of digital fluency, associated with the ability to use digital tools and their critical and creative use in solving complex problems, is growing (Voogt et al., 2015). The digitization of business processes, the growing importance of data-driven technologies, and the pressure to quickly adapt to changing market conditions are making organizational resilience one of the key factors determining the sustainability and development of enterprises (Duchek, 2020).

Therefore, the development of innovative digital tools is crucial, which in turn is related to the effective implementation of innovation projects. Applying the Design Thinking approach can be helpful in this regard. Implementing digital transformation projects based on the DT methodology promotes a better understanding of customer needs and the creation of innovative technological solutions that address the challenges of a dynamic environment (Awad, Martín-Rojas, 2024). Literature analysis indicates that the integration of DT-based design processes with digital transformation supports building resilience by developing the learning, innovation and adaptability capabilities of the organization (Oliveira, 2024).

Despite a growing number of publications, knowledge about combining DT with organizational resilience in the digital economy remains limited. While the literature increasingly examines digital transformation and its impact on resilience, there are fewer studies that connect Design Thinking as a specific method for creative problem-solving in the digital economy with building and strengthening organizational resilience. Most studies focus on describing innovative applications of DT in digital transformation projects. However, few directly analyze the impact of DT on specific resilience indicators or the ability to adapt in crisis conditions (Duchek, 2020).

The aim of this article is to identify the importance of creative problem-solving in the digital economy using the Design Thinking (DT) method in shaping organizational resilience. The article therefore focuses on explaining how implementing innovative projects using Design Thinking in the context of the digital economy, based on a creative approach, can contribute to shaping organizational resilience. To achieve this goal, a literature review was conducted to identify key concepts, mechanisms, and research gaps that justify the need for such research. Case studies on the implementation of Design Thinking in the context of the digital economy were also analyzed.

2. Literature review

2.1. The importance of creative problem-solving within the implementation of innovative projects in shaping organizational resilience

Creative problem-solving is a key factor enabling organizations to function in conditions of uncertainty and change. Mumford et al. (2013) emphasize that the ability to generate original ideas and experiment is a significant factor in competitive advantage, especially in turbulent environments. Research indicates that the ability to generate and implement innovative ideas strengthens an organization's adaptability and allows it to recover more quickly from disruptions (Amabile, 1996; Zhou, Hoever, 2014). Akgün and Keskin (2014) emphasize that product and service innovation is correlated with an organization's improved ability to survive market volatility. Therefore, it plays a fundamental role in innovation processes.

Other authors, such as Lengnick-Hall, Beck, Lengnick-Hall (2011), emphasize that organizational resilience is also related to the ability to transform and leverage crises as a catalyst for innovation. Within innovation projects, creativity is not limited to the generation of novel ideas but also encompasses processes of systematic experimentation, learning, and practical implementation of solutions (Drazin et al., 1999).

Therefore, the importance of creativity can be analyzed through the lens of dynamic capabilities, which form the foundation of organizational resilience. Teece (2018) emphasizes that the ability to integrate, build, and reconfigure resources enables organizations to adapt to new market conditions. Creative problem-solving supports the development of these capabilities by creating conditions conducive to exploration and exploitation, consistent with the concept of ambidexterity (March, 1991; O'Reilly, Tushman, 2013).

From the perspective of innovation projects, an organizational culture focused on openness, experimentation, and tolerance for error is crucial to fostering creativity. Edmondson (1999) points out that psychological safety in teams fosters open knowledge sharing and risk-taking, which are prerequisites for generating innovative solutions. Interpersonal relationships and team collaboration enable the integration of diverse cognitive perspectives, which increases the potential for creativity and resilience (Paulus, Nijstad, 2003). The role of leaders and managers is crucial in this regard. Research indicates that when creative problem-solving is supported by leaders and the organizational structure, organizations respond more quickly to disruptions and recover more quickly (Vogus, Sutcliffe, 2007).

Creative problem-solving also strengthens organizational learning processes, which, according to Duchek (2020), are a key component of organizational resilience. Nonaka and Takeuchi (1995) argue that the knowledge conversion process (SECI) is based on the interaction of explicit and tacit knowledge, which fosters the creation of innovative solutions. In innovative projects, the testing and prototyping phases are particularly important, as they not only accelerate the implementation of new solutions, but also develop organizational resilience through the ability to quickly learn from mistakes and iteratively improve processes (Brown, 2008; Liedtka, 2018).

Analyzing the literature on the subject, significant factors that foster organizational creativity can be identified, including:

- simultaneous support for the exploration of new solutions and the use of existing resources within the concept of ambidexterity (March, 1991; Andriopoulos, Lewis, 2009),
- dynamic team learning processes (Edmondson, 1999),
- development of cognitive abilities through practices such as continuous testing and prototyping (Nonaka, Takeuchi, 1995; Brown, 2008),
- interpersonal relationships that facilitate knowledge flow (Nonaka, Takeuchi, 1995),
- an organizational culture that supports tolerance for error and experimentation (Edmondson, 1999).

Creative problem-solving within innovation projects therefore contributes to increasing organizational resilience by synergistically impacting the following key areas: developing dynamic capabilities, strengthening an organizational culture open to change, and enhancing teams' competencies in learning and adaptation. This enables organizations to be better prepared for disruptions and transform crises into a source of competitive advantage.

Analysis of the literature indicates the need for further research on how creative approaches impact organizational resilience. It also explores the measures of these impacts (e.g., recovery time, scope of adaptation), what organizational resources determine the effectiveness of creative problem-solving, and how this impact evolves across various industries and organizations.

2.2. Design Thinking in the context of projects related to the digital economy.

The digital economy, characterized by the growing importance of information technology and digital tools such as big data, artificial intelligence, and the Internet of Things, requires organizations to be able to quickly create and implement innovative solutions. In this context, the Design Thinking (DT) method, which combines the user perspective with creative problem-solving, is gaining particular importance (Brown, 2008; Kelley, Kelley, 2019). Research indicates that DT is becoming an increasingly common method supporting the effective design of innovative services and products (Brown, 2008; Liedtka, 2018).

In innovation projects related to digital transformation, considering the needs of end users is crucial. DT is based on empathy and understanding user experiences, which allows for better adaptation of new digital solutions to real market expectations (Carlgren et al., 2016). The DT process, consisting of phases such as empathy, problem definition, idea generation, prototyping, and testing, is consistent with the nature of dynamic digital environments (Brown, 2008; Awad, Martín-Rojas, 2024). The iterative nature of the method reduces implementation risk by quickly verifying hypotheses and adapting solutions to user needs during development (Beckman, Barry, 2007). The literature emphasizes that prototyping is not only a solution-creating technique but also a tool for organizational learning, increasing adaptability to unpredictable technological changes (Seidel, Fixson, 2013).

DT is used in many areas of the digital economy. In the financial sector, this method supports the creation of new models of digital banking and mobile-based services that are more intuitive and accessible to users (Carlgren et al., 2016). In healthcare, the use of DT enables the design of digital diagnostic tools and medical applications that increase service accessibility and improve patient experience (Plattner, 2012). In the public sector, the use of DT enables the development of innovative e-government platforms that facilitate institutional interaction with the public (Kimbell, 2011).

The impact of DT on organizational culture in digital processes is also important. Implementing this method fosters a work environment focused on interdisciplinary collaboration, openness to experimentation, and tolerance for errors. This increases the chances

of success for innovative projects (Liedtka, 2018; Carlgren et al., 2016). Research shows that organizations using DT achieve higher levels of employee engagement in digital transformation projects and develop dynamic capabilities that foster organizational resilience (Awad, Martín-Rojas, 2024).

It is important to emphasize that DT also supports the integration of new technologies into existing business models. The ability to quickly test and adapt concepts enables reducing the costs of poor decisions and more efficient use of digital resources (Seidel, Fixson, 2013). As a result, this method not only contributes to the creation of innovative solutions but also increases the organization's resilience to technological and market risks.

In summary, applying Design Thinking to digital transformation projects is an effective way to combine innovation with adaptability. This method allows organizations to better respond to the challenges of digital transformation, develop new business models, and foster a culture open to experimentation. As a result, DT serves as a catalyst for innovation and a factor that strengthens organizational resilience in conditions of dynamic technological change.

2.3. Integrating Design Thinking in the implementation of projects for the development of the digital economy with mechanisms for building organizational resilience

The connection between Design Thinking (DT), which supports the implementation of innovative projects, and mechanisms for building organizational resilience is gaining ground in the scientific literature. Researchers indicate that implementing innovative projects can foster the development of dynamic organizational capabilities, which are the foundation of resilience (Teece, 2018; Williams et al., 2017). The DT method can play a significant role in this regard. A key element of this integration is the link between empathy for users, iterative prototyping, and solution testing with organizational adaptation processes. DT enables the creation of innovative digital services that not only meet customer needs but also strengthen the organization's ability to cope with disruptions (Brown, 2008; Liedtka, 2018). Design Thinking (DT) can be a tool supporting the development of these processes, as it promotes learning, interdisciplinary collaboration, and adaptability, which are the foundation of organizational resilience (Liedtka, 2018; Awad, Martín-Rojas, 2024).

Integrating DT with organizational resilience mechanisms involves creating an environment conducive to continuous testing and prototyping, which reduces the risk of digital project failure. The iterative nature of DT strengthens an organization's ability to respond to technological and market disruptions by quickly adapting solutions to changing conditions (Seidel, Fixson, 2013).

The literature emphasizes that organizational resilience depends not only on structures and processes, but also on organizational culture and interpersonal relationships (Vogus, Sutcliffe, 2007). DT supports the development of an organizational culture in which experimentation, collaboration, and tolerance for error are essential elements supporting innovation and

adaptability (Carlgren et al., 2016). Therefore, this method fosters the building of dynamic capabilities that enable organizations to capitalize on emerging opportunities in the digital economy while simultaneously reducing vulnerability to disruption (Teece et al., 2016).

A significant aspect of integrating DT with organizational resilience is the role of empathy and user-centricity. This allows organizations to better identify changing customer needs, allowing them to adapt their business models more quickly and minimize the risk of competitive disadvantage (Brown, 2008). Applying DT to digital solutions projects also fosters stronger stakeholder relationships, which is considered a key dimension of resilience, as diverse networks support the organization during times of crisis (Williams et al., 2017).

Literature indicates that DT supports resilience-building processes by developing organizational competencies related to learning, creative problem-solving, and innovation. In this regard, digital tools are playing an increasingly important role, supporting not only the act of generating new ideas but also enabling their transformation, testing, and refinement in a dynamic and interactive manner (Mumford et al., 2013). For example, implementing DT-based projects related to digital solutions contributes to the development of competencies in data analysis, agile work methods, and technology integration, which enhances the organization's ability to maintain stability in times of disruption (Plattner, 2012; Awad, Martín-Rojas, 2024).

In summary, integrating DT with organizational resilience mechanisms involves combining iterative innovation processes with the development of dynamic adaptive capabilities. From a management perspective, DT can strengthen an organization's ability to function and thrive in conditions of uncertainty through: greater operational flexibility, improved communication and collaboration, increased acceptance of digitization processes, employee innovation, a culture of experimentation, and building trust between the organization and its stakeholders (Vogus, Sutcliffe, 2007). This allows this method to serve not only as a tool for supporting innovation but also as a strategic driver of long-term organizational resilience.

3. Methods

This article uses a secondary data analysis approach, which allows for a synthetic overview of the existing scientific and practical work in the area of creative problem-solving using the Design Thinking method and its importance for organizational resilience in the digital transformation process.

First, a systematic review of the scientific literature was conducted using the Scopus, Web of Science, and Google Scholar databases. The analysis included scientific articles, books, and monographs published between 2000 and 2025, focusing on three key areas:

- the importance of creative problem-solving in shaping organizational resilience,
- the application of Design Thinking in innovation processes related to the digital economy,
- the relationship between creative problem-solving using the Design Thinking method and an organization's ability to respond to uncertainty and disruption.

The literature selection process was guided by criteria of quality (publications in indexed journals), currency, and relevance to the research topic.

The second stage of the study involved an analysis of existing case studies on the implementation of Design Thinking in organizations in the field of the digital economy. The case studies were drawn from the literature and research reports published in renowned journals and academic monographs. The analysis was qualitative in nature and based on the identification of:

- the main areas of application of Design Thinking related to the design and implementation of digital services and tools,
- the effects on organizational resilience (e.g., increased flexibility, adaptability, reduced response time to market changes),
- the barriers and factors facilitating the effective implementation of the method in the context of digital transformation.

This approach enabled the compilation of findings from several case studies, allowing for the identification of specific conditions and effects of Design Thinking implementation.

The results of the literature and case study analysis were subjected to a comparative synthesis, allowing for the identification of recurring patterns and relationships. The use of secondary data from various sources increased the credibility of the conclusions by combining theoretical (literature) and practical (case studies) perspectives.

The choice of methods based on literature and case study analysis was based on two premises. First, the issue of Design Thinking's impact on organizational resilience in the digital economy is relatively new and requires a thorough synthesis of existing research findings. Second, the availability of a growing number of practical implementations allows for a qualitative assessment of the effectiveness and determinants of this approach. The methods employed thus enable both the systematization of the state of knowledge and the development of application-specific conclusions relevant to management practice.

4. Results

The analysis focuses on the following four case studies of digital economy projects implemented using the Design Thinking methodology:

- IBM project example - IBM z14 mainframe system.
- IRIS Bank project example in Indonesia - improving the quality of digital banking services.
- Eudaemon Technologies project example - digitally streamlining the data collection and tracking process.
- Hospital pharmacy project example in the Asir region of Saudi Arabia - improving outpatient services.

The case studies are described using the following structure: project background, project participants, problem to solve, project goal, stages, and achieved results. The case studies are then compared and synthesized, taking into account their impact on organizational resilience.

IBM project example – IBM z14 mainframe system

IBM is an example of a company focused on Design Thinking projects, based on three fundamental elements of its approach: diverse teams, a focus on users, and continuous improvement (IBM Design, 2025). IBM combines DT with Agile methodologies in its project implementation (Eickhoff et al., 2018). The company has developed DT ideas, strategies, and tactics in a unique way to support team-based project implementation (IBM Design, 2025). Research conducted by Forrester Consulting on behalf of IBM clearly confirmed the effectiveness of the DT methodology and a number of the following benefits three years after its implementation (Hrpolska, 2019):

- financial savings (amounting to \$20.6 million),
- economic benefits (nearly \$50 million),
- shorter solution design time (up to 75% thanks to DT tools),
- accelerated decision-making,
- more effective teamwork,
- faster error identification and improvement through iteration,
- increased customer satisfaction.

An example of IBM's DT implementation is the IBM z14 project, developed based on the "IBM Design Thinking" method and Agile practices for the digital economy (Eickhoff et al., 2018).

Project implementers: A diverse and multidisciplinary team created by IBM, employing over 1000 engineers working on the IBM z14 mainframe system (Eickhoff et al., 2018; IBM Design, 2025).

Problems to solve: The primary challenge was the need to respond faster to customer requirements while maintaining high quality and secure transaction processing, supporting digital transformation.

Project goal: Using IBM Design Thinking methodology and Agile practices to understand user needs and adapt the solution to their perspective, delivering value across the project.

Project stages: The project implementation process was based on an iterative approach utilizing IBM Design Thinking and Agile methodologies, engaging key company stakeholders, i.e., user-sponsors, at an early stage (Eickhoff et al., 2018). The project stages were based on a cycle model that views the design process as a continuous loop consisting of three recurring activities (IBM Design, 2025):

- Observe – observing and thoroughly understanding user behavior and challenges, gathering research information to ensure solutions address their actual needs.
- Reflect – analyzing, synthesizing, and giving meaning to observational results, prioritizing them to ensure user understanding across the team.
- Make – creating rapid prototypes to test ideas and hypotheses with users to achieve a result focused on achieving effective, relevant, and proven innovative solutions.

Project outcomes: This project is an example of supporting the digital transformation of IT services and products. The z14 system, a secure, scalable transaction and data platform, was designed with the needs of administrators and corporate users in mind (IBM Redbooks). It supports faster digital transformation by supporting secure, encrypted cloud-based services, enabling improved customer service quality (IBM Redbooks). The use of IBM's methodology, based on an iterative process of continuous development, prototyping, testing, and re-creation, allowed for faster adaptation of the solution to user needs (Eickhoff et al., 2018). IBM's methodology, combining design thinking with Agile practices, enabled rapid iteration and minimized the risk of errors in a costly hardware-software environment (IBM Design, 2025). This increased product adaptability, accelerated solution testing, shortened correction times, better aligned the system with corporate client needs, and improved collaboration with key clients, which is directly related to strengthening the company's organizational resilience (Eickhoff et al., 2018; IBM Design, 2025; Lengnick-Hall, Beck, Lengnick-Hall, 2011). This contributes to greater flexibility and faster response to market needs, while reducing the risk of costly changes (Carlgren et al., 2016).

IRIS Bank project example in Indonesia – Improving the quality of digital banking services

An example of how the Design Thinking approach was applied to an innovation project by Bank IRIS is described based on research published by Simanjuntak and Ghazali (2025). The project, implemented by Bank IRIS, was developed in response to the challenges of digital transformation and the desire to improve digital banking services. The transition to digital banking revealed a number of challenges the bank had to face.

Project implementers: The project was implemented by the Bank IRIS team in Jakarta using the Design Thinking method (Simanjuntak, Ghazali, 2025).

Problems to solve: Bank IRIS faced a large number of technical issues with its digital services, including recurring frequent connection errors, poor online customer service, and declining user satisfaction with its banking applications. Low customer loyalty and the risk of customer defection to competitors were also a problem (Simanjuntak, Ghazali, 2025).

Project goal: Develop innovative solutions to improve the quality of digital banking by better understanding user needs, eliminating system errors, and streamlining customer service.

Project stages: The project was implemented using the DT method and divided into the following five stages (Simanjuntak, Ghazali, 2025):

- Empathize – online complaints and reviews were analyzed, in-depth interviews were conducted with two customers, and surveys were conducted with five corporate customers.
- Define – key issues related to the poor quality of services offered were identified, including difficulty logging in, frequent application outages, lack of effective communication in customer service, and connectivity issues.
- Ideate – customer-generated improvement ideas were identified, including the use of Content Delivery Networks (CDNs), AI-based chatbots, a new application interface, additional security features, a better support system, the use of a web index to minimize transaction risk, and employee training programs.
- Prototype – a narrative prototype of the new banking application was prepared.
- Test – the developed prototype was tested with customers and modified based on their feedback to address the issues identified in the empathy phase.

Project outcome: An improved banking app was created, with an improved interface, a more stable login system, and a better online customer service channel. As a result, IRIS Bank saw increased customer satisfaction and improved digital service quality. This contributed to its operational resilience in the face of increasing competition (Simanjuntak, Ghazali, 2025).

An example of a project by Eudaemon Technologies – digital improvement of the data collection and tracking process

The case study illustrates an exploratory design thinking approach to the rapid implementation of digitalization solutions (Mesa et al., 2022). The project addressed the challenges faced by Australian manufacturing SMEs related to the high levels of risk and uncertainty associated with implementing new technologies and digital tools. The companies struggled with digital transformation challenges, the risk of selecting appropriate technologies, limited digital competencies, and uncertainty regarding the cost-effectiveness of implementing digital tools (Mesa et al., 2022).

Project implementers: An interdisciplinary research and design team was established for the project, based on collaboration between academics from the University and a manufacturing SME using the Design Thinking method (Mesa et al., 2022).

Problems to solve: The project focused on the challenges faced by Eudaemon Technologies, which needed to improve its data collection and tracking process to manage production in a virtual environment. Despite its automated production process, Eudaemon struggled with data collection and processing. The company's IoT-enabled equipment was not fully utilized (Mesa et al., 2022).

Project goal: The primary goal was to identify the impact of technologies and practices on improving Eudaemon Technologies' production capabilities. Initially, the goal was to identify tools for creating dashboards to simplify data analysis and enable remote monitoring and control of production processes (Mesa et al., 2022). Specific project goals included (Mesa et al., 2022):

- review the existing IoT 4.0 environment,
- determine design assumptions for creating a digital production process dashboard,
- determine the input data and components required to create the dashboard.

Project stages: The project was based on an iterative process based on the Design Thinking methodology, encompassing four main phases (Mesa et al., 2022):

- **Discover** – activities aimed at understanding the problem through an analysis of existing practices and production equipment at Eudaemon Technologies, with the involvement of various stakeholders. A review of existing innovative solutions on the market was also conducted. A series of consultations were held with local technology providers and university experts.
- **Define** – a list of requirements and selection criteria were defined, based on which selected IoT platforms were selected.
- **Develop** – prototypes were developed and tested, allowing the team to analyze each presented solution using simulated data. This phase concluded with the development and presentation of several proof-of-concept prototypes.
- **Deliver** – after analyzing the proof-of-concept prototypes and the identified criteria, the platform with the greatest potential was selected. After improvements, it was fully integrated into Eudaemon's existing data collection and analysis process.

Project outcomes and results: The iterative design thinking process used had a key impact on: expertise, reduced investment risk through rapid testing of prototype solutions, and the creation of an effective and sustainable solution tailored to the needs without the need for high resources and costs. It also mitigated the barriers to company digitalization (Mesa et al., 2022). The solution created as part of the project contributed to:

- improved product efficiency and quality,
- eliminating many time-consuming steps and tasks in the company's data management process,

- minimizing data entry errors,
- increasing the flexibility of operations,
- facilitating supervision at production plants around the world.

Thanks to this process and the results achieved, the organization's flexibility and ability to learn and adapt were strengthened, which positively impacted the company's organizational resilience.

An example of a hospital pharmacy project in the Asir region of Saudi Arabia – improving outpatient services

This case study is based on a publication by Almaghaslah et al. (2021), presenting the results of a project implemented in the pharmaceutical sector in Saudi Arabia using Design Thinking methodology. The project focused on understanding the context of pharmaceutical service delivery in selected hospitals (Almaghaslah et al., 2021).

Project implementers: The project was implemented by an interdisciplinary project team in the pharmacies of two hospitals in the Asir region (Almaghaslah et al., 2021).

Problems to be solved: Patients in hospital pharmacies complained about long queues, inefficient service processes, uncomfortable pharmacy conditions, and insufficient service quality. Staff overload and a lack of digital tools supporting patient management were also issues.

Project Objective: To evaluate and improve the patient experience in two hospital pharmacies in the Asir region using DT (Almaghaslah et al., 2021).

Project stages: The innovation project was conducted in 2020 based on the Stanford University D-School Design Thinking methodology and was divided into the following stages (Almaghaslah et al., 2021):

- Empathize – semi-structured interviews with patients were conducted and the pharmacy environment of the hospitals selected for the study were observed.
- Define – based on the analysis of the obtained results, the following key problems were identified: uncomfortable customer service areas in pharmacies, lack of an effective queue management system, inefficient flow of medication orders and deliveries, lack of electronic prescriptions, and lack of equal treatment of patients based on gender. At the end of this stage, the most important needs were synthesized and prioritized.
- Ideate – using selected creative thinking methods and techniques such as brainstorming and mind mapping, solution ideas were identified, including a queue management system, the introduction of electronic prescriptions, redesigning pharmacy waiting rooms to improve the comfort of waiting in line, and solutions for patients with disabilities.
- 4. Prototype – Prototypes were developed to address defined challenges in the customer service process in pharmacies.

- Test – tests of the proposed interior design solutions and software solutions were conducted in the context of the identified needs and expectations of customers in both hospital pharmacies.

Project Outcome: In response to identified customer needs, a prototype of a digital queue management system was created. Solutions were proposed to address individual customer expectations, creating the potential to improve the pharmaceutical service experience using modern technologies and digital tools (Almaghaslah et al., 2021). These solutions can increase organizational resilience by supporting innovation and human-centric innovation, thus building greater credibility and trust among users.

Comparison of the analyzed case studies

The table below summarizes four different case studies using Design Thinking in the digital economy (Table 1). It considers the project context, the method of applying Design Thinking, and the results achieved in terms of organizational resilience. The comparison demonstrates that, despite the diversity of industries and geographies, Design Thinking enables effective solutions to digitalization challenges, improves service quality, and increases organizational agility and adaptability.

Table 1.

Comparison of case studies on the application of Design Thinking in the digital economy and its impact on organizational resilience

Case study	Context	Application of Design Thinking	Effect on organizational resilience
IBM – IBM z14 mainframe system (Eickhoff et al., 2018; IBM Design, 2025)	Project to develop a new z14 mainframe system for the digital economy; over 1000 IBM engineers involved.	An iterative process based on the Observe–Reflect–Make model, integrating DT and Agile; stakeholder engagement and solution prototyping.	Faster response to market needs, better system adaptation to customers, shorter time to market for innovations, reduction of the risk of costly mistakes.
IRIS Bank (Indonesia) (Simanjuntak, Ghazali, 2025)	Improving digital banking services in response to system errors and declining customer satisfaction.	The classic five-step DT process (Empathize–Define–Ideate–Prototype–Test), with interviews, surveys, and application prototype iteration.	A more stable banking application, increased customer satisfaction, improved loyalty, and service quality, contributing to enhanced operational resilience.
Eudaemon Technologies (Australia) (Mesa et al., 2022)	SMEs in the manufacturing sector; need to improve the process of collecting and tracking production data.	Iterative DT approach (Discover–Define–Develop–Deliver), prototyping of IoT solutions and dashboards for data analysis.	Reducing the risks of digitization, improving quality and efficiency, increasing flexibility and adaptability, supporting resilience to digital challenges.

Cont. table 1.

Hospital pharmacies in the Asir region (Saudi Arabia) (Almaghaslah et al., 2021)	Problems with long queues and outpatient service in hospital pharmacies.	The DT process in the Stanford D-School model; patient research, problem mapping, prototyping of a queueing system and e-prescriptions.	Improving patient experiences, developing a prototype digital queueing system, increasing user trust, orienting towards innovation, which affects organizational resilience in healthcare.

Source: own study based on: Almaghaslah, Alsayari, Alyahya, Alshehri, Alqadi, Alasmari, 2021, p. 854; Eickhoff, McGrath, Mayer, Bieswanger, Wojciak, 2018, pp. 1:1-1:9; IBM Design, 2025; Mesa, Renda, Kuys, Cook, 2022, p. 14358; Simanjuntak, Ghazali, 2025, pp. 2172-2184.

The analysis of four case studies indicates that applying Design Thinking methodology in various contexts of the digital economy, from IT and banking, through manufacturing, to the healthcare sector, enables effective solutions to complex digitalization-related problems, which increases an organization's resilience. The results of the analysis indicate that:

- IBM demonstrated that DT combined with Agile increases the speed and precision of implementing complex IT solutions, strengthening an organization's adaptability.
- IRIS Bank demonstrated that a classic DT process improves the quality of digital services and customer loyalty, strengthening an organization's competitive resilience.
- Eudaemon Technologies demonstrated that DT reduces the risk of digitization in the SME sector through rapid prototyping and stakeholder collaboration.
- Hospital pharmacies demonstrated the potential of DT in the public sector, where digital tools can improve patient service and strengthen trust in institutions.

The common denominator across all cases is that Design Thinking increases organizational resilience by:

- responding more quickly to change,
- reducing risks in digitalization,
- improving the quality of services and user experience,
- building user trust through human-centricity,
- strengthening flexibility and the ability to respond to threats and emerging opportunities to implement innovation.

5. Discussion and conclusions

The issues addressed in this article provide a new theoretical perspective, identifying Design Thinking (DT) as a systemic tool that can serve as a bridging mechanism between digital transformation and organizational resilience. The conducted literature analysis and case studies indicate that the use of DT methodology in projects related to the digital economy is an important factor in strengthening organizational resilience. This is influenced by user-

centricity, iterative testing and prototyping, and working in interdisciplinary teams. This promotes increased organizational agility, shortened innovation cycles, and reduced risk of failure. As a result, organizations implementing DT become more capable of quickly responding to changing market conditions and adapting in the face of unpredictable disruptions.

The results of the analyses confirm that creative problem-solving can be considered a strategic organizational resource supporting digital transformation processes. Creativity in the digital economy is essential for designing innovative digital tools and services, which is crucial for building competitive advantage in conditions of uncertainty (Bai et al., 2020). This, in turn, increases an organization's resilience to potential threats and disruptions. The high level of creativity used in implementing innovative projects using the Design Thinking method enables the design of more inclusive innovative solutions applicable across various fields (Nambisan et al., 2019).

The research conducted, based on secondary data, literature, and case studies, limits the generalizability of conclusions and the possibility of directly verifying the empirical relationship between the use of Design Thinking and organizational resilience. At the same time, it should be emphasized that the presented research and case studies focus primarily on selected sectors (IT, finance, healthcare), which limits the possibility of full generalization of the results. Future research should therefore encompass a broader spectrum of industries and analyze the relationships between DT practices and organizational culture, leadership, and digital transformation processes in a longitudinal approach. This justifies the need for research that combines qualitative and quantitative approaches.

From a practical implications perspective, the findings confirm that DT can be an effective tool supporting organizations in creatively designing innovative digital solutions, while simultaneously strengthening their strategic and operational resilience. Companies implementing DT should invest in developing employee design competencies, create space for experimentation, and build learning mechanisms within interdisciplinary teams.

In the social dimension, the dissemination of DT practices in the digital economy can contribute to the creation of more inclusive solutions that respond to real user needs, while also supporting social responsibility and sustainable development. Therefore, the use of DT in organizational digitization processes becomes not only a tool for strengthening competitiveness but also a mechanism for building societal resilience in the face of the challenges of the digital era.

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ARTIFICIAL INTELLIGENCE IN PROJECT MANAGEMENT: ANALYSIS OF TRENDS AND CHALLENGES BY LITERATURE REVIEW

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Purpose: This paper aims to conduct a comprehensive literature review of the application of artificial Intelligence (AI) in project management, focusing on research trends, challenges, and directions for further study. The author examines whether current research sufficiently considers organisational implications and changing competence requirements for project managers, or mainly emphasizes technical aspects.

Design/methodology/approach: The article is based on a systematic literature review conducted per the PRISMA 2020 guidelines. A total of 4558 records were extracted from Web of Science and Scopus databases, from which 118 publications from 2020 to 2025 were selected. The study combines bibliometric and qualitative content analysis, focusing on the types of AI used, application areas, implementation challenges, and references to managerial competences.

Findings: The findings confirm that most of the academic literature on AI applications in project management focuses on technical and operational aspects such as predictive models, scheduling optimisation, or decision support. Only 8 of the 118 publications analysed refer directly to the organisational implications of AI implementation, and only seven address the topic of competence requirements for project managers. This confirms the research hypothesis set out regarding the marginalisation of organisational and human factors. The review also identified key thematic clusters and research gaps.

Research limitations/implications: The study was limited to English-language publications released over a six-year period and available in two databases. In the future, it is advisable to expand the sources with case studies and empirical evidence to provide deeper insights into AI's practical and organisational impact. An interdisciplinary approach is recommended.

Practical implications: The paper highlights the need for a comprehensive approach to AI implementation in a project environment, addressing not only technological issues but also organisational structures and competence requirements. The creation of new competence models for project managers in digital environments is emphasised.

Social implications: Noting the under-recognition of the organisational impact of AI implementation, the author encourages more balanced research that also includes ethical, cultural, and project team transformation issues.

Originality/value: The paper is one of the few studies that provide a systematic literature analysis of not only AI application in project management, but also neglected organisational and competence-related aspects. It offers value to researchers and practitioners interested in AI implementation in project environments.

Keywords: Artificial Intelligence, project management, AI applications, project manager competences.

Category of the paper: Scientific paper.

1. Introduction

Recent years have seen the rapid development of artificial Intelligence, which is increasingly entering project management practice. Implemented solutions range from simple process automation, such as schedule management or information flow, to advanced systems based on machine learning that support decision-making, risk management, or resource allocation (Dimcheva, 2024; Salimimoghadam et al., 2025; Fridgeirsson et al., 2021). Artificial Intelligence enables automation of routine tasks, increases productivity, and supports decision-making based on data analysis (Sarafanov, Valilai, Wicaksono, 2024; Čančer, Tominc, Rožman, 2023).

Project management has long been a field susceptible to the adaptation of new technologies, but AI application brings a new transformation dimension in terms of quality. This may affect the way in which planning, monitoring, anticipating risks or communicating within the project team is carried out (Walee et al., 2024). The literature also points to the role of artificial Intelligence in improving project outcomes and reducing risk (Sarafanov, Valilai, Wicaksono, 2024; Dimcheva, 2024).

Although the number of publications on AI application in project management continues to grow, there is no comprehensive picture of what aspects are most commonly studied, what challenges prevail, and whether there is an outline consensus on the direction of further AI development in this field (Salimimoghadam et al., 2025).

This raises the validity of the following research problem: How does AI affect project management in light of trends and challenges identified in the academic literature? The following questions are intended to be addressed to resolved the above problem:

1. What AI applications in project management are most commonly analysed in the academic literature?
2. What are the main challenges and risks associated with AI implementation in project management identified in the literature?
3. Is there a consensus in the literature on the development of artificial Intelligence in project management?

Therefore, this paper aims to conduct a systematic review of the scientific literature on AI application in project management to identify the main research trends as well as theoretical and practical challenges. The author analyses publications from two scientific databases, i.e. Web of Science and Scopus, in accordance with the PRISMA 2020 methodological

guidelines. Both bibliometric analysis and qualitative content analysis of selected publications were used.

Based on the literature analysis, the following research hypothesis was attempted to be verified: The scientific literature on AI application in project management mainly focuses on technical aspects, marginalising issues related to organisational consequences and the required managerial competences.

The verification of this hypothesis was based on an analysis of the publications, including the classification of types of AI applications, the identification of threats related to implementation challenges, and the presence of references to competences, organisational changes, and the cultural context. The results aim to add to existing knowledge by demonstrating the current research state and identifying gaps that should be addressed in future theoretical and empirical work.

2. Research methodology

The study aimed to identify current trends and challenges in AI application in project management. The study constituted a systematic review with elements of bibliometric and quality analyses. For the systematic literature review, an approach in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines was used to ensure transparency and clarity in the research process (Page et al., 2021). It included the following stages: research problem formulation, criteria selection and searching, selection of publications and data analysis. The research problem, questions and hypothesis are presented in the introduction, and a focus on describing the systematic literature review process.

2.1. Searching for Scientific Publications

A literature search was conducted in two leading scientific databases: Web of Science (WoS) and Scopus. The scope of the search was limited to English-language publications, published between 2015 and 2025, and to three documents: scientific papers, review papers and conference presentations.

The following search query was applied to the Web of Science database: TS = ("artificial intelligence" OR "machine learning" OR "deep learning") AND TS = ("project management" OR "project planning" OR "project manager"). On the other hand, the Scopus database featured the following query: (TITLE-ABS-KEY("artificial intelligence") OR TITLE-ABS-KEY("machine learning") OR TITLE-ABS-KEY("deep learning")) AND (TITLE-ABS-KEY("project management") OR TITLE-ABS-KEY("project planning") OR TITLE-ABS-KEY("project manager")).

A total of 4558 records were identified, of which 696 were from the WoS database and 3862 from Scopus. The results were exported in structured forms for bibliometric analysis.

2.2. Selection of Relevant Publications

The selection of publications followed the steps recommended by Page et al. (2021). The publication selection process is shown in the diagram (Figure 1), which was prepared using the free online Shiny App software developed by Haddaway, Page, Pritchard and McGuinness (2022).

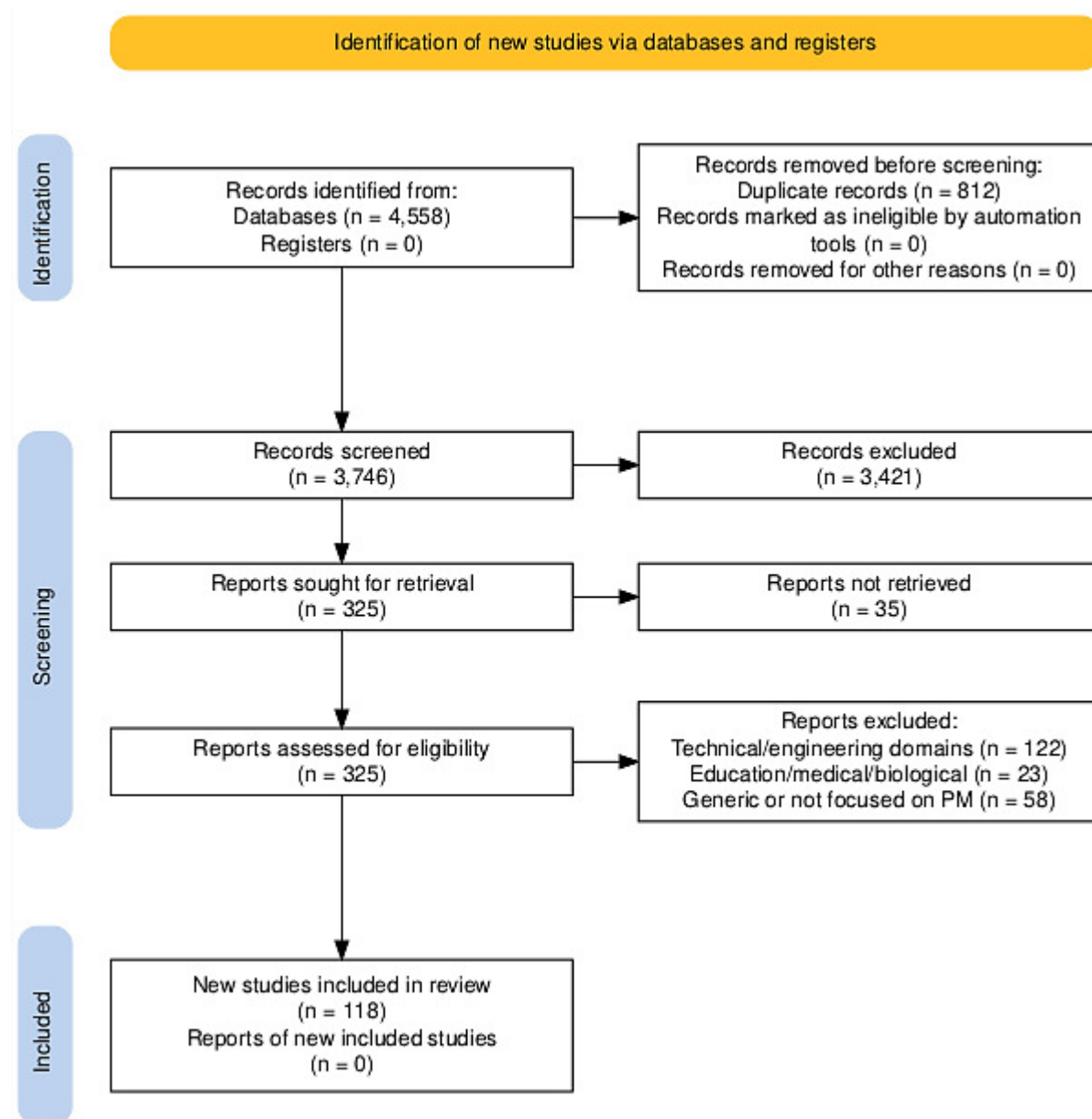


Figure 1. Diagram of a systematic literature review in line with the PRISMA2020 guidelines.

Source: elaboration prepared using the Shiny App.

In the first instance, 812 duplicate and incomplete records were removed, leaving 3746 publications. A preliminary review of titles and abstracts was then carried out, resulting in the exclusion of 3421 publications that did not relate to the topic of AI and project management. 325 publications were shortlisted for the next stage, of which 35 could not be obtained in full text. The remaining 290 publications were subjected to full-text analysis. The thematic selection excluded 203 publications that dealt exclusively with technical issues (e.g. construction, robotics, software engineering), as well as papers focused on medicine, education or biology, without reference to project management processes. The decision was made to focus on general trends and organisational challenges related to AI application. In addition, the time horizon for publication has been narrowed to 2020-2025. As a result, 118 scientific publications meeting thematic, linguistic and time criteria were included in the final analysis. A summary of all exclusion and inclusion criteria is presented in Table 1.

Table 1.

Criteria for the selection of publications for the literature review

Category	Inclusion Criteria	Exclusion Criteria
Timeframe	Publications from 2020–2025	Publications before 2020
Publication Language	English language	Other than English
Document Type	Article, Review, Conference Paper	Non-scientific (e.g., editorial, note)
Presence of Keywords	Presence of at least one keyword from AI and PM	Lack of references to artificial Intelligence or project management in the title/abstract
Main Topic	AI in the context of project management	Artificial Intelligence treated marginally, or project management as background
Excluded Fields	None	Medicine, education, biology, agriculture
Excluded Industries	No dominance of a single industry – general or organizational perspectives preferred	Construction, engineering, infrastructure, IT

Source: own elaboration.

2.3. Review of Selected Publications

Qualitative content analysis using a structured coding scheme was used to analyse 118 selected scientific publications. Each publication was assessed in terms of the following:

- areas of AI application in project management,
- type of AI used in project management,
- benefits of AI application in project management,
- barriers and challenges of AI application in project management,
- references to the project manager's competences and other contexts.

In addition, the selected publications were used to identify research gaps and areas worth considering for further research.

3. Results

3.1. Bibliometric Analysis

The bibliometric analysis identified the main research directions and thematic links in the field of AI application in project management. A co-occurrence analysis of authors' keywords was carried out using the VOSviewer tool. The source data in .txt and .csv form was imported with the standard configuration. A minimum threshold of 10 keyword occurrences was set and the analysis was performed in co-occurrence – author keywords mode. Data from two databases were analysed: Web of Science (n = 696) and Scopus (n = 3862). The results are presented in Figures 2 and 3. The figures show a visualisation of the co-occurrence of keywords from both databases. The size of the labels reflects the frequency of occurrence, while the colour indicates affiliation to a particular thematic cluster.

In the case of the Web of Science database (Figure 2), 151 keywords were eligible for analysis, forming five clearly distinguishable thematic clusters. The most common concepts include:

- project management,
- Artificial Intelligence,
- machine learning,
- deep learning,
- optimization,
- natural language processing,
- construction management.

His analysis pointed to a strong link between concepts related to AI implementation in engineering, information management, and risk and cost management. The clusters point to thematic diversity from technical aspects (i.e.: neural network, software effort estimation) to strategic elements (i.e.: digital transformation, economic security).

In contrast, an analysis of publications from the Scopus database (Figure 3) identified 314 keywords, which also fall into five clusters. The most significant nodes include:

- project management,
- machine learning,
- deep learning,
- big data,
- BIM (Building Information Modelling),
- decision-making support systems.

The 15 most frequent keywords in both databases were identified based on the frequency of their co-occurrence. Table 2 provides a summary of the key terms that dominate the literature on AI application in project management in the Web of Science and Scopus databases.

Table 2.

Most frequently occurring keywords in the Web of Science and Scopus databases

Web of Science Keywords		Scopus Keywords	
Keywords	Number of Occurrences	Keywords	Number of Occurrences
project management	201	machine learning	506
artificial Intelligence	172	project management	485
machine learning	160	artificial Intelligence	465
model	59	deep learning	171
management	54	construction management	123
performance	52	decision support system	93
artificial-intelligence	42	decision support systems	86
construction	40	risk management	73
system	35	natural language processing	58
deep learning	35	artificial Intelligence	54
classification	32	optimization	54
big data	27	construction	53
framework	26	big data	48

Source: own elaboration.

The following keywords ranked highest in the Web of Science database: project management, machine learning, artificial Intelligence, deep learning and optimization. In the Scopus database, on the other hand, the most frequent keywords are: machine learning, project management, artificial Intelligence, deep learning, construction management and decision support systems.

Six keywords appear at the top of both bases and they are: artificial Intelligence, machine learning, project management, deep learning, big data and construction. This demonstrates a specific core of terminology that prevails regardless of the data source. However, it is worth noting the significant thematic equality between the databases. There are unique keywords in the Web of Science database such as model, classification, performance, system or prediction, which may suggest a greater interest in modelling and data analysis. On the other hand, the Scopus database includes headings typical of practical and industry applications, such as decision support systems, construction management, optimization, risk management, and natural language processing.

Based on a comparative analysis of the data from both databases, it can therefore be concluded that publications from the Scopus database are characterised by a greater range of topics and a broader keyword index than publications from the Web of Science, which may be due to differences in editorial policies and a larger number of indexed conference presentations. The observed pattern of keyword clusters in both databases confirms the interdisciplinary nature of the field under study and points to clear links between artificial intelligence technologies and their specific applications in project management.

3.2. Areas of AI Application in Project Management

A content analysis of the 118 scientific publications shortlisted for further study identified the main areas of AI application in project management, which are: automation, planning, monitoring, risk management and others. The classification was carried out in a qualitative manner based on a review of the publications and aimed to isolate the dominant functions that artificial Intelligence performs in project practice. Table 3 shows the classification of publications according to these application areas.

Table 3.

Classification of publications by areas of AI application in project management

Application area of AI	Authors of the publication
Project monitoring	Zhao (2023); Zaidouni, Idrissi, Bellabdaou (2024); Wu, Zhu, Zhao (2022); Wachnik (2022); Vergara et al. (2025); Vărzaru et al. (2022); Uddin et al. (2023); İnan, Narbaev, Hazir (2022); Georgiev et al. (2024); Tashkinov (2024); Tariq et al. (2024); Tamura et al. (2024); Sahadevan (2023); Sousa et al. (2023); Solana-González et al. (2021); Singh, Garg (2023); Sarafanov, Valilai, Wicaksono (2024); Salimimoghadam et al. (2025); Sabahi, Parast (2020); Ribeiro et al. (2024); Abd Rahman et al. (2023); Phung, Ogunshile, Aydin (2025); Pérez Castillo, Orantes Jiménez, Letelier Torres (2024); Allal-Chérif, Simón-Moya, Cuenca Ballester (2021); Nenni et al. (2025); Naz et al. (2022); Müller et al. (2024); Müller (2023); Miller (2022, 2021a, 2021b, 2020); Merhi, Harfouche (2023); Merencio, Grander (2024); Mancini, Mariani, Manfredi, (2023); Mbizo et al. (2024); Al Mamlook et al. (2024); Malik et al. (2021); Mahdi et al. (2021); Madson, Gade, Srivastava (2025); Liu et al. (2024); Kultan (2022); Biesialska, Franch, Muntés-Mulero (2021); Kanakaris et al. (2020); García Vásquez, Kumral (2025); Santos et al. (2023); Jauhar et al. (2023); Hashfi, Raharjo (2023); García Villena et al. (2022); Fridgeirsson et al. (2021); Anyadiiegwu, Kabamba (2022); Engel, Ebel, van Giffen (2021); Degli et al., (2021); Das et al. (2025); Koudriachov, Tam, Aparicio, (2025); Čančer, Tominc, Rožman (2023); Bodea, Mitea, Stanciu, (2020); Bakhshi et al. (2022); Angara, Prasad, Sridevi (2020); Bahi, Gharib, Gahi (2024); Aljaž (2024); Albrecht, A., Albrecht, E. (2021); Felicetti et al. (2024); Ahmadi et al. (2023); Adamantiadou, Tsironis (2025); Dotsenko et al. (2023); Hossain et al. (2024); Titu, Pana, Moldoveanu (2025); Mariani, Mancini (2024); Jiang et al. (2022).
Project planning	Zaidouni, Idrissi, Bellabdaou (2024); Wu, Zhu, Zha (2022); Wachnik (2022); Vergara et al. (2025); Vărzaru et al. (2022); Uddin et al. (2023); İnan, Narbaev, Hazir (2022); Georgiev et al. (2024); Tashkinov (2024); Tariq et al. (2024); Tamura et al. (2024); Sousa et al. (2023); Solana-González et al. (2021); Sarafanov, Valilai, Wicaksono (2024); Salimimoghadam et al. (2025); Sabahi, Parast (2020); Rodríguez et al. (2025); Ribeiro et al. (2024); Abd Rahman et al. (2023); Phung, Ogunshile, Aydin (2025); Nenni et al. (2025); Naz et al. (2022); Müller et al. (2024); Müller (2023); Miller (2022, 2020); Merhi, Harfouche (2023); Merencio, Grander (2024); Mbizo et al. (2024); Mansoor et al. (2024); Malik et al. (2021); Mahdi et al. (2021); Madson, Gade, Srivastava (2025); Liu et al. (2024); Lishner, Shtub (2022) Biesialska, Franch, Muntés-Mulero (2021); Kanakaris et al. (2020); García Vásquez, Kumral, (2025); Santos et al. (2023); Jauhar et al. (2023); Mahdi et al. (2021); Hashfi, Raharjo (2023); Hosni, Idri, Abran (2021); García Villena et al. (2022); Fridgeirsson et al. (2021); Anyadiiegwu, Kabamba (2022); Engel, Ebel, van Giffen (2021); Dimcheva (2024); Aiken et al., (2021); Das et al. (2025); Koudriachov, Tam, Aparicio, (2025); Čančer, Tominc, Rožman (2023); Bodea, Mitea, Stanciu (2020); Bakhshi et al. (2022); Angara, Prasad, Sridevi (2020); Bahi, Gharib, Gahi (2024); Aljaž (2024); Albrecht, A., Albrecht, E. (2021); Felicetti et al. (2024); Ahmadi et al. (2023); Adamantiadou, Tsironis (2025); Titu, Pana, Moldoveanu (2025); Mariani, Mancini (2024); Ammar et al. (2022); Olukoga, Feng, (2022); Alketbi, Dweiri, Dalalah, (2025); Allal-Chérif, Simón-Moya, Cuenca Ballester (2021); Hossain et al. (2024); Urata, Kawanaka, Rokugawa (2022).

Cont. table 3.

Automation of routine tasks and communication processes	Zhao (2023); Zaidouni, Idrissi, Bellabdaoui (2024); Yasmin, Haider Butt, Daud (2024); Wu, Zhu, Zha (2022); Wachnik (2022); Vergara et al. (2025); Vărzaru et al. (2022); Vărzaru (2022); Uddin et al. (2023); İnan, Narbaev, Hazir (2022); Georgiev et al. (2025); Tashkinov (2024); Tariq et al. (2024); Tamura et al. (2024); Sousa et al. (2023); Solana-González et al. (2021); Singh, Garg (2023); Sarafanov, Valilai, Wicaksono (2024); Sabahi, Parast, (2020); Rodríguez et al. (2025); Ribeiro et al. (2024); Phung, Ogunshile, Aydin (2025); Pérez Castillo, Orantes Jiménez, Letelier Torres (2024); Allal-Chérif, Simón-Moya, Cuenca Ballester, (2021); Nenni et al. (2025); Naz et al. (2022); Müller et al. (2024); Miller (2022, 2020); Merhi, Harfouche (2023); Merencio, Grander (2024); Mbizo et al. (2024); Al Mamlook et al. (2024); Malik et al. (2021); Mahdi et al. (2021); Madson, Gade, Srivastava (2025); Liu et al. (2024); Kultin (2022); Kanakaris et al. (2020); García Vásquez, Kumral (2025); Jauhar et al. (2023); Hazil et al. (2020); Hashfi, Raharjo (2023); García Villena et al. (2022); Fridgeirsson et al. (2021); Anyadiegwu, Kabamba (2022); Engel, Ebel, van Giffen (2021); Dimcheva (2024); Aiken et al., (2021); Das et al. (2025); Koudriachov, Tam, Aparicio (2025); Čančer, Tominc, Rožman (2023); Bodea, Mitea, Stanciu (2020); Bakhshi et al. (2022); Angara, Prasad, Sridevi (2020); Bahi, Gharib, Gahi (2024); Aljaž (2024); Albrecht, A., Albrecht, E. (2021); Felicetti et al. (2024); Ahmadi et al. (2023); Adamantiadou, Tsironis (2025); Sarwar, Rahman (2024); Holzmann, Zitter, Peshkess (2022); Senarath, Berntzen (2025); Popa et al. (2023); Anyadiegwu, Kabamba (2022); Muravev et al. (2025).
Project risk	Zhao (2023); Miller (2022); Merhi, Harfouche (2023); Merencio, Grander (2024); Mancini, Mariani, Manfredi, (2023); Mbizo et al. (2024); Liu et al. (2024); Kanakaris et al. (2020); Angara, Prasad, Sridevi (2020); Albrecht, A., Albrecht, E. (2021); Zaidouni et al. (2024); Titu, Pana, Moldoveanu (2025); Lai et al. (2024); Zwilling, Eckhaus (2021); Nazarenko et al. (2022); Sousa et al. (2021); Imbugwa, Gilb, Mazzara (2025); Aslan (2021).
Other	Vial et al. (2023); Taye, Feleke, (2022); Sakhravi, Sellami, Bouassida (2022); Miller (2021b); Mbizo et al. (2024); Hosni, Idri, Abran, (2020); Hassanali et al. (2025); Mostaeen et al. (2020); Jiang et al. (2022); Bohn, Braun (2021); Anitha, Parveen (2024); Vyas (2025); Haidabrus (2024); Pastierik (2024); Mikhaylov (2023); Odeh (2023); Ogunleye (2023); Jang (2022); Holzmann, Zitter, Peshkess (2022); Ribeiro, Ramos (2023); Lopes Gomes et al. (2024); Khan, Adil (2023); Zhang, Y., Zhang, C., Hu (2025); Prakiljačić et al. (2024); Mikhaylov (2023); Shukla, Kumar (2023).

Source: own elaboration.

The most significant number of studies (70 publications) were identified on AI application for project monitoring. This type of research is conducted by Singh and Garg (2023), Tariq et al. (2024) and Solana-González et al. (2021), among others. In this area, the use of artificial Intelligence is being explored for ongoing project progress tracking, data quality control and resource utilisation. Just two fewer publications (69 papers) point to research on the AI application for project planning, which focuses on areas such as predicting schedules, optimising resource allocation, or creating decision-making scenarios. Researchers working in these areas include Nenni et al. (2025), Biesialska et al. (2021) as well as Adamantiadou and Tsironis (2025). In contrast, the automation of project management processes is pointed out by the authors of 66 publications, which include, in particular, Zhao (2023), Wachnik (2022), Müller et al. (2024), and Ribeiro et al. (2024). In this area, AI is applied to streamline routine project tasks, such as communication, reports generation, documentation analysis or integration of data from different systems. Much less research was identified on risk (18 publications) and other areas such as AI impact on the role of the project manager, ethical issues or digital transformation (26 publications). In terms of risk, AI is used to identify, assess and predict project risks. Researchers on this topic include Mancini et al. (2023), Zwilling and Eckhaus

(2021), and Nazarenko et al. (2022). In contrast, research on other areas is being conducted by Vial et al. (2023), Mikhaylov (2023) or Hassanali et al. (2025), among others.

3.3. Type of AI Applied in Project Management

Four predominant types of AI technology applied in project management were identified in the scientific literature analysed, such as machine learning (ML), deep learning (DL), natural language processing (NLP) and less represented other AI forms such as expert systems or hybrid algorithms. Figure 4 shows the distribution of AI types in project management. The most common AI type was machine learning (72 publications), used, among others, to build predictive, classification and decision support models (Adamantiadou, Tsironis, 2025; Ahmadi et al., 2021; Taboada et al., 2023). In second place in terms of numbers was deep learning (65 publications), which was mainly used in image analysis, processing of large data sets and process automation (Zabala-Vargas, Jaimes-Quintanilla, Jimenez-Barrera, 2023; Mohamed, Moselhi, 2022).

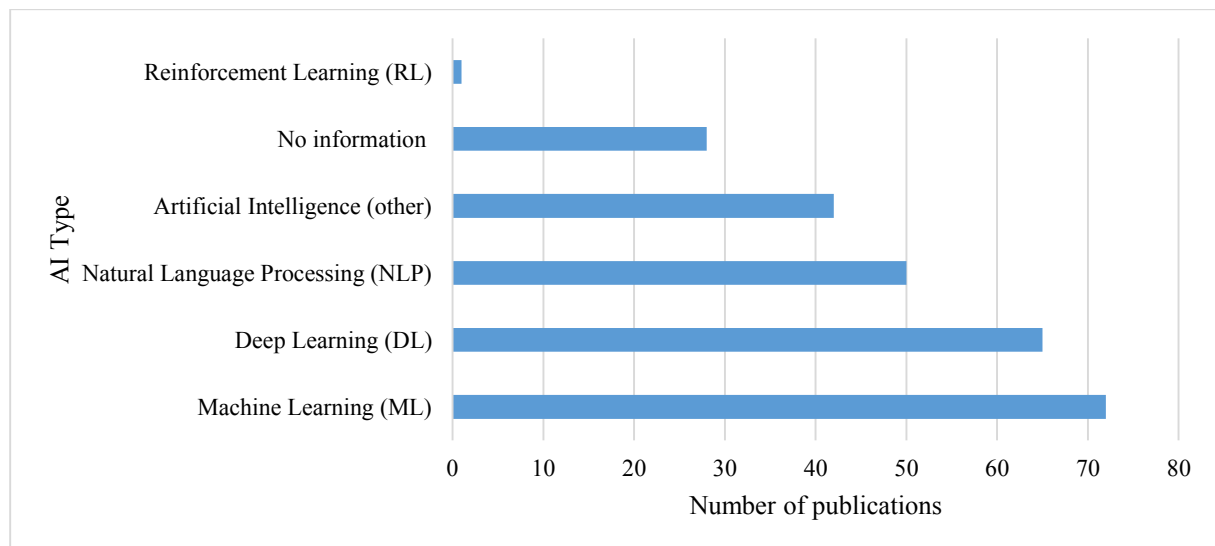


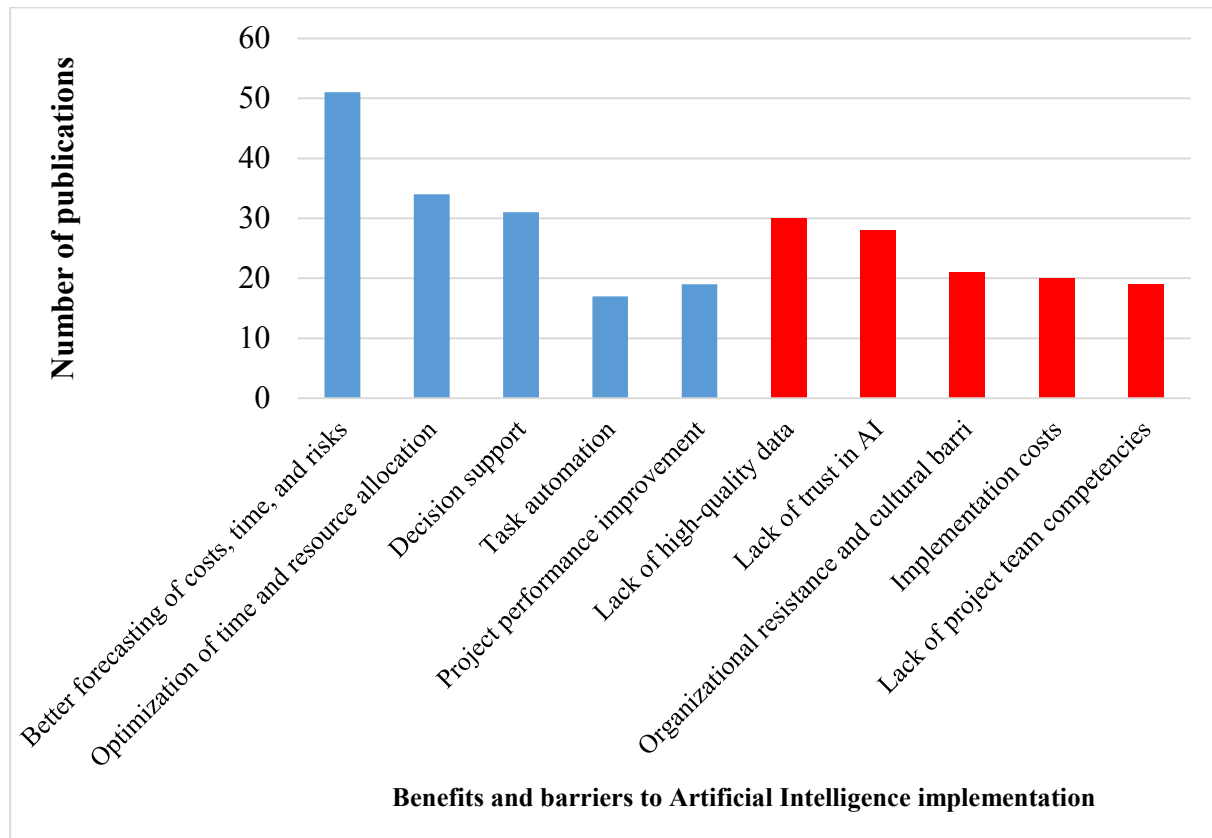
Figure 4. Type of Artificial Intelligence used in project management.

Source: own elaboration.

Just under half of the publications describe the use of natural language processing in project management (50 publications). It has been used to analyse documentation, extract information from test data and support human-machine communication (Ahmadi et al., 2021, 2023). The use of general artificial intelligence techniques without clear attribution to a specific category has been reported in a smaller number of cases, which may point to an early stage of exploration (Adamantiadou, Tsironis, 2025; Ahmadi, 2023; Yu, 2023). In addition, more than 20% of the publications analysed did not precisely specify the AI type used, making it difficult to classify them.

3.4. Benefits of and Barriers to AI application in project management

A content analysis of 118 scientific publications indicates that AI application in project management is associated with a number of essential benefits, but also barriers that may limit its implementation or effectiveness. Figure 5 provides a summary of the number of publications specifying the benefits of and barriers to AI application in project management.



Blue indicates the benefits and red the barriers to implementing AI.

Figure 5. A summary of the number of publications specifying the benefits of and barriers to AI application in project management.

Source: own elaboration.

Publications tend to identify three main areas where AI application has the greatest beneficial impact: predictability, optimisation and decision-making. More than 50 publications have indicated that AI applications have brought the benefits of better forecasting of costs and project performance. AI supports a more accurate prediction of risks, delays and budget deviations, resulting in greater control over project delivery. Such opportunities have been particularly highlighted in the work of authors such as Adamantiadou and Tsironis (2025), Fridgeirsson et al. (2023), Nenni et al. (2025), Zhao (2023), Bahroum et al. (2023), Langroodi, Vahdatikhaki and Doree (2021), Mohamed and Moselhi (2022) and Yu (2023). The publications analysed further indicate that AI methods, including machine learning and deep learning, enable the creation of predictive models that support not only cost planning, but also the assessment of project feasibility, estimation of lead times and probability of operational success.

Another important benefit of AI implementation in project management is the optimisation of resource allocation and project duration, which appeared in 34 publications. Authors addressing this issue include Wachnik (2022), Liu et al. (2024), Fridgeirsson et al. (2021), Ribeiro et al. (2024), Tamura et al. (2024), Sousa et al. (2023), Mbizo et al. (2024), Bahi, Gharib, Gahi, (2024) and Mancini, Mariani and Manfredi (2023). The next frequently identified area is decision support, which was identified in 31 publications. Authors addressing this topic include Müller (2023), Singh and Garg (2023), Raharjo (2023), Adamantiadou and Tsironis (2025), Zaidouni, Idrissi, Bellabdaou (2024), Abd Rahman et al. (2020), Ribeiro et al. (2024), Pérez Castillo, Orantes Jiménez, Letelier Torres (2024), Kanakaris et al. (2020) and Mahdi et al. (2021). Also, the automation of repetitive tasks was identified as an important benefit and is addressed by 17 publications. Authors exploring this area include Wachnik (2022), Müller (2023), Zaidouni, Idrissi, Bellabdaou (2024), Allal-Chérif, Simón-Moya, Cuenca Ballester (2021) and Sarafanov, Valilai, Wicaksono (2024).

Despite the growing interest in AI application in project management, the literature reviewed points to a number of barriers limiting the successful implementation of these technologies. The most commonly identified challenges include limited access to quality data and a lack of adequate infrastructural and organisational preparedness (Wachnik, 2022; Adamantiadou, Tsironis, 2025). A number of publications have also pointed out the lack of trust in such solutions and the reluctance of stakeholders to delegate decisions to learning systems (Fridgeirsson et al., 2023; Tominc et al., 2024; Tominc, Oreški, Rožman, 2023). In addition, authors such as Zhao (2023) and Yu (2023) highlight the difficulties associated with the interpretability of the algorithms and the lack of transparency in the decisions made. A part of the research also emphasises the high cost of implementation, the lack of digital competence of project teams and cultural resistance in organisations (Langroodi et al., 2021; Mohamed, Moselhi, 2022). Although technically recognised, these barriers are often marginalised in publications presenting an analysis of the effectiveness of AI application, confirming the research hypothesis that the organisational consequences and changing competences of project managers are under-exposed in research.

4. Discussion

4.1. Interpretation of the Results in Light of the Study's Aim

The research aimed to determine how AI affects project management in light of the trends and challenges identified in the academic literature from 2020 to 2025. Based on a systematic review of 118 scientific publications from the Scopus and Web of Science databases, it was possible to answer the research questions posed:

1. What AI applications in project management are most commonly analysed in the scientific literature?
2. What are the main challenges and risks associated with AI implementation in project management identified in the research?
3. Is there a consensus in the literature on the development of artificial Intelligence in project management?

With regard to the first research question, the most frequently analysed AI applications include: project duration and cost forecasting (more than 50 publications), resource allocation and scheduling optimisation (34), decision support (31), automation of repetitive activities (17), and risk analysis and threat prediction (20). This points to the dominance of the technical and operational aspects of applying AI to project management. AI application in a strategic, organisational or interpersonal context was analysed far less frequently.

In answering the second question, the authors of the scientific publications analysed point to the following as challenges and threats to AI implementation: lack of high-quality data (30 publications), lack of trust in the algorithms (28), high implementation costs (21), organisational resistance and cultural barriers (20), as well as insufficient competences of project teams (19). Exactly nine publications raised issues related to the lack of clear regulations and the difficulty of prescribing responsibility for decisions made by AI.

Only eight publications (6.8%) directly addressed the organisational implications of AI implementations or the competence requirements for the project manager, which could be a starting point for further research.

Regarding the lack of a consistent consensus in the literature on the future development of AI application (the third research question), some authors predict that there will continue to be a move towards operational automation. Others point to AI potential for strategic decision support and risk management. What is lacking, however, is a deeper consideration of the transformation of project roles in an AI implementation environment.

Based on the analysis of 118 scientific publications, it can be concluded that the research hypothesis has been confirmed. The literature on AI in project management focuses mainly on the technical and functional aspects, with marginal consideration of the organisational implications and the issue of project manager competences. This is an important research gap that should be explored more extensively in future research.

4.2. Organisational and Competence Challenges for the Project Manager in the Context of AI Implementation

Despite the growing interest in AI in project management, most publications focus mainly on technological aspects, such as the accuracy of predictive models, the efficiency of algorithms or the improvement of operational processes. Only 8 of the 118 analyzed publications refer explicitly to implementing AI solutions' organizational consequences. Publications have pointed out that AI implementation necessitates a change in management structure,

transformation of processes and the need to adapt new working systems. These issues were addressed by Wachnik (2022), Vărzaru et al. (2022), Georgiev et al. (2024), Salimimoghadam et al. (2025), Rodríguez et al. (2025), Naz et al. (2022), Müller (2023), Miller (2020), Hashfi, Raharjo (2023), Engel, Ebel and van Giffen (2021), Aljaž (2024).

Even less attention has been paid to questions of project manager competences. Only seven publications (5.9%) mentioned the impact of artificial intelligence solutions on the competence requirements for project managers. This issue was raised by Fidegeirsson et al. (2021), Felicetti et al. (2014), Senarath, Berntzen (2025), Bahi, Gharib, Gahi (2024), Aslan (2021), Khazaei et al. (2022) and Mancini, Mariani, Manfredi (2023). They mentioned the following aspects: the need to develop analytical skills, data interpretation, collaboration with intelligent systems and adaptation to new decision-making models.

This low percentage of papers referring to organisational aspects and competences of project managers confirms the research hypothesis adopted, according to which The academic literature on AI in project management focuses mainly on the technical aspects, marginalising issues related to the organisational implications and the required competences of project managers.

The results of the analysis are part of the observed trend that AI research still rarely enters into dialogue with the literature on management, organisation and competence development. The identified gap provides an important direction for future research, especially in terms of the need to build new competence models for project managers operating in digital environments.

4.3. Identified Research Gaps

Despite the growing interest in the topic of AI in project management, an analysis of the scientific literature has identified a number of significant research gaps that limit the understanding and practical implementation of AI solutions in this area. Firstly, there is a conspicuous lack of interdisciplinary research on AI application in project management. In contrast to the extensive studies on the impact of AI on finance, industry, the economy or the labour market, the area of project management remains relatively under-researched (Salimimoghadam et al., 2025; Fridgeirsson et al., 2021; Wachnik, 2022).

Another important gap is the insufficient exploration of the 'soft' aspects of project management, such as the management of communication, stakeholders or project teams. These areas, although crucial to project success, are rarely addressed in studies that focus mainly on technical issues such as cost prediction or process automation (Adamantiadou, Tsironis, 2025; Sarafanov, Valilai, Wicaksono, 2024).

Furthermore, as mentioned earlier in this chapter, there is a lack of research on the impact of AI on the roles and competences of the project manager and the project team. Few publications signal a potential deficit of AI-related knowledge and skills among project

managers, which may contribute to low organisational readiness to implement new technologies (Fridgeirsson et al., 2021; Wachnik, 2022).

The literature reviewed also identifies the following research gaps and challenges (Fridgeirsson et al., 2021; Middleton, 2024; Wachnik, 2022; Sarafanov, Valilai, Wicaksono, 2024):

- the need for empirical research into the long-term impact of AI on project management and process transformation,
- challenges related to the interpretability of AI-based decisions and the resulting organisational resistance,
- problems with data availability and consistency,
- limited level of creativity of current AI solutions, which makes it difficult to apply to complex, non-standard project situations.

These research gaps point to the need for interdisciplinary and applied research that integrates technological, organisational and competence perspectives. Complementing these can contribute to a fuller use of AI in projects and better prepare managers to manage digital transformation.

5. Conclusions

This paper presents a systematic literature review of AI application in project management between 2020 and 2025. An analysis of 118 selected publications identified the main areas of AI application, technology types as well as benefits of and barriers to AI implementation.

The analysis results indicate that the dominant AI applications in project management are forecasting, schedule optimisation and resource allocation, automation of routine tasks and decision support. The most commonly used technologies are machine learning (ML), deep learning (DL) and natural language processing (NLP).

In turn, the identified benefits of implementing AI include increased efficiency in planning processes, improved decision accuracy, reduced errors and predictability of project outcomes. However, the authors also point to a number of barriers and challenges, such as a lack of access to high quality data, a lack of confidence in AI models, high implementation costs and resistance from organisations.

One of the review's key findings is that the scientific literature mainly focuses on technical aspects. Only a small number of publications address the organisational implications of AI implementation, and even fewer address the changes in the competences required of project managers. This confirms the underlying research hypothesis and points to an important research gap.

Future research would do well to place more emphasis on the integration of organisational perspectives and project manager competences in analyses of AI applications in project management. It is also worth considering interdisciplinary research combining management, organisational psychology and computer science.

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HUMAN CAPITAL AND REGIONAL RESILIENCE: PROFESSIONAL ENGAGEMENT OF UKRAINIAN WAR-AFFECTED REFUGEE WOMEN

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Purpose: This article examines regional resilience from the perspective of human capital and its contribution to the adaptive capacities of communities. The objective of the study is to analyze the determinants influencing labor market engagement of Ukrainian war-affected refugee women in the Lublin region.

Design/methodology/approach: The research was conducted using two methodological approaches. The literature critique method involved a systematic analysis of scholarly works addressing the role of human capital in enhancing regional resilience, as well as the labor market situation of Ukrainian refugee women in Poland. This informed the methodological framework for the subsequent empirical investigation. The diagnostic survey method, employing a questionnaire technique, was used to collect data from Ukrainian refugee women residing in the Lublin region. The findings enabled an in-depth understanding of the factors determining their professional engagement.

Findings: The findings indicate that more than half of the respondents are employed in Poland, frequently in sectors with low entry requirements and below their qualification levels, resulting in professional dissatisfaction and intentions to change employment. The primary obstacles to labor market integration are insufficient proficiency in Polish and restricted access to childcare.

Research limitations/implications: This research employed a cross-sectional design and was conducted exclusively in the Lublin Voivodeship. The use of purposive sampling constrains the generalizability of the findings to the broader population of Ukrainian refugee women.

Practical implications: The findings underscore the necessity of implementing comprehensive strategies to support the labor market integration of refugee women, encompassing free and flexible Polish language courses, enhanced accessibility and adaptability of childcare services, streamlined recognition of qualifications, and the promotion of stable employment arrangements. Such measures would contribute to the effective utilization of refugee women's potential, thereby reinforcing human capital and enhancing the resilience of the Lublin region.

Social implications: The labor market integration of refugee women plays a crucial role in fostering social cohesion and economic stability within the region. Enhancing employment conditions and addressing existing barriers may mitigate the risk of marginalization, promote greater socio-economic engagement, and strengthen the regional adaptive capacity in anticipation of future crises.

Originality/value: This article contributes novel knowledge regarding the determinants of professional engagement among war-affected refugee women. The results may inform policymakers, non-governmental organizations, labor market institutions, and scholars focusing on migration, labor markets, and regional development.

Keywords: regional resilience, war-affected refugee women, labor market engagement, Lublin Voivodeship.

Category of the paper: Research paper.

1. Introduction

Amidst escalating environmental and socio-economic challenges, the concept of regional resilience has emerged as a pivotal field of inquiry within economic geography, regional economics, and management sciences. The dynamically evolving understanding of this concept has led to an expansion of its scope. Currently, it is no longer confined solely to the economic dimension but also encompasses a wide spectrum of social, environmental, institutional, and cultural aspects. Resilience has thus become a guiding approach to shaping and supporting regional transformation towards sustainable development.

Regional resilience is not just a fashionable term, but a fundamental condition for the long-term stability and prosperity of the region. This concept aids in understanding how regions anticipate, prepare for, respond to, adapt to, and recover from political, economic, environmental, or social shocks (Christopherson, Michie, Tyler, 2010; Neuhuber, 2025). The literature on this subject has expanded significantly over the past few decades, especially in connection with the increased frequency of various types of disruptions. Representatives of various scientific disciplines, as well as politicians, social activists, and business practitioners from around the world, consistently assert that regional resilience is a dynamic, multidimensional process.

Within this broad framework, human capital is increasingly recognized as one of the foundations for building and strengthening regional resilience. This is justified by the fact that it is people's skills and experience, their creativity and adaptability, as well as their capacity for collaboration, that drive innovation and economic and social development. In the face of dynamic changes such as economic crises, technological transformations, and demographic challenges, well-developed and flexible human capital enables the region to respond more quickly to threats, exploit opportunities more effectively, and build long-term competitive advantage. At the same time, problems in the realm of human capital, whether demographic or socio-economic in nature, can significantly undermine regional resilience.

For the Lublin Voivodeship, one of the most pressing issues is the mass influx of refugees, which began in February 2022 as a result of Russia's full-scale aggression against Ukraine. The scale of this phenomenon poses significant humanitarian, infrastructural,

and administrative challenges. Ukrainian female refugees report actively seeking stable employment to secure adequate living conditions for themselves and their families; however, their professional integration process encounters numerous barriers. The presented research aimed to analyze the determinants of professional activity among Ukrainian female refugees in the Lublin region.

2. Regional resilience – the role of human capital

The resilience concept is constantly developing and evolving. Definitions vary depending on the research field-resilience is perceived differently by representatives of such sciences as sociology, urban planning, ecology, economics, and management. Moreover, the broad range of meanings and the open-ended nature of the term result in its interpretation through various conceptual frameworks. In the literature on regional resilience, three main types of approaches can be distinguished (Boschma, 2014; Fingleton, Garretsen, Martin, 2012; Liu et al., 2023; Martin, 2012; Masik, 2022; Simmie, Martin, 2010; Zampieri, 2021):

- The engineering concept defines a system's ability to withstand sudden, significant shocks and return to its pre-disturbance state or a stable equilibrium. This approach does not fully address the conditions of today's highly unstable world, as it fails to account for changes in the structure and functioning of regions.
- The ecological concept is based on the idea of dynamic equilibrium. A region may alter its structure and function in response to an external shock and achieve a new state of balance. A resilient region can withstand disturbances without transitioning to a new equilibrium, or one that is capable of moving from a less favorable to a more favorable long-term equilibrium along a previously chosen development trajectory.
- The evolutionary (adaptive) concept views resilience as a process of continuous change rather than a return to a previously existing or new stable state of equilibrium. Unlike the two previous concepts, a region never fully achieves equilibrium, or does so only temporarily. Its resilience depends on the ability to reorganize its internal social, economic, and institutional structures in response to external disturbances. This concept encompasses a region's capacity to cope with short-term shocks as well as to escape the effects of 'lock-in' and develop new development pathways. It therefore provides a comprehensive understanding and interpretation of the dynamic evolution of regional systems.

Numerous definitions of regional resilience formulated by various authors emphasize that it is a multidimensional capacity of a given area to anticipate, prepare for, respond effectively to, and recover from disruptions or transform in the long term, while maintaining key functions, structure, and identity. It is also noted that disruptions may originate externally (e.g., global

crises) or internally (e.g., local social conflicts). In a comprehensive approach to regional resilience, the following interrelated processes are identified (Bobowski, Menkes, 2024; Bristow, Healy, 2014; Cooke, 2012; Giacometti, Teräs, 2019; Holling, Gunderson, 2002; Martin, Sunley, 2007; Masik, 2022):

- 1) Forecasting and preparation - actively identifying potential threats and developing plans and programs to minimize their impact.
- 2) Response and shock absorption - buffering and mitigating the initial impact of a shock without losing the system's core properties.
- 3) Adaptation and recovery - flexibly transforming internal structures, procedures, and regional relationships to enable effective adjustment to new conditions.
- 4) Transformation and long-term development - not only restoring stability but also progressing to a higher level of complexity, thereby enhancing the region's capacity to cope with future challenges.

A key aspect of understanding regional resilience is the systems perspective: the region is treated as a network of nonlinearly interconnected elements (social, economic, infrastructural, and environmental) that, through diversification, self-organization, and local resources, can not only recover from a crisis but also evolve (Hayter, 2004). Among these resources, human capital stands out as a lever—a dynamic factor driving the processes that constitute resilience.

In every interpretation of the concept of 'resilience', regardless of the specific definitional perspective adopted, a fundamental element remains the reference to the scale of disturbances that a given system is able to absorb or withstand. According to Holling's original concept (1973), resilience is the capacity of a system to maintain its structure, functions, and feedbacks before undergoing a transformation to an alternative state of equilibrium. This transformation entails surpassing a critical threshold, after which the system loses its original properties and adopts a new configuration. Based on this and other interpretations, the social resilience of a region can be considered from the perspective of three key attributes (Carpenter et al., 2001; Holling, 1973; Maclean, Cuthill, Ross, 2013):

- 1) The range of changes that the social system can withstand while maintaining its structure and functions.
- 2) The extent to which the regional community is capable of self-organization.
- 3) The degree to which the social system can develop the capacity for learning and adaptation.

Human capital in the literature on regional resilience is understood in a very broad sense. It encompasses the knowledge and skills of residents, their physical and mental health and well-being, adaptive capacities, creativity and innovativeness, as well as social norms and values that facilitate cooperation and coordination of activities. Well-educated and highly skilled individuals adapt more quickly to economic and environmental changes, absorb knowledge and new technologies, and generate innovations. This, in turn, strengthens the region's capacity to 'bounce back' from various types of shocks or disturbances (Cappelli, Montobbio, Morrison,

2021; Zhou, Qi, 2023). Investments in education and skills development ensure high economic returns and enable the achievement of sustainable and long-term development goals. The physical health and mental well-being of residents form the foundation of social resilience, as they enhance professional activity, adaptability, and mobility, and consequently increase labor market flexibility (GUS, 2023). Meanwhile, social relationships and support networks facilitate the coordination of actions during a crisis and the rapid dissemination of information about resources and needs (Carmen et al., 2022).

Regional resilience largely relies on the accumulated potential of civil society, entrepreneurship, and the strengthening of regional institutions that are capable of setting development directions and coordinating the actions of local actors. Both public and private infrastructure - technical, telecommunications, and research - as well as the competencies of residents, are important. Local social structures, educational institutions, and other entities that enhance the capacity of local communities to collaborate in the face of crises also play a significant role. Leadership within regional structures is crucial: strong leadership enables rapid response to threats, the development of strategic solutions, and the implementation of changes necessary to maintain continuity of operations under conditions of shocks and disturbances (Bobowski, Menkes, 2024; Pike, Dawley, Tomaney, 2010; Sienkiewicz-Małyjurek, 2024; Stęпка, 2021; Wolfe, 2010).

In the event of disturbances in the area of human capital, a significant weakening of the region's adaptive capacities and resilience mechanisms is observed. The most important negative phenomena include (Andersson et al., 2025; Raczowska, Mikula, Utzig, 2021):

- An excessive influx of migrants, which burdens local social, healthcare, and educational systems, leading to temporary or permanent disruption of demographic balance and increased socio-economic tensions.
- The outflow of skilled labor (brain drain), which reduces the region's capacity for rapid crisis response and limits its innovation potential.
- A high proportion of unemployed individuals whose skills do not match labor market needs, resulting in employment stagnation, decreased productivity, and reduced readiness of the region to implement new technologies.
- Population aging, which reduces the number of economically active workers, increases healthcare and social care costs, and diminishes labor market flexibility.
- Health and psychosocial problems, which lower the efficiency of human capital, increase absenteeism, and reduce the community's resilience to prolonged stressors.

Each of these phenomena, individually and in synergy, reduces the region's ability to recover quickly from crises, implement innovations, and maintain stable economic and social development.

In summary, it can be concluded that human capital constitutes not only a fundamental pillar of regional resilience but also a key lever of transformational processes and a driver of long-term economic growth. Consequently, regional policy instruments should include initiatives

aimed at strengthening human capital. These may encompass systemic investments in formal education (schools, universities) as well as support for individuals seeking to establish their own businesses (entrepreneurship incubation programs, mentoring, administrative facilitation). Equally important are professional activation programs, such as retraining courses, internships, and career counseling. Such measures will promote the development of resilient, innovative, and dynamically growing regions.

3. The professional activity of female war refugees from Ukraine in the Polish labor market

In recent years, Poland has experienced a range of challenges that have negatively influenced social resilience: the deepening effects of climate change, shortages of energy resources on global markets, the COVID-19 pandemic, Russia's aggression against Ukraine accompanied by a large influx of refugees, and the instrumental use of migrants as a weapon at the Polish - Belarusian border (PAP, 2023). On 25-26 June 2025, a seminar of ESPON (European Observation Network for Territorial Development and Cohesion) was held in Gdańsk, bringing together representatives of public administration, academia, and regional policy practitioners to exchange insights on the key challenges facing Europe and the evolving concept of resilience. Under the theme 'Resilience to Challenges in Border Regions', more than 180 participants analyzed the challenges facing Europe in the context of social, economic, and climate change. The seminar emphasized the need to redefine the concept of resilience. What is essential is the development of the capacity for adaptation and transformation, rather than merely the preservation of the current state. This is particularly important in view of the challenges along the eastern borders of the European Union (Gov.pl, 2025).

On 24 February 2022, the Russian Federation launched a full-scale invasion of Ukrainian territory, leading to a fundamental transformation of the socio-economic conditions of the entire Ukrainian population. The consequence of this military aggression was the mass displacement of civilians, forced to leave their permanent residences and abandon their previous way of life in search of shelter. This resulted in a sudden and unexpected influx of over one million war refugees (primarily women and children) into Poland's border regions. This situation generated a range of unprecedented humanitarian, infrastructural, logistical, and administrative challenges. It created an urgent need for local authorities and non-governmental organizations to rapidly implement integration and aid programs.

Over the past decade, migration from Ukraine to Poland has intensified, initially for economic reasons, and subsequently as a result of the armed conflict since 2014, the COVID-19 pandemic, and the full-scale Russian invasion in 2022. Currently, nearly one million Ukrainians reside in Poland, including approximately 600,000 adults. There is a clear

predominance of women (67%). Their numbers were higher both among pre-war migrants (54%) and refugees (76%). The employment rate among pre-war immigrants is 93%, whereas for refugees it is 68% (NBP, 2024). More than half of the women arrived in Poland with children under the age of 18. Most women had no prior work experience in Poland and did not speak Polish. The vast majority express a desire to be professionally active, and about one fifth intend to rely on their own financial resources (Długosz, Kryvachuk, Izdebska-Długosz, 2022; Zymnin, 2022).

Finding employment for female refugees is not an easy task, while at the same time it constitutes a form of testing their ability to achieve independence and secure one of the most basic needs for themselves and their children-safety and stability. Women who migrated to Poland independently show a willingness to undertake almost any type of work, whereas those who arrived with children tend to prefer employment in the form of part-time or shift-based work (Otto, Nowosielska, 2023).

The entry of Ukrainian women into the Polish labor market is accompanied by both positive and negative aspects (Deloitte, 2022; Konfederacja LEWIATAN, 2022; Otto, Nowosielska, 2023; Zymnin, 2022; Zyzik et al., 2023):

1. Positive aspects:

- Rapid, simplified access to legal employment thanks to the provisions of the Act of 12 March 2022 on Assistance to Ukrainian Citizens in Connection with the Armed Conflict on the Territory of that State (Dz.U. 2022, poz. 583).
- High demand for workers in sectors with low entry barriers (trade, eldercare, home care, childcare, logistics, food industry, education).
- Support and engagement of employers in facilitating refugees' entry into the labor market (specialized workshops, mentoring for newcomers, Polish language classes, career counseling, provision of computer equipment, assistance in finding housing, etc.).
- High levels of education and motivation among Ukrainian female refugees, as well as their willingness to improve qualifications (language courses, vocational training).
- Access to support networks, integration programs, local aid centers, and EU-funded initiatives. Since the beginning of the war, approximately 80% of Poles have been involved in assisting refugees (charity collections, food and clothing packages, volunteering, providing apartments and houses, etc.).

2. Negative aspects:

- Lack of fluency in Polish, limited knowledge of legal regulations, and insufficient familiarity with other aspects of social and economic life.
- Having underage children and limited access to childcare and eldercare, which restricts the ability to engage in full-time employment.

- Challenges in recognizing qualifications, time-consuming procedures for the nostrification of diplomas and certificates confirming educational attainment.
- Cases of discrimination and unequal treatment of Ukrainian women, along with a low level of mutual trust.
- Employment instability, short-term contracts, piecework, or employment through temporary work agencies, which generate a lower sense of job security.

Poland plays a crucial role in providing aid to Ukraine, offering not only financial, humanitarian, military, political, and diplomatic support, but also access to education, healthcare, and social assistance for refugees on an equal footing with Polish citizens. Despite significant support, Ukrainian women face difficulties in integrating into the Polish labor market. Only a few of them undertake employment commensurate with their qualifications, and they rarely occupy managerial positions. Most commonly, they find work in the service sector, particularly in hospitality and catering (51%), trade (20%), and in physical or technical jobs (20%) (Zymnin, 2022).

An important task for both central authorities, local governments, and non-governmental organizations is to create sustainable support mechanisms for Ukrainian female refugees, which would enable not only their immediate entry into the labor market, but, above all, the development of long-term careers and the full utilization of their potential in Poland. It is essential to consider additional specific barriers, such as traumatic experiences related to the war or the need to adapt to a new social environment, for support to be both effective and sensitive to individual needs.

4. Research methodology

The present study adopted an approach comprising a series of logically connected stages, allowing for the reliable achievement of the stated objective. Initially, a review of Polish and international publications on regional resilience and the conditions of professional activation of Ukrainian migrants was conducted. The results of this review were presented in the previous sections of the article. Subsequently, the research problem was formulated: Which factors influence the labor market participation of Ukrainian female refugees in the Lublin region? The authors aimed to conduct a study that would allow for the verification and refinement of the developed research instrument, as well as an assessment of the feasibility of a larger project (including practical aspects of implementation, such as participant recruitment, data collection logistics, and the clarity of survey questions). The objective of the research was to analyze the determinants of labor market participation of Ukrainian female refugees in the Lublin region. The following hypotheses were formulated:

- H1:** Ukrainian female refugees in the Lublin region undertake work that is inconsistent with their previous professional experience in Ukraine, primarily in unstable forms of employment, which leads to job dissatisfaction.
- H2:** Ukrainian female refugees wish to be professionally active; however, the unacceptability of difficult working conditions and barriers to labor market entry contribute to high unemployment within this group.
- H3:** Ukrainian female refugees are aware that insufficient knowledge of the Polish language hinders their ability to find or perform work in Poland and therefore strive to improve their language competencies.
- H4:** Ukrainian female refugees with a larger number of underage children experience greater difficulties in finding or performing work and are less likely to engage in employment.

To verify the hypotheses, a diagnostic survey method was employed, using a questionnaire technique. The research instrument was an original survey questionnaire prepared in both electronic and paper formats. The questionnaire consisted of 21 substantive questions and 2 demographic questions. A purposive (arbitrary) sampling of respondents was applied, based on the subjective selection by the researcher, whose aim is generally to create a sample approximating representativeness (Szreder, 2010). This technique was used due to the impossibility of preparing a random sampling frame, that is, a list of refugees residing in the Lublin Voivodeship.

The survey questionnaire was translated into Ukrainian. The electronic version was shared on social media (Facebook, Telegram, Instagram) in groups popular among Ukrainian female refugees residing in the Lublin Voivodeship. The paper version of the questionnaire was made available at a shelter for Ukrainian refugees on Podwale Street and on Czwartaków Street in Lublin (after obtaining permission to conduct the study). In total, 122 completed questionnaires were collected, 32 in paper form and 90 electronically. After verification, 9 questionnaires were rejected due to formal errors. The responses of 113 participants were included in the subsequent analysis.

Sample structure:

- Age: 18-25 years - 41 women; 26-35 years - 36 women; 36-45 years - 29 women; 46-55 years - 6 women; over 55 years - 1 woman.
- Education level: higher education - 73 women; secondary education - 27 women; vocational education - 13 women.

During the study, participants' rights were respected: each respondent gave informed consent to participate, anonymity and confidentiality of data were guaranteed, and all procedures were prepared in accordance with GDPR guidelines.

5. Research results and analysis

The study was conducted more than a year after the Russian invasion of Ukraine. Most respondents have been residing in the Lublin region almost since the beginning of the war: 79% reported staying for more than six months, while 21% for up to six months.

To verify H1, respondents were asked 10 questions regarding their professional activity in Ukraine and in Poland.

At the beginning of the survey, respondents were asked about their professional activity in Ukraine and in Poland. The vast majority of women (98, i.e., 86.7%) were employed in Ukraine. Upon arriving in Poland, slightly over half of the refugees - 62 women (54.9%) - found employment, including 7 individuals who had not previously worked in Ukraine. Only 26 Ukrainian women (23%) had prior work experience in Poland. Table 1 presents the employment flows of women who worked in various sectors in Ukraine before coming to Poland.

Table 1.

Professional activity of Ukrainian female refugees in Ukraine and in the Lublin region (number of individuals)

Work in Ukraine	Work in Poland						
	Transport and Logistics	Industry	Service Sector	Administration, Office Work, Media	Education and Science	Trade	Unemployed
Construction		1					
Transport and Logistics	1						
Industry		2					3
Service Sector		3	11			2	12
Administration, Office Work, Media		3	8	1	1		12
Education and Science	1	2	2		5		5
Agriculture		3	1				6
Trade		2	4		1		6
Unemployed			5	1		1	8

Source: own elaboration.

The majority of respondents had to change their sector of employment upon arriving in Poland. In Ukraine, most women worked in the service sector, totaling 28 individuals. Of these, 11 found employment in a similar field in Poland, 12 remain unemployed, and 5 had to retrain. Among the 25 refugees previously employed in administration, office work, and media, only 8 continue to work in their original specialization, 5 are employed in other sectors, and 12 remain without employment. The service sector in the Lublin region offered the most job opportunities for women from various sectors - currently, 31 respondents are employed in this sector. In the industrial sector in Poland, 16 women are employed, significantly more than in Ukraine, where most of them require retraining.

A significant proportion of respondents who are professionally active in the Lublin region (84%) found employment relatively quickly, within up to three months of arrival. Another 14% of respondents obtained employment within four to seven months, while the remaining 2% secured work within eight to twelve months. The methods used by respondents to seek employment were as follows (multiple answers were allowed, so the results do not sum to 100%):

- Recommendations from friends and acquaintances - 32% of women.
- Through online job portals (e.g., olx.pl, pracuj.pl) - 21% of women.
- Through employment agencies - 19% of women.
- Announcements/information on social media - 14% of women.
- Invitation from a previous employer - 11% of women.
- Through the district labor office - 3% of women.

Participants in the study indicated their forms of employment in Poland as follows: under civil-law contracts - 50%; under employment contracts - 31%. Meanwhile, 19% of women reported working informally (without a contract), which is a concerning finding pointing to the presence of undeclared employment. None of the respondents operate their own businesses. When asked on what basis they would like to work in the Polish labor market, 69% of Ukrainian women indicated a permanent or fixed-term employment contract. This is an obvious choice, as such contracts provide greater stability, insurance, and a sense of security, which is particularly important for women with children. Employment under civil-law contracts is preferred by 6% of respondents. Twelve percent of women expressed a desire to start their own business. One individual indicated a willingness to work informally, while 12% of respondents stated that they do not wish to work (having another source of income).

Comparison of the employment structure of women in Ukraine and Poland indicates significant changes in the nature of work performed. Upon arriving in the Lublin region, many women were forced to change sectors, often taking jobs below their qualifications. Therefore, it is not surprising that 61% of study participants wish to change their current job, of whom 74% hold higher education degrees. When asked why they are considering changing their current employment, respondents provided the following answers (multiple responses were allowed, so the results do not sum to 100%):

- The job does not match their qualifications - 25% of women.
- Unfavorable working conditions, work overload - 20% of women.
- Low salary - 18% of women.
- Lack of opportunities for promotion and professional development - 17% of women.
- Work-related stress (conflicts, discrimination) - 8% of women.
- Lack of possibility to work remotely - 7% of women.
- Lack of flexible working hours - 5% of women.

The responses of the participants indicate that they often take employment in sectors different from their previous experience, frequently below their qualifications. This is associated with the need to adapt to new conditions in Poland. Many of them plan to change jobs, mainly due to a mismatch with their qualifications, low wages, difficult working conditions, and lack of career development prospects. Therefore, there are no grounds to reject Hypothesis 1.

Three questions were used to verify Hypothesis 2. Participants indicated what motivated them to take up employment upon arriving in Poland (multiple responses were allowed, so the results do not sum to 100%):

- Desire for independence - 28% of respondents.
- Lack of means to support themselves and their children - 25%.
- Striving to improve their financial situation - 19%.
- Desire to start a new stage in life - 13%.
- Recognition of new opportunities and willingness to take advantage of them - 10%.
- Change in family circumstances - 5%.

For the majority of refugees, the decision to take up employment in Poland was not driven by a single factor, but by a combination of various needs and life circumstances. Women were guided not only by economic necessity, although lack of means to support themselves was an important motivator. Equally significant were factors related to personal independence, the need for stability, and the desire to rebuild their lives following forced migration. For the study participants, work represents not only a source of income but also a tool for constructing their own identity and agency in a new country. The fact that nearly all respondents indicated multiple motivations demonstrates that the process of professional adaptation for refugees is complex and strongly embedded in both economic and socio-emotional contexts.

The next question concerned the employment conditions that respondents would be willing to accept to support themselves and their children. Responses were provided on a scale from 1 - not acceptable at all, to 5 - fully acceptable (Table 2).

Table 2.

Acceptable employment conditions for Ukrainian female refugees in the Lublin region (in %)

Item	Rating					Mean rating
	1	2	3	4	5	
Work inconsistent with qualifications	18.6	8.6	14.3	42.9	15.7	3.3
Work not meeting expectations	27.1	24.3	15.7	32.9	0.0	2.5
Work far from place of residence	34.3	25.7	2.9	27.1	10.0	2.5
Overtime work	40.0	22.9	10.0	24.3	2.9	2.3
Night work	51.4	20.0	4.3	17.1	7.1	2.1
Low-paid work	52.9	30.0	11.4	4.3	1.4	1.7
Physically demanding work	67.1	18.6	7.1	7.1	0.0	1.5

Source: own elaboration.

The most acceptable condition, with a mean rating of 3.3, is work inconsistent with qualifications. This type of employment was rated positively by 58.6% of respondents (ratings 4 and 5), indicating their willingness to change sectors or perform tasks below their qualifications. Moderate acceptability was observed for work not meeting expectations and work far from the place of residence (mean rating 2.5). Less acceptable conditions include overtime work (mean rating 2.3) and night work (2.1). For over 80% of women, low-paid work (mean rating 1.7) and physically demanding work (mean rating 1.5) are difficult to accept.

The labor market participation of Ukrainian female refugees in the Lublin region, despite a clear willingness to work, is significantly burdened by various barriers of a personal, institutional, or socially prejudiced nature. In both the job search process and the subsequent performance of professional duties, women encounter a range of challenges. Respondents were asked about factors that hinder their professional activity. Table 3 presents the responses measured on a scale from 1 - 'does not hinder' to 5 - 'hinders very much'.

Table 3.

Factors hindering the labor market participation of Ukrainian female refugees in the Lublin region (in %)

Item	Rating					Mean rating
	1	2	3	4	5	
Language barrier	25.5	15.7	4.9	23.5	30.4	3.2
Having underage children	40.2	7.8	3.9	26.5	21.6	2.8
Excessive employer requirements regarding experience, qualifications, certifications, etc.	36.3	18.6	11.8	24.5	8.8	2.5
Discrimination based on nationality	40.2	25.5	11.8	18.6	3.9	2.2
Discrimination based on gender	75.5	12.7	3.9	5.9	2.0	1.5
Discrimination based on age	69.6	12.7	3.9	10.8	2.9	1.6
Employers' reluctance to legalize employment	60.8	16.7	5.9	10.8	5.9	1.8

Source: own elaboration.

The language barrier (mean score of 3.2) emerges as by far the most significant challenge - almost 54% of respondents rated it at 4 or 5, indicating that without support in learning Polish, they find it difficult to enter the labor market effectively. A second pronounced barrier concerns childcare responsibilities (mean score of 2.8), with more than 48% of women assigning ratings of 4 or 5. This suggests that the lack of flexible working hours or accessible childcare options substantially constrains their employment opportunities. For approximately one-third of the study participants, employers' excessively high demands regarding qualifications or professional experience also constitute a considerable barrier (ratings of 4 and 5). On a more positive note, relatively few refugee women reported experiences of discrimination on the grounds of nationality, gender, or age.

A little over half of refugee women have entered employment in Poland. While they demonstrate both a declared willingness to engage in professional activity and strong motivation to work, they do not accept adverse working conditions. Furthermore, a range of structural barriers - most notably insufficient command of the Polish language and the responsibility of caring for underage children - contribute to the persistence of unemployment

among a considerable share of refugee women. These findings provide substantive grounds for accepting Hypothesis 2.

Hypothesis 3 was verified based on four questions. The desk-based and literature review revealed that access to the Polish labor market for refugee women from Ukraine is substantially constrained by the language barrier. In the survey, participants were asked to assess their linguistic competencies. A mere 11% reported possessing a good command of Polish, while 27% indicated an intermediate, communicative level. A significant proportion of respondents (41%) stated that they are able to understand Polish but are unable to speak it. Meanwhile, 16% of women possess only basic expressions, and 5% reported no knowledge of Polish whatsoever.

In a subsequent question, respondents were asked to specify how inadequate linguistic competencies impede their ability to secure or perform employment (multiple responses were permitted; therefore, percentages do not sum to 100%):

- Inability to obtain employment commensurate with their qualifications - 45.1%.
- Limited access to information concerning their workplace rights and employers' obligations - 24.8%.
- Difficulties in establishing relationships with employers and colleagues - 12.4%.
- Incomplete understanding of the requirements associated with the position - 5.3%.
- No difficulties related to the language barrier - 18.6% of respondents.

The findings demonstrate that the language barrier significantly limits Ukrainian women's ability to secure employment that meets their aspirations. In some cases, they are compelled to accept low-skilled positions that do not require interaction with clients or colleagues. Their sense of security in the workplace is further undermined by an incomplete understanding of employment conditions, labor rights, remuneration principles, and related regulations.

In this context, it might be expected that participants would seek to enhance their linguistic competencies. Nevertheless, when asked whether they intended to study Polish, only 66% responded affirmatively. Respondents who provided a negative answer were further asked to specify the reasons for their decision. A lack of motivation was cited by 33% of women, which may be associated with moral and emotional exhaustion resulting from displacement caused by the war and the necessity of residing in a foreign country. A further 27% reported insufficient time due to work and childcare responsibilities, while another 27% stated that Polish was unnecessary in their current occupations, as they performed only simple tasks. For 11% of women, financial constraints - specifically, the inability to afford language courses - were decisive. Only 2% of respondents indicated that they lacked the aptitude for foreign language learning.

An analysis of refugee women's responses indicates that Hypothesis 3 can be positively verified in its initial dimension: more than 80% of Ukrainian respondents acknowledge that inadequate proficiency in Polish constrains their professional opportunities. Concerning the second dimension, however, Hypothesis 3 may be confirmed only partially. While two-thirds

of participants reported an intention to pursue language learning, the remainder did not plan to enhance their linguistic competencies, citing a range of barriers including lack of motivation, limited time, financial constraints, and the nature of their current work.

To test Hypothesis 4, participants were asked four questions. Desk-based and literature analyses indicate that a considerable proportion of Ukrainian refugee women arrived in Poland accompanied by underage children. The responsibility for their care, coupled with the provision of emotional and psychological support during the process of adapting to new living conditions, educational settings, and social interactions, imposes significant temporal and energetic burdens on mothers. These factors constitute a natural barrier to labor market engagement, affecting both job-seeking efforts and actual employment. Among the participants, 38% have one child, 26% have two children, and 5% have three or more children. Nearly one-third (31%) report having no children under 18 years of age.

In response to the question regarding childcare arrangements, participants reported the following: managing childcare independently - 20% of women; children attending nursery, kindergarten, school, or daycare - 33%; and a combination of both approaches - 47%. While the majority of refugee women rely on educational and childcare institutions, they frequently encounter a range of challenges, including:

- Fixed operating hours of facilities that do not coincide with mothers' work schedules - 31% of respondents.
- Insufficient financial resources to cover childcare expenses - 24%.
- High costs associated with childcare services - 16%.
- Lack of available childcare facilities - 14%.
- Limited availability of places in childcare facilities - 3%.
- No obstacles in this regard - 12% of respondents.

In a subsequent phase of the study, participants evaluated the influence of having children on their labor market engagement in the Lublin region. The findings are as follows:

- Mothers with one child more frequently reported substantial challenges (74.4%) but, notwithstanding these difficulties, had the highest relative employment rate (41%). This suggests that while challenges are perceptible for mothers with a single child, they are comparatively easier to manage, potentially through the use of childcare facilities, familial support, or flexible employment arrangements.
- Mothers with two children less frequently reported difficulties (65.4%), yet their employment rate was approximately half that of mothers with one child (21%). This may indicate that, although they perceive their situation as somewhat less challenging, their practical employment opportunities are more limited due to increased domestic responsibilities and fewer flexible childcare solutions.

- Mothers with three or more children reported difficulties even less frequently (60%), but nearly none were employed (2%). The reduced reporting of difficulties may reflect acceptance of circumstances or assistance from older siblings, but the actual capacity to engage in employment is minimal given the magnitude of caregiving responsibilities.

In conclusion, the lower incidence of reported difficulties among participants with larger numbers of children does not indicate that employment is comparatively easier for them. Instead, it highlights that subjective evaluations do not fully capture the objective constraints, which are most pronounced for mothers with three or more children. Accordingly, Hypothesis 4 is rejected with respect to the relationship between the number of children and perceived difficulties, but is supported regarding the correlation between the number of children and actual labor market participation.

6. Conclusions

The findings underscore the multifaceted nature of professional integration for war-affected refugee women in the border region of Lublin. Despite the implementation of simplified employment procedures and a local demand for labor, a significant number of women are employed below their qualification level, diminishing job satisfaction and impeding sustainable integration into the labor market. Over the longer term, this may contribute to a 'low-skills trap' and occupational marginalization. In Poland, refugee women frequently engage in sectors differing from their previous professions, predominantly in services and industry, and less commonly in roles aligned with their formal education. Such circumstances necessitate substantial adaptation efforts and increased time investment for professional adjustment. Employment without formal contracts or under civil law agreements is common, fostering perceptions of instability and vulnerability. Consequently, many refugee women plan to change jobs, primarily due to qualification mismatches, low remuneration, challenging working conditions, and limited prospects for career advancement.

The findings suggest that the labor market participation of Ukrainian refugee women in the Lublin region is predominantly constrained by structural and economic barriers. Of particular significance are linguistic limitations, restricted access to childcare, and employers' demands, alongside a low tolerance for low-paid and physically demanding employment. The presence of children markedly impedes engagement in work, with actual professional opportunities diminishing as the number of children rises, despite a comparatively lower subjective perception of difficulty in these cases.

The current study presents certain limitations. A purposive sampling strategy was employed, which constrains the generalizability of the findings to the broader population of refugee women. Additionally, the research was conducted exclusively in the Lublin

Voivodeship, whose specific characteristics as a border region may have influenced the results. Nonetheless, the data obtained are informative and provide a basis for further investigation into the circumstances of Ukrainian war-affected refugee women. Prospective research avenues include longitudinal studies to evaluate how the professional situation of refugee women evolves over time in Poland. A comparative analysis between border and central regions could elucidate the influence of local labor market conditions on professional integration. Conducting qualitative research would further enhance understanding of subjective barriers and coping mechanisms. Future studies should also assess the effectiveness of support programs designed for refugee women.

The limited labor market integration of refugee women has the potential to undermine local human capital, a critical pillar of resilience in the Lublin region. Qualification - job mismatches, precarious forms of employment, and barriers to labor market participation diminish the effective utilization of refugees' skills and capacities. In the longer term, these dynamics may entrench labor market segmentation, exacerbate inequalities, and reduce the region's capacity to respond to future crises. Consequently, effective strategies to bolster the resilience of the Lublin region should encompass measures that facilitate the full integration of refugee women into the local workforce - including investments in language acquisition, improved access to childcare, recognition of qualifications, and the creation of stable employment opportunities. Such a comprehensive approach would not only enhance the well-being of the migrants but also strengthen the adaptive resources of the region, rendering it more resilient to socio-economic shocks.

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COOPERATION BETWEEN COMPANIES AS A FACTOR IN SHAPING THE RESILIENCE OF SUPPLY CHAINS, ON THE EXAMPLE OF THE CLOTHING INDUSTRY

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Purpose: The aim of this article is to present the issue of threats and resilience of supply chains on the example of the clothing industry, with particular emphasis on the impact of cooperation between companies on the resilience of supply chains. The reason for addressing this issue is the serious disruptions in the economy caused by various factors and the desire to examine whether close cooperation, which is one of the elements of various contemporary management concepts, increases resilience to these disruptions.

Design/methodology/approach: The author analyzed reports from the largest Polish clothing company from 2018 to 2025. The supporting method was literature analysis.

Findings: Based on the research, it can be concluded that close cooperation can have a positive impact on the supply chains of clothing companies in times of disruption, but diversification in various areas proved to be more important.

Research limitations/implications: The research was conducted in a globally operating clothing company. The research should be continued and conducted in other companies from other industries. Research on other types of interference is also necessary.

Practical implications: Companies should cooperate in supply chains, but the resilience of supply chains increases primarily as a result of diversification in various areas.

Originality/value: The article fills a research gap concerning threats and resilience in supply chains in the apparel industry, with particular emphasis on the impact of cooperation between companies in the supply chain on resilience to disruptions. The article is addressed to managers of companies developing supply chain strategies and researchers studying this topic.

Keywords: supply chain; apparel industry; resilience; disruptions; cooperation; diversification; Covid-19 pandemic; war in Ukraine.

Category of the paper: research paper; case study.

1. Introduction

In subjective terms, a supply chain consists of cooperating companies: subcontractors, suppliers, manufacturers, and distributors, between which there are flows of material goods such as raw materials, materials, and finished products (from source to outlet), finances (from the outlet to the source) and information (in both directions). The scope of this cooperation may vary, as may its strength. The scope may relate, for example, to logistics, production, research, and development. Relationships in the supply chain may be based on cooperation, competition, or control between individual entities (companies), or they may be a mixture of these. Supply chains usually have a leader – an entity that creates the chain. This may be a manufacturer who creates a network of suppliers and cooperates with distributors of its products, but increasingly often the leader is a distributor. This is the case in the clothing industry, where the largest clothing companies are distributors with their own networks of stores and distribution centers, outsourcing production to other companies (sewing factories), often located in countries with low production costs, especially in the Far East.

In today's world, there are various threats, such as pandemics, wars, extreme weather events, natural disasters, terrorism, sabotage, cyberattacks, etc. Logistics chains operate in environments prone to a range of internal and external instabilities, necessitating the constant management of logistics risks and the reinforcement of resilience, particularly in the face of complex challenges like the COVID-19 crisis (Logistics chains operate in environments prone to a range of internal and external instabilities, necessitating the constant management of logistics risks and the reinforcement of resilience, particularly in the face of complex challenges like the COVID-19 crisis) (Parra-Hernández et al., 2024). These threats can affect the economy and society and cause serious disruptions in the functioning of supply chains, e.g., long-term interruptions in the supply of raw materials, finished products, water, electricity, or gas, as well as negative changes in the supply chain environment, such as inflation, sharp increases in energy, fuel, and transportation costs.

One of the pillars of commonly used supply chain management concepts today, such as Lean Management, ECR, and Quick Response, which is dedicated to the apparel industry, is close cooperation between individual entities in the supply chain. Close cooperation has many advantages: it allows for a reduction in inventory levels and costs throughout the chain, improves the level of customer service, and enables a faster response to the needs of end customers. Close cooperation is based on long-term agreements and the rapid, ongoing flow of information, especially regarding final demand. Thanks to IT solutions, information about purchases of a specific product at a specific point of sale is forwarded to other links in the chain—the distribution center, the manufacturer of the product, and its sub-suppliers—so that each link can prepare for the arrival of an order for that specific product before it has

even been placed. Thanks to close cooperation, the flow of goods can be harmonized between individual links, smooth, with minimal inventory, Just-In-Time.

However, in the context of disruptions such as the Covid-19 pandemic, it turned out that there were also negative effects of integrated supply chains with minimal inventories based on close cooperation, as exemplified by broken supply chains, e.g., the automotive industry based on LM I JIT suspended production. So, is close cooperation, which works well in stable conditions, also a factor in the resilience of the supply chain to disruptions, or are other factors more important?

The aim of this article is to present the threats and resilience of supply chains using the example of the clothing industry, with particular emphasis on the impact of cooperation between companies on the resilience of supply chains. The reason for addressing this issue is the current economic disruptions caused by various factors (most recently, the outbreak of war in Ukraine) and the desire to provide recommendations for companies in the event of further disruptions. The article fills a research gap concerning the impact of cooperation between companies in the supply chain on their resilience to disruptions, using the clothing industry as an example.

2. Methods

The research consisted of:

- Literature review on supply chain resilience.
- Report analysis – the author analyzed the reports of the largest Polish clothing company, LPP Group (annual reports for 2018-2024 and reports for the first quarter and first half of 2025). These were the following reports:
 - Consolidated annual report for 2018.
 - Consolidated annual report for 2019/20.
 - Consolidated annual report for 2020/21.
 - Consolidated annual report for 2021/22.
 - Consolidated annual report for 2022/23.
 - Separate annual report for 2023.
 - Consolidated annual report for 2024.
 - Mid-year consolidated report for 1Q 2025.
 - Consolidated semi-annual report for 1H2025.

The reports are available on the LPP website¹.

¹ <https://www.lpp.com/>

The article is addressed to company managers planning supply chain strategy, especially those planning to increase supply chain resilience, and researchers studying this topic.

3. Literature review

Disruption can be defined as “unforeseen or foreseen events that interfere with planned processes or the stability of an organization” (Kramarz, 2013). Disruptions can be classified in various ways. For example, depending on the area: global disruptions (an example was the disruption caused by the Covid-19 pandemic), regional (an example would be the disruption caused by the war in Ukraine) or local (e.g., transportation disruptions caused by a traffic accident) (Milewska, 2024).

According to the source of disruptions, we can distinguish between external and internal disruptions (Ivanov et al., 2010). Disruptions in the logistics processes of a manufacturing company can also be divided by area into disruptions in supply, production, distribution, transport, storage, and support processes (Gaschi-Uciecha, 2015). Disruptions in the supply chain can affect a single company (e.g., the failure of a single machine) or the entire supply chain (e.g., trade disputes between the US and China). Disruptions can affect supply chains for a short, medium, or long period of time. Their effects can range from insignificant and minor to critical or even catastrophic. Disruptions can also be classified according to their level of predictability and type of impact (Bukowska-Piestrzyńska et al., 2022):

- Mild effect, high predictability (e.g., change in customer needs).
- Mild impact, low predictability (e.g., fire, hurricane, act of terrorism, loss of a key supplier).
- Strong impact, high predictability (e.g., economic recession).
- Strong impact, low predictability (e.g., cyberattacks on global systems, pandemic).

This raises the question of whether supply chains are resilient to emerging threats or, on the contrary, are they vulnerable to them?

Supply chain vulnerability is “the susceptibility to serious disruption resulting from risks within the supply chain, as well as to serious threats external to the supply chain” (Svensson, 2000). Resilience, on the other hand, is the ability to respond to the effects of negative events in order to achieve the basic objectives of the supply chain. Resilience has its origins in the Latin word *resiliō*, which loosely translated means “return to previous form”. Resilience can also be defined as the ability of a logistics system to withstand adverse events occurring in its environment. Resilience assumes the constant occurrence of changes that can destabilize the environment of the system in question, as well as the need to respond to them (Zaczyk, 2016). A resilient supply chain means that all its components are equally resilient. The resilience of the entire chain is determined by the resilience of its weakest link (Szymczak, 2025). Resilient

supply chains are able to either avoid disruptions or reduce their negative effects. They adapt their strategies and operations to changes in the environment in order to reduce the risk of losing their ability to operate (Boin et al., 2010).

The symptoms of supply chain resilience are the ability to mitigate internal and external factors that cause disruptions in its functioning, as well as the ability to prevent the transmission of these disruptions within the supply chain itself. The issue of disruption transmission in supply chains is currently a very important research topic in the area of supply chain resilience, which is currently represented in only a few studies (Szymczak, 2025, p. 16).

Types of supply chain resilience (Välikangas, 2010):

- proactive – actions are taken before a crisis situation arises,
- reactive – actions are taken only after a crisis situation has arisen.

The division into proactive and reactive measures does not only apply to supply chains. For example, calling on EU citizens to build up supplies for at least 72 hours is an example of preparatory measures before a crisis occurs, and is therefore a proactive measure.

The rest of the article analyzes strategies for increasing resilience, taking into account cooperation in the supply chain, based on an analysis of literature in two periods—before and after the COVID-19 pandemic, i.e., before and after 2020. The Covid-19 pandemic has made increasing resilience a priority for most global supply chains in industry and trade, and work has also been done on the resilience of supply chains in other industries and areas, such as tourism (Witkowski, 2022).

Even before the outbreak of the Covid-19 pandemic, some authors pointed out that achieving a high level of supply chain resilience should be treated as a priority (see, for example, Zaczek, 2016). As ways of achieving resilience, the authors pointed to the role of cooperation in the supply chain, e.g.:

- J. Rice (2003) classified four levels of dealing with disruption risk, from “basic initiatives” (level one), which include protective measures such as physical security, information security, and transport security, to “advanced initiatives” (level four). He classified cooperation between the supplier and the receiver as level four disruption risk management.
- According to M. Christopher and H. Peck (2004), supply chain resilience can be built through four capabilities. One of these is collaboration, while the others are supply chain re-engineering, agility, and risk awareness. According to these authors, a high level of collaboration is one of the key principles for building supply chain resilience.
- C.S. Singh, G. Soni, G.K. Badhotiya, (2019), describing the pillars of supply chain resilience, point out that one of the pillars is the ability to resist, and one of its elements is cooperation.

- In his model of a resilient supply chain, Wilding (2013) includes close cooperation as one of its elements, alongside supply chain engineering, risk management, and agile management.
- Ten principles for managing supply chain disruption risk were formulated by P.R. Kleindorfer and G.H. Saad (as cited in Lavastre et al., 2012). One of these principles is cooperation, coordination, and collaboration between partners in the supply chain, while the others are internal integration and optimization of the supply chain, diversification of locations of facilities, products, and supply options, identification of weak points throughout the supply network along with an early warning and crisis management system, risk assessment and contingency planning, trade-off management between disruption resilience and overall supply chain efficiency in normal operations, embedding the measurement of weaknesses in current process management, and backups. between resilience to disruptions and overall supply chain efficiency in normal operations embedding the measurement of weak points in current process management, backups and reserves, flexibility and mobility of resources, modular design, delayed product customization, application of total quality management (TQM) principles.

The authors therefore agree that strengthening the resilience of supply chains should be linked to increased cooperation between its links. It should also be added that when writing about disruptions, the authors usually meant disruptions caused by changes in end customers' demand for the products offered. According to the previously cited studies, disruptions caused by changes in customer needs have a mild effect and are highly predictable, while the pandemic has a strong effect and is highly unpredictable (of course, changes in demand can be more or less predictable, but the Covid-19 pandemic was undoubtedly much more unpredictable and had a much stronger effect). The Covid-19 pandemic was a black swan – a metaphor for an extremely unlikely and unexpected event with a high destructive force. Disruptions of this type are rare, but when they do occur, they have very serious consequences (Konecka, 2015).

Also, following the outbreak of the COVID-19 pandemic, many authors point to the role of cooperation in achieving resilience in the supply chain, e.g.:

- Based on surveys conducted after the outbreak of the COVID-19 pandemic by the consulting firm Gartner among global supply chain leaders, six basic strategies for increasing resilience can be identified (Hippold, 2020). One of them is the partnership strategy, which strengthens trust, information transparency, and the durability of relationships between supply chain participants. The others are the strategy of increasing safety stock buffers and production and storage capacity; the strategy of diversifying the production network, including, in particular, avoiding total dependence on Chinese manufacturers; a multi-supplier strategy, which reduces the risk associated with the monopoly of supplies of specific raw materials, components, and parts from a single source; a strategy of regionalizing supply chains in order to reduce the distance,

time, and cost of transport from local suppliers—so-called nearshoring; a strategy of harmonizing platforms, products, and factories, which means standardizing the technological standards for the flow of products and information in supply chains.

- Gartner, Inc. (2021) strategies for increasing supply chain resilience include system partnerships (i.e., cooperation), surplus inventory and production capacity, diversification of production and distribution networks, multisourcing, nearshoring, and harmonization of platforms, technologies, and products.
- Research conducted by Ryciuk and Zabrocka (2024, pp. 30-50), based on in-depth individual interviews with supply chain management experts, showed that cooperation, integration, and information exchange in the supply chain are crucial for effectively responding to unforeseen events. Interestingly, the research highlighted the positive impact of unforeseen events on supply chain innovation.
- Building resilient supply chains does not necessarily mean moving away from just-in-time. This strategy can still be used successfully, provided that risks can be effectively managed. As Choi et al. (2023), this is possible through close cooperation with suppliers, which will enable the creation of buffer solutions, just-in-time segmentation, and increased visibility of resources in the supply chain, including those in transit (Szymczak, 2025, p. 21).

4. Threats and disruptions in the apparel supply chain and measures to increase its resilience, as exemplified by the LPP Group

The author analyzed reports from Poland's largest clothing company, LPP, from 2018 to the first half of 2025, mainly in terms of threats and disruptions to the supply chain and its resilience to these disruptions. The selected period therefore covers the time before, during, and after the Covid-19 pandemic, as well as before and after Russia's invasion of Ukraine, events which had a huge impact on supply chain disruptions.

The LPP Group designs clothing and distributes and sells it under its own brands – Reserved, Cropp, House, Mohito, and Sinsay. It has its own sales network (brick-and-mortar stores and online stores) in a total of 42 countries on three continents. The brick-and-mortar sales network currently has 3195 stores in 31 countries, and the LPP Group is present in 35 markets online. Online sales in the first half of 2025 accounted for 26.9% of the Group's total sales.

However, the LPP Group does not have any production facilities. It outsources the production of clothing based on its own designs to sewing factories located mainly in countries with low production costs (especially in Southeast Asia). In 2024, approximately 94% of products were ordered in Asia.

The analyzed reports contain a lot of information about risks and disruptions, as well as preventive measures taken by the LPP Group.

The 2018 annual report, published before the outbreak of the Covid-19 pandemic (as well as subsequent reports), shows that LPP is striving to diversify its revenues, i.e., to increase the number of countries in which it has its distribution network and retail outlets. This type of diversification is an important element of supply chain resilience, especially in the event of local or regional disruptions. If, for example, in one place, e.g., in a given country, there are disruptions and, for example, due to war, it is not possible to sell goods there, other markets remain. However, this does not protect against global disruptions, such as those caused by a pandemic.

The 2018 report also presented goals related to the development of online stores in individual countries. Therefore, in addition to diversifying its revenues, LPP's strategy was to diversify its distribution channels (developing both its brick-and-mortar and online store networks). To this end, LPP invested in logistics and technology (RFID, big data, m-commerce). LPP has separate distribution centers for deliveries to stores and separate ones for deliveries to online customers. In Poland, online customer service in 2018 was entrusted to Arvato Polska, and a decision was also made to expand the existing distribution center in Pruszcz Gdański and to build a new one in Brześć Kujawski. In 2019, a distribution center was leased in Romania to serve online customers from Southern Europe.

Even before the Covid-19 pandemic, LPP was developing this sales channel in Poland and abroad. LPP also took steps to integrate both sales channels (omnichannel). During the pandemic, it turned out that investments in e-commerce had a significant impact on the resilience of the chain.

Before the outbreak of war in Ukraine, LPP was developing its sales network in Eastern Europe, especially in Russia, where it had distribution centers serving both retail stores and online customers. The 2019/20 report shows that almost 13.9% of sales were to the Russian subsidiary Re Trading OOO. The share of other customers did not exceed 10%. At that time, the eastern direction still seemed very promising, but after Russia's invasion of Ukraine, LPP's warehouses, stores, and inventories in Russia turned out to be a serious problem.

Supply chain resilience is enhanced by not being dependent on suppliers. In 2018, there were over 1100 suppliers (none of which exceeded the threshold of 6% of annual purchases), and a year later – 1200 (none of which exceeded the threshold of 5% of annual purchases). LPP minimizes risk in the supply chain by diversifying the countries in which production is outsourced. However, most of them are suppliers from countries in one region (Southeast Asia), mainly from China, Bangladesh, Myanmar, India, Pakistan, and Cambodia. In 2019/20, 2.5% of LPP products were manufactured in sewing factories in Poland, and in 2024 only 0.6% of clothing (slightly more in Turkey, and some in North African countries such as Morocco, Tunisia, and Egypt). Such outsourcing reduces production costs while providing access to constantly changing technologies, but on the other hand, it involves the risk of poorly selected

suppliers and a close link to the economic and political situation in the supplier countries. Therefore, LPP supervises its suppliers on an ongoing basis through its offices in Shanghai (China, established in 1997) and Dhaka (Bangladesh, established in 2015), selecting suppliers not only on the basis of price, range of products, and modernity of machinery, but also on the basis of ethical treatment of employees.

The 2019/20 report already contained information about the disruptions caused by the COVID-19 pandemic. The most significant disruptions were related to restrictions introduced in almost all countries, such as the closure of shopping malls, which meant that 95% of LPP stores ceased to operate immediately. However, thanks to the earlier diversification of its distribution channels, LPP was able to sell its goods to online customers, and so in this respect, distribution proved to be resilient. During the COVID-19 pandemic, LPP accelerated the expansion of this sales segment, thus minimizing the risk of focusing solely on the traditional sales segment. In connection with the accelerated development of e-commerce, LPP increased the area of its Fulfillment Center in Stryków, and established Fulfillment Centers in Slovakia and Romania.

The report also points out that the spread of the pandemic in countries where suppliers' factories are located may have a negative impact on the supply chain – there may be delays or shortages in the supply of fabrics, raw materials, and accessories, or even the closure of sewing factories; Logistical problems related to the transport and storage of goods may arise, which may negatively affect product availability. On the other hand, the outbreak of the epidemic in countries where goods are sold may have a negative impact on customer demand. Restricted mobility of people, resulting from fear of infection, as well as regulations introduced to minimize the spread of the epidemic, may lead to a decline in purchases, especially in the case of brick-and-mortar store closures.

The 2019/20 report also highlighted the risk of dependence on service providers. To reduce the risk of transport disruptions, sea freight is organized by several shipping companies, thanks to which LPP is not dependent on a single supplier. Similarly, LPP does not want to become dependent on other outsourced services, such as courier services, store construction, packaging production, etc.

The 2021/22 report shows that in 2021, LPP faced many challenges: the Covid-19 pandemic, disrupted supply chains, problems in sourcing raw materials, especially cotton, rising costs, and inflation. Due to the instability of supply chains and delays in sea transport, just-in-time deliveries were abandoned and higher stock levels were deliberately maintained in order to minimize the risk of shortages in the event of delivery delays. As a result, stock levels and the associated costs were high. However, after a series of lockdowns in 2020, clothing sales increased significantly in 2021, both in brick-and-mortar stores and online, and overall, the year was a good one for LPP in terms of financial results.

The 2021/2022 report also draws attention to the risk of armed conflict or war in countries where the LPP Group has a distribution and sales network and where its suppliers' factories are located, which may affect, for example, the continuity of the supply chain, but also on the deterioration of the company's image if it conducts business in a country that is the initiator of conflicts. More information on the disruptions caused by the war in Ukraine can be found in the 2022/23 report. In connection with Russia's attack on Ukraine and the international sanctions imposed on Russia, LPP suspended deliveries of goods to both markets. At that time, the Russian and Ukrainian markets played a significant role, generating about a quarter of the LPP Group's revenue. The outbreak of war in February 2022 resulted in the closure of both the Group's online and brick-and-mortar stores in Ukraine, and their full operation has not returned to pre-war levels. At the same time, in March 2022, the Group ended the sale of its products in Russia by closing all brick-and-mortar stores and decided to sell its Russian subsidiary to an Asian investor.

LPP has also launched a project to help Ukraine, and above all its employees, by ensuring safe passage to Poland for those employees from Ukraine and their families who have decided to do so, organizing temporary accommodation and financial, psychological, and legal support for them.

At the same time, decisions were made to change the Group's development strategy, i.e., to expand its operations not in Eastern Europe but in Southern Europe. This required the expansion of the distribution network, and a new Distribution Center was established in Brześć Kujawski, as well as warehouses to handle online sales: in Pruszcz Gdański and near Rzeszów, as well as in Romania and Slovakia.

Reports from 2022/2023 show that LPP responded to the risk of disruptions in the supply chain by:

- diversification of supplier countries, including by transferring part of production from Asia to Europe (e.g., by increasing orders in Turkey and reducing them in China) or to North Africa,
- diversification of transport modes: increasing the share of rail transport and reducing the share of maritime transport,
- implementation of a new ordering strategy that takes into account current delays in the supply chain and accelerates the ordering of goods,
- investments in the expansion of logistics facilities and technologies in logistics and IT, resulting in a reduction of the “last mile”,
- diversification of countries in which LPP has its logistics centers, e.g., the construction of a distribution center in Romania will change the route of goods deliveries from factories.

The 2023 report draws attention to, among other things, the risk of limited availability of raw materials for production and an increase in their prices. The main raw material used in clothing production is cotton. Extreme weather events, such as droughts or heavy rainfall, can adversely affect cotton crops, especially in regions where most of the world's production is concentrated.

Operating in many countries and cooperating with suppliers and manufacturers from around the world, the company also recognizes the risks of working with contractors who may not comply with accepted principles of respect for human rights.

At the end of 2023, due to Houthi attacks in the Red Sea, there was a sudden global change in maritime transport, as ships were rerouted around the Cape of Good Hope. As a result, sea transport times increased by approximately 10-12 days, and there were problems with the availability of containers and space on ships. This led to the introduction of freight surcharges by shipowners. However, thanks to long-term agreements with shipowners, LPP has no problems with containers or space availability on ships. Similarly, with any significant disruption in the global supply chain, the risk is minimized thanks to many years of cooperation with logistics partners.

Both the 2023 and 2024 reports draw attention to, among other things:

Macroeconomic risk – The LPP Group sells its products in many markets, which exposes it to changes in the economic, regulatory, social, and political environment. LPP's revenues depend on the economic situation of households and may decrease as a result of rising living costs caused by inflation or high energy costs. Economic growth or slowdown in countries where stores are located may translate into an increase or decrease in spending on clothing. Similarly, economic growth or slowdown in countries where clothing is manufactured may translate into higher or lower production costs. The Group minimizes this risk in the following ways:

Sale of goods:

- presence in many European markets – diversification of risk across many countries with varying economic situations,
- selling goods under several brands aimed at different target groups – spreading the risk across several age groups,
- offering goods at a wide range of prices.

Purchase of goods:

- outsourcing clothing production to numerous manufacturers in several countries,
- long-term cooperation with selected suppliers, which allows for negotiating favorable prices for goods.

Business costs:

- strict cost control,
- investments in renewable energy sources:

- green energy supplies, thanks to which LPP will avoid high costs of conventional energy,
- LPP has technologically advanced electricity consumption management systems in its warehouses,
- energy consumption in offices is monitored, and in 2023, the process of remote metering of all LPP stores, both in terms of energy and water consumption, was completed, which allows for the identification of inefficient consumption points.

Geopolitical risk – Armed conflicts in countries where the LPP Group has a distribution and sales network, but also in areas where suppliers' factories are located, may have a negative impact on the Group's operations.

The Group takes measures to reduce risks, such as:

- presence in many markets,
- sales limits for a given country (the share of sales in a single country cannot exceed 20% of total sales – with the exception of Poland),
- ongoing monitoring of the Group's financial settlements to prevent excessive liabilities/receivables from arising,
- monitoring of the current political and economic situation,
- conducting sales through two independent distribution channels (brick-and-mortar stores and online sales).

The reports for Q1 2025 and H1 2025 highlight the trade war. In terms of the supply chain, LPP treats the trade war as both an opportunity and a threat. It is an opportunity because it increases the company's bargaining power with suppliers in China. However, it is also a threat because the trade war may result in disruptions in the supply chain. In both reports, geopolitical instability and possible disruptions in the supply chain were ranked first among the threats. Other threats stem from increased competition, unusual weather for the season, which reduces customer purchasing motivation, and an increase in the minimum wage in Poland, which has a negative impact on LPP's costs. However, according to the author, wage growth can also be an opportunity, as the improved economic situation of households may translate into higher spending on clothing.

5. Conclusions

In scientific literature, both before and after the outbreak of the Covid-19 pandemic, cooperation is mentioned as one of the important factors supporting the resilience of supply chains.

However, after analyzing the reports of the largest Polish clothing company, the LPP Group, it must be said that there is very little mention of cooperation as a factor in improving supply chain resilience. The fact that cooperation is important in a crisis situation was mentioned in the context of long-term cooperation:

- with shipowners and logistics partners,
- with suppliers.

In both cases, it concerned the possibility of negotiating prices, and in the case of shipowners, also the provision of containers and space on ships in crisis situations. However, it should be added here that LPP has a much stronger position than its suppliers of goods and services.

However, diversification proved to be more important for the resilience of supply chains.

The diversification strategy is very important for the resilience of supply chains, as evidenced not only by the results of the author's research in the apparel industry, but also by the research of other authors cited in the literature review. These studies were conducted before the Covid-19 pandemic, but especially after its outbreak. In studies published before the Covid-19 pandemic, the principles of managing the risk of disruptions in supply chains (Kleindorfer and Saad) include both cooperation between partners in the supply chain and diversification of the location of facilities, products, and sources of supply. Also studies published after the outbreak of the pandemic highlighted the importance of both cooperation in the supply chain and diversification. This issue was highlighted by Hippold (2020), who wrote about the diversification of production networks and suppliers, and Gartner, Inc. (2021), who wrote about the diversification of production and distribution networks.

The need to apply a diversification strategy and its importance for achieving resilience was also demonstrated by research conducted by the author of this article in another industry—the automotive industry. The author conducted research at POLST, a manufacturer of aluminum alloys (Milewska, 2020). At this company, diversification concerned the product (liquid and solid aluminum alloys) and customers (in addition to Toyota, for which the company produced liquid aluminum alloys, the company also had customers for whom it produced solid aluminum alloys). During the pandemic, when production for Toyota was halted and it was not possible to produce liquid aluminum alloys (they must be produced and delivered on an ongoing basis because they must be at a temperature of over 700 degrees Celsius), POLST was able to produce solid aluminum alloys in advance and store them. When car production resumed, the company was able to sell solid aluminum alloys from its stock and use all its production capacity to produce liquid aluminum alloys for Toyota.

However, based on the author's research in the LPP Group, diversification that influenced the resilience of the supply chain concerns:

- diversification of sales across multiple countries,
- diversification of distribution channels (traditional and e-commerce),
- diversification of transport (maritime, rail, or air),

- supplier diversification,
- diversification of countries where suppliers are located.

The pandemic caused a certain increase in inventories (but not as large as expected) and the development of warehouses dedicated to serving online customers. It was also expected that the disruptions caused by the Covid-19 pandemic would lead to a return of production to Europe, but this has not been the case for the clothing industry—the vast majority of clothing is still produced in countries with low production costs, mainly in Southeast Asia.

Based on the research conducted, practical recommendations for managers of various companies that can be helpful in increasing the resilience of the supply chain are as follows:

- Cooperation between entities in the supply chain should not lead to dependence on a limited number of suppliers and customers located in a single region.
- Companies should have alternative solutions in place before disruptions occur.
- Diversification in the supply chain should concern:
 - The number of entities (e.g., suppliers and customers) with which the company cooperates.
 - Geographical areas where suppliers and customers are located (e.g., suppliers not only from countries with low production costs, but also located regionally and/or locally).
 - Modes of transport (possibility of transport not only by sea, but also by rail or air).
 - Diversification of distribution channels – companies that only use traditional distribution channels should also develop e-commerce channels.

Diversification can reduce economies of scale and thus increase unit costs. It may also involve certain expenditures, but it increases the resilience of the supply chain (trade-off).

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“LARG” IN TIMES OF CHALLENGES. CAN “LEAN” BE ALSO AGILE, RESILIENT AND GREEN?

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Purpose: The topic of the article is the LARG concept, in particular the problem - whether a company (or supply chain) can be Lean, Agile, Resilient and Green at the same time, or whether in some areas there is a contradiction between these paradigms. The aim of the article is to present the possibilities of combining these management concepts, which are often treated as competitive, and which, according to the author, can and should be combined. These considerations are made taking into account contemporary problems and challenges (pandemic, political situation, social issues, technological development) that require verification of the methods, concepts, strategies, and management tools used so far.

Design/methodology/approach: The author reviewed the literature and interviewed an employee of a company that has been successfully applying the concept of Lean Management for years. The author also presented (in a synthetic manner) the results of his research, which he has been conducting for years and which have already been presented in previous publications. This article is therefore a kind of summary of his work to date.

Findings: The author hypothesized that there are LARG paradigms that support each other, but some of them are mutually exclusive in certain areas. The connections between the four paradigms were examined. The same company can combine Lean and Agile concepts. The area where the greatest contradiction in the LARG concept occurs is primarily inventory management. Lean requires a reduction of inventories in the company, while Agile requires larger inventories. Inventories help to achieve greater supply chain resilience, while smaller inventories are consistent with the ecological concept. The second area where there is a fundamental contradiction between Lean and Agile is the number of suppliers and the stability of connections in the supply chain.

Research limitations/implications: Although the author has been conducting research on this topic for years and has found confirmation for the hypotheses presented in his publications, further research is necessary—in a larger number of companies, from various industries in different countries (previous studies have focused on Polish companies).

Practical implications: Changes in methods, systems, tools for managing a company and its processes are necessary in the face of challenges in today's world. This article attempts to find answers to the question of what changes should be introduced.

Social implications: Although streamlining processes and managing them effectively helps to reduce social costs, in many cases there is a conflict between the two. The intention of this article was to show how to reconcile social goals (external costs) with business goals.

Originality/value: The author's intention was to present how companies should take into account contemporary economic and social challenges by modifying the concepts of

organization management and its resources and processes that have been used so far. The article is therefore addressed to both researchers and practitioners.

Keywords: Management, “LARG” (Lean, Agile, Resilient, Green), disruptions in the functioning of the company, process efficiency.

Category of the paper: Research paper.

1. Introduction

Companies operating in a competitive market want to use a strategy that will allow them to achieve success. For a long time, Lean was considered to be such a strategy, which is not always effective in conditions of instability and unpredictability. Some companies have therefore started to implement an Agile strategy. The disruptions that have occurred in recent years, primarily the Covid-19 pandemic, but also the outbreak of the war in Ukraine and large fluctuations in fuel prices, have made the resilience of both companies and entire supply chains to disruptions a valuable asset. Problems of environmental pollution and global warming make consumers want to buy goods produced by companies and supply chains that are green, forcing companies to put more emphasis on green logistics and production. The research question posed by the author is: can a company (or supply chain) be Lean, Agile, Resilient and Green (LARG concept) at the same time? Is there a contradiction (trade-off) between these paradigms in some areas?

The aim of the article is to present the possibilities of combining management concepts that are often treated as competitive, and which, according to the author, can and should be combined to achieve a synergy effect. In other words, not trade-off, but trade-up.

Hypothesis: there are LARG paradigms that support each other, but some of them are mutually exclusive (contradictory) in certain areas.

To this end, the author reviewed the literature and interviewed an employee of one of the Polish manufacturing companies that successfully applies the concept of Lean Management, but also strives to adapt the solutions used so far to new business and social conditions.

2. Literature review

The Lean strategy uses a set of techniques and tools (Kanban, visual management, visual control of shop floor performance, SMED) aimed at cost reduction, continuous improvement and customer satisfaction (Womack et al., 1990; Womack, Jones, 1996). The metrics used to assess the efficiency of output are the amount of waste (Shah, Ward, 2007) and defects (Soriano-Meier, Forrester, 2002), the time or cost of work that does not generate added value

of processes (e.g. handling, waiting time or setup time (Parveen, Rao, 2009), effective use of internal resources (Shah, Ward, 2007), the level of process integration and the size of inventories (Soriano-Meier, Forrester, 2002). It is worth noting here that the positive effects of this concept also have an environmental dimension.

The use of the Lean Management concept is intended to reduce wastes but some tools like SMED also increase the flexibility of processes in enterprises and supply chains. However, for years it has been proposed to increase this flexibility by using the Agile concept, thanks to which the economic efficiency of companies can be improved (Abdelilah et al., 2023). The concept of "agility" was introduced in this regard by the Iacocca Institute (USA) and immediately gained popularity as a strategy for competing in global and unstable markets (Yusuf et al., 2004). Eshlaghy et al. (2009) hypothesized that supply chain flexibility can be achieved through the use of four components: product development flexibility, supply flexibility, production flexibility, and logistics flexibility. According to Van Hoek et al. (2001), supply chains should develop capabilities that allow flexibility and the ability to respond to (variable) market demands.

According to research conducted in enterprises using the concept of "agility", it is based on: cooperation and even long-term relationships with customers, suppliers and even competitors, use of a resource base with other companies, data integration based on shared information systems with other companies and co-production alliances (Yusuf et al., 2004). The benefits of such cooperation include the company's ability to introduce new products (Agarwal et al., 2007), speed of customer service (Swafford et al., 2008), implementation of joint plans (Agarwal et al., 2007), use of ICT tools for coordination and integration activities in the supply chain (Lin et al., 2006) and the company's flexibility in adapting to changes in deliveries to customers (Swafford et al., 2008).

Therefore, it can be concluded that the goals and even the solutions and approach used are similar to those in the Lean Management concept. Yet they are often treated as competitive. We are dealing with a kind of paradox here - the need to combine various strategies and management concepts exists, although companies in the modern world face challenges that make this combination difficult. However, companies with efficient supply chains perform better than companies focused solely on implementing lean practices or supply chain integration, which is also confirmed by research conducted by the author of this article.

However, if a company becomes both "lean" and "agile", will this be enough?

Modern supply chains and networks are increasingly exposed to the risk of disruption, which requires increasing their "resilience" (Christopher, Peck, 2004). Supply chain resilience is the ability to respond to shock or disruption (Blackhurst et al., 2011). These disruptions are often beyond the control of companies and supply chains (Juttner et al., 2003). A resilient supply chain is able to respond effectively to unexpected events and disruptions and maintain the planned quantity of production, deliveries and the quality of processes and products (Vlajica et al., 2012). Traditional ways of counteracting these problems are increasing inventories

(Xiaohui et al., 2005) or accurate selection of supplies (Wu et al., 2006), which can shorten delivery times and increase the flexibility and resilience of supply chains (Azevedo et al., 2016; Cardoso et al., 2015).

The source of such disruptions in supply chains in recent years was, of course, the Covid-19 pandemic (Jha et al., 2021), which resulted in a return to “traditional” strategies. This is an interesting phenomenon in the context of the demands made for years and the strategies used in practice by companies, which were aimed at reducing resources (inventories, number of suppliers, carriers) through better integration and cooperation. And here we can ask another question, similar to the previous one - should we accept these conditions or look for solutions that will allow us to maintain the current strategies and at the same time increase their resilience?

A similar approach can be taken to the issue of including ecological (green) aspects in company strategies. There is usually a perceived conflict between business and environmental goals. This also applies to the functioning of supply chains. If companies included these aspects in their strategies, one could get the impression that it was due to image reasons, which may bring benefits in the form of higher revenues, despite higher costs.

However, it is increasingly recognized that green management and sustainable supply chains could contribute to cost reduction through more efficient use of resources such as water, energy and raw materials (Walker et al., 2008). Green SCM (Hervani, 2005) can lead to an overall increase in corporate profits, quality levels, reliability, cost reduction, increased productivity and energy efficiency (Srivastava, 2007).

The above-mentioned paradigms have been combined in the form of the LARG concept (Azevedo, Carvalho, Cruz-Machado, 2011), i.e. the postulate to be simultaneously lean, agile, resilient and ecological. Sustainable LARG supply chains are lean (Chun Wu, 2003, Dora et al., 2016), eliminate waste (Taylor, Pettit, 2009; Dey et al., 2019), are flexible (Baramichai et al., 2007), resilient (Cabral et al., 2012) but also ecological (Srivastava, 2007). They help reduce production and transportation lead times, improve the level of integration and achieve effective information exchange (Alqudah et al., 2020).

Implementing LARG (Lean, Agile, Resilient, Green) practices in supply chain management is a complex task, mainly because ecological, economic and operational goals are usually contradictory. To successfully implement LARG practices, companies need the right decision-making tools to control process performance and visibility into improvement strategies. RMA may be such a tool – (Rachid, 2017).

It is necessary to identify and understand the trade-offs between these paradigms. Research conducted in the automotive industry in a supply chain context shows that not all companies in the same supply chain need to have a higher level of implementation for all LARG practices (Carvalho et al., 2014). Some companies may be more resilient than others, and the same thing happens with the Lean paradigm: not all companies in the supply chain need to be completely lean.

Although it can be demonstrated that there are possibilities for combining these four concepts, the authors rightly admit that this is not easy and requires the support of machine and equipment technology. For example, in the automotive industry, “Lean” and “Green” are often combined, while the combination of ‘Agile’ and “Resilient” is limited (Purba et al., 2025; Sunmola et al., 2024; Jothi et al., 2023; Revutska, Antlová, 2022; Fowler et al., 2023; Sambowo, Hidayatno, 2021; Kaviani et al., 2020; Kolasani, 2024; Britsche, Fekete, 2024; Sweeney et al., 2020; El Ahmadi et al., 2022).

The increasing impact of technology, Volatility, Uncertainty, Complexity, Ambiguity (concept of VUCA) development of lean, agile, flexible and green (LARG) cause that the classical chain understanding should be changed (Doğan, Derici, 2025).

The possibility and necessity of combining these concepts has been presented in publications by the author of this article in recent years.

The outbreak of the Covid-19 pandemic and the subsequent disruptions in Europe and around the world sparked a lively debate about the effectiveness of Lean Management and Just-In-Time systems. The results of the research conducted by the author showed that the scale of production and logistics processes is important factor of is an important factor in broadly understood efficiency (LARG). Disruptions can be not an obstacle but an inspiration for change. For example disruptions in global supply chains and increased transport costs can contribute to the shortening the distances of deliveries and decreasing of the logistics costs, including external costs of these processes (Milewski, 2022).

The companies studied by the author successfully implement various concepts (Lean, Agile, Teal, Green) at least some of their elements (Milewski, Milewska, 2023). This combination may prove to be more effective than using "pure" strategies. The effect of using various strategies is lower costs, better product quality, higher level of logistics service, greater customer satisfaction (trade-up effect).

The results of research on the resilience of companies using management concepts such as Lean Management, Agile, and Six Sigma to the crises that companies have had to face in recent years: the COVID-19 pandemic, rising energy prices, and the war in Ukraine showed, that the implementation of these management concepts should lead to process improvements and a reduction in the consumption of production resources, including energy (Milewska, Milewski, 2025). The results of this research show that companies using Lean Management, Agile, and Six Sigma strategies and their combinations were able to adapt to the new conditions. Eliminating waste and increasing the efficiency of production or logistics processes leads to a reduction in energy consumption and external costs. It is necessary however to use modern technologies (digital technologies, Industry 4.0) and new, specialized solutions - e.g. to increase the energy efficiency. The publication cited above contains interviews with employees of Polish companies that use Lean Management. The conclusions are positive—Lean companies tend to be resilient, provided that they take into account the new conditions in which modern business operates.

The second part of these interviews was presented in the author's subsequent publication—a monograph on the productivity of enterprises in the modern economy—and contains similar conclusions (Milewski, 2025). Effective companies have coped well during these difficult times. However, new challenges of a social nature must also be taken into account, such as generational change and the aging of societies. Technological progress does not eliminate humans from the production process, so it requires adaptation to new conditions. Lean Management and Six Sigma also require modification and adaptation to the contemporary conditions of business operations.

3. Interview – The case of ZMM MAXPOL

One of the people who gave these interviews was Mr. Paweł Dąbek, who is a production optimizer at ZMM MAXPOL and who shared his comments on the issue of resilience for the third time, which are presented in the next section of this article.

ZMM Maxpol (Rzeszów, Poland) has been operating since 1985 and specializes in the production of plastics (0.36 million parts per day, including both aesthetic and designer household appliances and electronics, as well as components for gardening and construction).

The production processes are: Automatic material feeding, PUR, Double / triple injection, Blow molding, Hot – stamping, Tampoprinting, Paint shop, Plastic injection.

The threats and disruptions that the company has faced and continues to face over the past five years are not only external—related to cooperation with other companies and the business environment—but also internal:

- COVID-19 pandemic: decline in orders, decline in availability of raw materials, employee absenteeism.
- War in Ukraine: rising energy prices, geopolitical uncertainty, labor migration.
- Cyber threats: attacks on email accounts.
- Employee turnover: shortage of qualified staff, resignations, burnout.

In the face of disruption, the company focused on building a Lean culture, but also on solutions that Lean had not been associated with for decades: automation, robotization, and process optimization. Despite smaller orders due to the COVID-19 pandemic, ZMM MAXPOL, unlike some LEAN organizations, did not abandon Lean solutions but sought solutions to problems. As the employee giving this interview rightly stated, “nothing lasts forever”, and besides, a crisis is an opportunity for growth. This observation is correct—changes are necessary, and not only when crises occur.

A crisis, however, may not be an obstacle but, on the contrary, an inspiration to make changes. For example, the outbreak of the Covid-19 pandemic resulted in internal training, closer cooperation between departments, and a higher level of organizational culture, which made the company feel stronger than before the pandemic.

The lack of availability of materials forced the company to look for new suppliers, giving it more choice than before. This is worth noting, as this approach may seem to be a departure from the dogmatic principles of close integration with suppliers, which may be more associated with Agile than Lean.

Similarly, the war in Ukraine and the associated increase in energy prices prompted the company to look for ways to reduce energy consumption costs. These opportunities are again created by a process-based approach to reducing these costs. Optimizing the operation of machines and robots, as well as minimizing and optimizing the amount of equipment, has reduced energy costs by approximately 10-15%.

The migration of workers has increased the number of Ukrainians working in the company, but the company has long employed workers from Ukraine and Belarus, as well as deaf people and people with other disabilities, because our company has the status of a sheltered workshop. This diversity of employees has led to the development of an individual approach during training and daily work. For example, the employee surveyed conducts 5S training in several different ways, depending on the person undergoing such training. This is worth emphasizing, because this theme of an individual approach recurs in these descriptions.

The company approaches the issue of uncertainty not only procedurally but also strategically. Its response to geopolitical uncertainty was to expand its two own brands: DOMELO and HAGSEN—construction and gardening products and small household appliances. At the same time, the company is expanding its cooperation with such giants as BOSCH, Siemens, and Elektrolux.

Intensive work is underway on Quality, Efficiency, and Availability, which has allowed the OEE (Overall Equipment Effectiveness) index to be maintained at between 83% and even 99% for individual processes, which before the pandemic fluctuated between 71% and 86%.

Another problem is cyber threats and a similar response. For the first time in its history, the company experienced a cyber attack on its email accounts. However, the IT department did not stop at securing them, but secured the entire company server. The security measures consisted of replacing hardware and software. Training on cybersecurity was also conducted.

Changes are not only made because of crises that occur in the companies' environment and force them to change. The company has been innovating for a long time—simply by looking for effective solutions. These solutions concern not only process efficiency and related costs, but also quality in the broadest sense.

Process improvement resulted in fewer quality issues and lower production costs – reduced material consumption, shorter time, fewer employee errors due to the elimination of human involvement in certain processes.

The company is also working on its image through “aggressive” advertising and sponsorship (the company sponsors sports teams) in order to become even more visible on the market but also to reduce.

Employee absenteeism was also an inspiration to take action in the area of HR and achieve more benefits than before COVID. The company is trying to increase its attractiveness—lunches subsidized by the company, subsidies for sports, professional skills development and an improved work atmosphere. Employees talk more often during lunch breaks and comment on sports competitions. The result is lower absenteeism. The company has its own soccer team, runners, and wrestler, and the CEO's grandson competes in Formula 1 and is successful on tracks across Europe. Team-building events have a significant impact on the development of the company culture, and the company culture is the source of the company's resilience. The company's resilience, in turn, is influenced by people—that is, the internal culture of respect and continuous improvement

The company has full access to AI language models – ChatGPT and Gemini, which employees use very often. The company uses three AI assistants (prompts) – for 5W1H and 5WHY, and for 8D Reports (support in creating reports and in Ishikawa). Once again, it is worth emphasizing that the company uses modern technologies and does not just improve processes using traditional methods associated with Lean Management.

The company continues and accelerates the digitization of data and reporting, as well as the display of KPIs, in order to minimize the use of Excel spreadsheets. The company aims to conduct internal audits using smartphone applications. To this end, the IT department is developing dedicated software. In addition, applications for KJ, UR, and the Tool Room are used.

The process planning process is optimized to increase machine availability and fulfill customer orders on time. The MES system update significantly improves the work of planners.

Work is ongoing on 5S, which is recognized within the company as the best tool for increasing employee engagement and, as a result, improving process efficiency. Building a culture of continuous improvement is also based on KAIZEN. Processes are analyzed and optimized in the PDCA cycle with the support of SPC, Pareto, Ishikawa, 5WY, and 8D reports, including internal ones, FMEA, and VSM. Currently, the surveyed employee conducts 5S training with each new employee and has developed a proprietary calculator for calculating operating times, all of which means that awareness and experience in the field of continuous improvement continues to grow. This is worth emphasizing because a characteristic feature of Lean Management is employee engagement and creativity.

More and more internal audits of processes, products, and 5S are being conducted. There are several certified internal auditors, which ensures that the audits are conducted at a very high level. After the audits, the results are analyzed and actions are developed and implemented, which is a prerequisite for continuous improvement.

The company is currently building a third production hall and purchasing machines, 3D printers, cobots, robots, and equipment, thereby increasing its potential.

Once a year, an analysis of opportunities and risks for the entire company and individual departments is carried out, and appropriate measures are taken over the following months. All this has a positive impact on the company's resilience.

The surveyed employee also expressed his opinion on the differences and similarities between Lean and Agile, which are often treated as competitors: Lean is a philosophy/concept of continuous improvement through minimizing waste, with people at its core. Agile, on the other hand, emphasizes quick response, adaptability, and collaboration. In the employee's opinion, the opportunities offered by both Lean and Agile should be exploited, as one does not exclude the other:

- Lean refers to stable processes that are optimized “every day and endlessly,” while Agile refers to adaptability. However, process optimization must also take new conditions into account, so the process must be adapted and optimized in these new conditions.
- Lean requires employee engagement, while Agile is about autonomy and teamwork. However, Lean also requires teamwork and the utilization of each employee's potential.
- Lean uses analytical tools such as PDCA and Kaizen, while Agile uses quick “optimization sprints,” but even these “sprints” should be preceded by analysis.
- Lean emphasizes standardization and continuous improvement, while Agile emphasizes experimentation and feedback, yet experimentation must be followed by standardization, and continuous improvement is not possible without information transfer.

Greater benefits will therefore be achieved from combining Lean and Agile than from separating these two concepts.

To sum up this part:

- A company's resilience is most influenced by its culture. A company with a deeply rooted culture of continuous improvement is much more resilient.
- People are the most important factor—investments in buildings and machinery alone are not enough. It is the employees who create a culture of continuous improvement.
- Digitization and AI are another very important factor in a company's resilience.
- Building a culture of continuous improvement based on Lean, and preferably on a combination of Lean and Agile, by knowledgeable and competent individuals greatly increases the resilience of the company.
- Both Agile and Lean will not be effective without the knowledge and awareness of management and without proper training/attitude of employees.
- The source of resilience is not the method itself, but the people who apply it with conviction and flexibility.

4. Conclusions

The conclusions drawn from the author's research are as follows:

- There are no contradictions between the Lean and Agile paradigms in some areas, the contradiction may occur primarily in the area of "inventories", because Lean postulates to "lean" the company by reducing inventories, while in Agile they constitute a buffer allowing for flexibility. However, Lean organizations also use inventories if it is justified, e.g., economically or by the conditions in which the processes are carried out.
- Lean and Agile are suitable for different characteristics of the product, production and demand (Lean - typical product, mass production, stable demand, Agile - typical product, small series or unit production, unpredictable variable demand), but the same company can combine the concepts of Lean and Agile.
- There are no contradictions between Lean and Green, the use of the Lean strategy may promote ecology, e.g. the reduction of resource waste postulated by Lean has a positive impact on the natural environment.
- Between Lean and Resilient, there is no contradiction in some areas, but a contradiction may occur in the "stock" area, just like between Lean and Agile. Diversification also promotes resilience, which may lead to underutilization of scale.

The area where the greatest contradiction in the LARGE concept occurs is primarily inventory. Lean postulates the reduction of inventory in the company, while larger inventories are created in Agile. Inventories promote greater supply chain resilience, while smaller inventories are consistent with the Green concept.

The second area in which there is a major contradiction between Lean and Agile is the number of suppliers and the stability of connections in the supply chain. Lean postulates having a small number of suppliers and stable connections, Agile - a larger number of suppliers and weaker integration. Supply chains with a larger number of suppliers are more resilient, but from "Green" point of view, it is not the number of suppliers that matters, but rather their location (local, regional or global suppliers) and the size of the delivery batch, which affects the frequency of deliveries. However, the essence of Lean Management has never been about giving up inventory, frequent deliveries in small quantities, reducing the number of suppliers, etc. First of all, Lean organizations have always strived to simplify processes, including reducing inventory and limiting the number of cooperating companies.

However, this was never treated as a dogma, and solutions were applied that were feasible in a given situation and cost-effective.

We can say the same about the concept of "Resilience". A resilient supply chain will not be the most economically efficient in the short term. However, in the long run it may also turn out to be economically effective.

However, perhaps the most important conclusion from the research presented in this article is that although there are similarities, commonalities, and therefore possibilities for combining these four concepts, it is not easy to do so. Technological progress offers the most important opportunities for their effective combination.

An interview with an employee of the company under study, which applies the concept of Lean Management, shows that social aspects are important. On the one hand, in the era of Artificial Intelligence, people are still an important part of the process. Secondly, solutions aimed at increasing process efficiency also have an impact on social aspects. This applies primarily to employees, who should feel comfortable in the company and pursue their interests e.g., in recreational activities organized by the company (the company surveyed managed to achieve this, which reduced absenteeism, thereby strengthening the company's resilience). Employees should be able to identify with the company and its values, if we are to demand efficiency, creativity, and resilience from them. In addition, employees cannot feel threatened that, for example, after streamlining the process, it will turn out that some employees will not be needed and will be laid off.

An analysis of the literature presented in this paper, an interview with an employee of ZMM MAXPOL, and the results of the author's years of research lead to the following conclusions:

In the unstable conditions in which we operate, in order to achieve an adequate level of resilience, it is necessary to move away from a dogmatic approach to the methods used to manage the organization, its processes, and resources. Instead of comparing and evaluating management concepts such as Lean Management, SixSigma, or Agile, we should look for what they have in common and try to combine them. In the author's opinion, there are two approaches to their evaluation: one is to assess which of them is more effective, and the other is that they are suitable for different types of activities, markets, customers, and products, so they should not be compared and cannot be used together. However, cases such as ZMM MAXPOL (but also others studied by the author) prove that at least some of their elements can be effectively combined. The same applies to technological progress – for decades, it was emphasized that Lean Management does not need advanced technologies because process improvement is sufficient for their efficiency and resilience. Nowadays, technological progress offers benefits that should not be overlooked.

There is no other option anyway – the situation on the labor market (social aspect) will force us to use e.g. AI.

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SUCCESS FACTORS IN INFRASTRUCTURE PROJECT MANAGEMENT

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Purpose: The main objective of this thesis is to identify critical success factors in infrastructure project management.

Design/methodology/approach: The research conducted for the purposes of this study included a literature review, surveys, and analysis of research results. Based on a review of the literature, a research tool for conducting a survey was developed in this article. The survey questionnaire was addressed to project managers, project team members, members of Project Board, and other individuals involved in infrastructure projects and with experience in project management.

Findings: Based on the research conducted, critical success factors in infrastructure project management in Poland were identified. The results of the research are largely consistent with previous analyses of critical success factors in Poland. These similarities stem primarily from the universal principles of effective project management, which apply regardless of the organizational context. The observed differences can be attributed to different research conditions and the specific nature of infrastructure projects.

Research limitations/implications: Although the study allowed for the identification and prioritization of critical success factors in infrastructure project management in Poland, it has certain limitations. Firstly, the research sample consisted of 104 respondents, mainly representing entities operating in Poland. Although this ensures contextual consistency, it limits the possibility of generalizing the results to other countries or regions where institutional, legal, and economic conditions may differ. Second, the study was based on the respondents' self-assessment, which may involve the risk of subjective answers and cognitive errors. Furthermore, the study did not take into account in detail the impact of contextual factors such as the type of infrastructure (transport, energy, social) or the financing model.

Practical implications: The presented results can serve as a tool supporting the decision-making process in infrastructure project management, helping managers and decision-makers focus on areas with the greatest impact on the success of the project. By combining theoretical and practical perspectives, the article is a valuable source of knowledge for both the scientific community and practitioners who seek to increase the effectiveness of infrastructure project implementation in conditions of growing complexity and risk.

Originality/value: This article contributes to the national and international discussion on infrastructure project management, focusing on the identification and prioritization of critical success factors in the Polish economic context. The study is valuable for the development of knowledge, learning, and improving the quality of infrastructure project management.

Keywords: project management, critical success factors, infrastructure project management.

Category of the paper: Research paper.

1. Introduction

In times of dynamic economic growth and ever-increasing social expectations regarding quality of life, infrastructure development plays an increasingly important role in shaping the reality around us. Investments in infrastructure, such as the construction of bridges, roads, water and sewage systems, public facilities and energy infrastructure, are the foundation of an efficiently functioning state and a prerequisite for sustainable development. Infrastructure development improves the quality of life of citizens, increases the investment attractiveness of a given region and boosts economic competitiveness.

Infrastructure projects are highly complex undertakings, which makes their effective management a serious challenge (Yescombe, 2014; Flyvbjerg, Gardner, 2023). These projects require careful planning, appropriate resource management, effective risk management and efficient communication between various stakeholders. In conditions of limited budgets, time pressure, political and legal constraints, and the growing importance of environmental issues, it is crucial to identify the factors that have the greatest impact on the success of such projects (Gudienė et al., 2013; Saqib et al., 2008).

Analysis of these factors allows for a better understanding of how to effectively plan and implement complex investments and how to avoid mistakes that can lead to delays, budget overruns or problems in achieving the set objectives. Previous research on critical success factors in project management has focused on various sectors (Thomas, Fernández, 2008; Wilczewski, 2015; Spalek, 2004; Wirkus, Tubielewicz, 2018). Most of the available studies on critical success factors in infrastructure projects are general in nature or refer to international experiences (Yamany et al., 2024; Wang et al., 2022; Chan et al., 2004; Müller, Jugdev, 2012), which makes it difficult to transfer conclusions to local economic conditions.

With this in mind, the main objective of the study was to identify critical success factors in infrastructure project management in Poland. As part of the considerations, two fundamental research questions were formulated, which guide the research process and enable the main objective of the study to be achieved:

1. What are the success factors in project management?
2. What are the success factors in infrastructure project management and which of them can be considered the most important?

The identified success factors in infrastructure project management can be used as a tool to support the decision-making process in assessing and improving the effectiveness of project implementation.

2. Theoretical background

2.1. Infrastructure projects

Infrastructure plays an important role in socio-economic development. According to A. Carse, infrastructure refers to the vast, complex and changing systems that support modern societies and economies (Carse, 2017). Infrastructure systems form the backbone of modern society, providing essential services such as water supply, energy distribution, transport and waste management (Thacker et al., 2019). In order to create such systems, it is necessary to implement many projects. A project is „a temporary endeavour undertaken to create a unique product, service, or result” (PMBOK, 2019). An infrastructure projects can therefore be defined as „large investment projects of strategic importance that are costly, complex, require a long time to complete and have a significant economic, social and environmental impact” (Flyvbjerg, Bruzelius, Rothengatter, 2003). According to the OECD, „infrastructure projects involve long-term capital investments in public goods that provide essential services to society and the economy, and their implementation requires significant financial resources and the cooperation of many stakeholders” (OECD, 2007). Infrastructure is the foundation of the economy, and infrastructure projects are investments that provide long-term public services and require a special approach to financing and management due to the scale of risk and longevity of the assets (Grimsey, Lewis, 2002).

In summary, infrastructure projects are investment ventures aimed at creating, expanding, modernising or maintaining technical and social infrastructure systems and facilities necessary for the proper functioning of the economy and society. They may include, among others, transport (roads, railways, airports, ports), energy (power plants, transmission networks), water management (water supply systems, sewage systems, dams), telecommunications and social infrastructure (schools, hospitals, cultural facilities).

2.2. Success criteria and success factors

Success criteria are dependent variables used to assess the extent to which a project has been successful. They can be classified, among other things, as subjective or objective, or as measurable or immeasurable, as well as quantitative and qualitative (Pandremmenou et al., 2012). Initially, their division was based solely on the concept of the iron triangle, but over time a distinction was made between criteria at the micro level, where they were

identical to the dimensions of the iron triangle, and at the macro level, where they concerned customer and stakeholder satisfaction (Muller, Turner, 2010) and the market share maintained by the company (Eriksson, Westerberg, 2011; Alam et al., 2008; Toor, Ogunlana, 2010).

Other classifications can also be found in the literature on the subject, such as the one presented by Thomas and Fernandez (2008). They distinguish success criteria according to three perspectives. The first perspective concerns project management and includes continuous monitoring of time, budget, and the satisfaction of the project sponsor, customer, and other stakeholders. The second perspective concerns technical evaluation and includes criteria such as customer satisfaction with the compliance of project results with technical specifications. The last perspective concerns the operational level, which takes into account criteria such as continuity of operation and sustainable development.

A slightly different approach to project success is presented by researchers who attempt to identify factors that contribute to project success. Most often, these factors are identified based on observations of their recurrence in successful projects. From among these factors, the most important ones are selected, which are called critical success factors (Pinto, Pinto, 2021; Pinto, Slevin, 1987; Ika, Pinto, 2022).

On this basis, it can be said that success criteria are standards or benchmarks that determine how we recognise success, i.e. they set the assessment criteria. Success factors in project management are key areas that have a decisive impact on the achievement of project objectives. Proper identification and management of these factors increases the chances of project success.

2.3. Critical success factors

The theory of critical success factors applies not only to projects, but also to the functioning of enterprises. J.F. Rockart developed critical success factors as a tool for strategic planning and management. He defined critical success factors as ‘a limited number of areas in which satisfactory performance will ensure that an organisation functions successfully in a competitive environment’ (Rockart, 1982). In relation to projects, critical success factors describe a limited number of areas in which satisfactory results will ensure that the project objectives are achieved. Thus, critical success factors are both necessary and, sometimes, sufficient conditions for achieving objectives

There is a wealth of literature on critical success factors in project management, covering various projects, often implemented in different countries. In Poland, research on critical success factors focused on projects implemented in various companies (Spalek, 2004), and critical success factors specific to the type of project were also identified (Frączkowski, 2016; Wilczewski, 2015; Wirkus, Tubielewicz, 2018; Węgrzyn, 2014). In the field of construction and infrastructure projects, Gündüz and Almuajebh (2020) identified 40 critical success factors and assigned them to seven categories. Ihuah et al. (2014) identified 22 critical success factors for project management that are essential for the implementation of sustainable social housing in Nigeria, while Saqib et al. (2008) identified 77 factors and 10 critical success

factors in construction projects in Pakistan. Osei-Kyei and Chan (2017) analysed success factors for public projects in Ghana implemented under public-private partnerships, while Gudienė et al. (2014) classified critical success factors for construction projects in Lithuania using the AHP method.

In summary, the most common success factors in infrastructure and construction project management (Gunduz, Almuajebh, 2020; Osei-Kyei, Chan, 2015; Ika et al., 2012; Gudienė et al., 2014; Saqib et al., 2008; Yamany et al., 2024) are:

1. Support and commitment from management/decision-makers (top management, government, public institutions).
2. Clearly defined project objectives and scope.
3. Effective communication and cooperation between stakeholders.
4. Competent and experienced project team (managers, contractors, consultants).
5. Accurate planning and scheduling.
6. Appropriate risk and uncertainty management.
7. Adequate funding and stable sources of funds.
8. Control of costs, time and quality (iron triangle).

An analysis of the literature therefore allows us to identify recurring and key factors that determine the success of infrastructure and construction projects.

3. Methods

In order to determine the impact of individual factors on project success, research was conducted to identify critical success factors. The research was carried out in the following stages:

- Stage 1: Identification of success factors in infrastructure project management.
- Stage 2: Assessment of success factors in infrastructure project management.
- Stage 3: Identification of critical success factors in infrastructure project management.

Stage 1: Identification of success factors in infrastructure project management

Based on the literature review, a list of 70 factors influencing the success of infrastructure projects was compiled. The list was consulted with experts (project managers and members of project teams involved in the planning and implementation of infrastructure projects), which allowed the number of factors contributing to the success of infrastructure projects to be reduced and focus to be placed on the most important ones, resulting in 31 factors being identified. The identified factors were assigned to specific stages of project management. Table 1 presents 31 success factors that influence the management of infrastructure projects.

Table 1*Success factors for infrastructure projects*

Project management stages	Success factors
Initiation	A.1 Accurate identification and clarification of customer requirements before starting the project. A.2 Accurate identification of the main objectives of the project before starting implementation.
Planning	B.1 Ensuring qualified and experienced contractors. B.2 Obtaining external sources of financing. B.3 Appointing a Project Board with appropriate qualifications and experience. B.4 Appointing a project manager with appropriate competences, high authority and experience. B.5 Developing clear rules for communication with stakeholders. B.6 Precisely defining the organisational structure of the project. B.7 Ensuring the availability of financial resources throughout the duration of the project. B.8 Planning resources for the project. B.9 Setting a project completion date with the project team during project planning. B.10 Establishing a project team with appropriate competencies, extensive experience and skills.
Implementation	C.1 Motivating project team members. C.2 Compliance with current legal and environmental standards. C.3 Managing changes in the project. C.4 Ensuring efficient flow of information between all project stakeholders. C.5 Appropriately adapting the project management style to the specific nature of the project and the team. C.6 Risk management. C.7 Applying modern technologies and innovative solutions in the project. C.8 The same project manager as in the planning phase. C.9 Regularly organising team working meetings during the project implementation. C.10 Motivation and commitment of project team members. C.11 Project stakeholder management. C.12 Full involvement of project management staff in project implementation. C.13 Legal support for the project. C.14 Motivation of the project manager. C.15 No changes in project team members. C.16 No changes in Project Board members.
Monitoring and control	D.1 Regular control and monitoring of project progress. D.2 Monitoring and control of expenditure in relation to the planned budget. D.3 Regular reporting to the client on project progress.
Closing	-

Source: own elaboration.

Stage 2. Assessment of success factors in infrastructure project management

Project managers, project team members, members of the Project Board and other persons involved in infrastructure projects with experience in project management were invited to participate in the survey.

A total of 160 questionnaires were distributed, of which 104 correctly completed sheets were returned, giving a response rate of 65%. The survey was conducted by making the questionnaire available in electronic form and sending it by e-mail to companies located throughout Poland that are involved in the implementation of infrastructure projects. A total of 104 people took part in the survey, with project team members constituting the largest group (46.15%). Project managers accounted for 30.77%, while members of Project Board accounted

for 19.23%. The remaining respondents were construction managers, quality controllers and investors.

More than half of the respondents stated that they most often worked on local projects (53.85%), another group (39.42%) most often implemented national projects, while 6.73% of respondents declared that they implemented international projects.

The study was conducted in the form of a survey, which was divided into two stages. The first part consisted of closed questions, to which respondents could choose one of the given answers. The second part involved assessing the given success factors on a five-point scale of their impact on the success of the project.

Next, based on the responses obtained, a statistical analysis was conducted to organise the factors provided and identify those that are crucial for the implementation of infrastructure projects.

Stage 3: Identification of critical success factors in infrastructure project management

In the third stage of the research, critical success factors in project management were identified. The following factors were considered critical:

- high average ratings (the higher the average, the greater the importance of the factor),
- low coefficient of variation below 20% (the lower the coefficient, the greater the homogeneity of respondents' opinions) We classify the coefficient of variation according to the following parameters (Mucha, 1994): low $CV < 20\%$, average $20\% \leq CV < 40\%$, high $CV \geq 40\%$.

The Pareto principle, according to which 80% of results come from 20% of causes, was also used to identify critical success factors. This is an empirical law that allows the identification of factors that have the greatest impact on the success of an infrastructure project (Głowienka, 2021).

4. Results

As a result of the empirical research, data were obtained that made it possible to determine the significance of success factors in the management of infrastructure projects in Poland. For the examined factors, basic descriptive statistics were calculated: mean, median, standard deviation, and coefficient of variation. Based on these results, a hierarchy of success factors in infrastructure project management was developed (Table 2).

Table 2.*Descriptive statistics of success factors in project management, hierarchy of factors*

Success factor	Mean	Median	Standard deviation	Coefficient of variation	Hierarchy of success factors
B.4	4.67	5	0.47	10%	1
A.1	4.64	5	0.54	12%	2
C.6	4.63	5	0.49	11%	3
D.2	4.57	5	0.6	13%	4
A.2	4.56	5	0.62	14%	5
B.7	4.56	5	0.62	14%	6
B.10	4.53	5	0.62	14%	7
B.1	4.48	5	0.64	14%	8
B.5	4.39	4	0.49	11%	9
D.1	4.3	4	0.57	13%	10
C.2	4.22	4	0.62	15%	11
C.3	4.19	4	0.64	15%	12
C.4	4.16	4	0.66	16%	13
D.3	3.79	4	0.87	23%	14
B.6	3.71	4	0.62	17%	15
C.5	3.7	4	0.62	17%	16
C.1	3.57	4	0.69	19%	17
C.7	3.55	4	0.62	18%	18
B.2	3.51	3	0.7	20%	19
B.8	3.49	3	1.03	30%	20
C.8	3.43	3	0.73	21%	21
C.9	3.41	3	0.65	19%	22
C.10	3.41	3	0.62	18%	23
C.11	3.34	3	0.63	19%	24
C.12	3.06	3	0.79	26%	25
C.13	3.05	3	0.82	27%	26
C.14	2.9	3	0.7	24%	27
B.9	2.43	2	0.91	37%	28
C.15	2.43	2	0.66	27%	29
C.16	2.38	2	0.78	33%	30
B.3	1.9	2	0.7	37%	31

Source: own elaboration.

The group of critical success factors includes those factors whose arithmetic mean falls within the range (4.5-5.00) and which are characterized by a low coefficient of variation <20%. On this basis, the group of critical success factors in infrastructure project management includes:

During the initiation phase:

- A.1 Accurate identification and clarification of customer requirements before starting the project.
- A.2 Accurate identification of the main objectives of the project before starting implementation.

During the planning phase:

- B.4 Appointing a project manager with appropriate competences, high authority and experience.
- B.10 Ensuring the availability of financial resources throughout the duration of the project.

- B.11. Establishing a project team with appropriate competencies, extensive experience and skills.

During the implementation phase:

- C.6 Risk management.

During the monitoring and control phase:

- D.2 Monitoring and control of expenditure in relation to the planned budget.

The limitation of the group of critical success factors to 7 is based on the Pareto principle, according to which 20% of the causes determine 80% of the effects. The seven critical success factors account for 22.6% of all identified factors.

Based on the above considerations, it can be concluded that the largest number of critical success factors occur at the planning stage (3 factors), followed by the initiation stage (2 factors). Consequently, these should be considered the key phases of an infrastructure project. For this reason, project initiation and planning require special attention, as their proper implementation largely determines the effectiveness of further activities and the ultimate success of the project.

5. Discussion

The results of the research confirm that effective management of infrastructure projects requires particular focus on the initiation and planning stages, which determine the success of the entire undertaking. The identified critical success factors, such as: accurate determination of customer requirements, precise definition of project objectives, appointment of a competent project manager and project team, ensuring stable financing, effective risk management, and budget control, constitute the foundation of effective infrastructure project management in Poland. The results obtained are largely consistent with previous studies on success factors in project management in Polish companies (Spalek, 2004). They confirm the importance of appointing a competent project manager, establishing an appropriate project team, and clearly defining project objectives. This indicates the universal nature of these elements as the foundations of effective project management, regardless of the type of project. However, differences arise in terms of additional factors, i.e., financial issues (budget control, availability of funds) and precise definition of customer requirements and risk management, which proved to be fundamental in infrastructure projects, characterized by greater complexity, long implementation times, and high sensitivity to risks and financing.

Comparing the results of this study on critical success factors in infrastructure projects in Poland with studies on success factors in construction and infrastructure projects conducted in various countries, it can be seen that regardless of the region where the infrastructure project is implemented, it is very important to define the project objectives accurately and clearly,

establish a competent project team, securing project financing, and effective risk management are of great importance. Among the critical success factors in infrastructure projects in Poland, the factor of effective communication with stakeholders was not included, even though it often appears in studies on success factors in construction and infrastructure projects (Yamany et al., 2024; Gudienė et al., 2014; Gunduz, Almuajebh, 2020; Ika et al., 2012). It should be noted, however, that although this factor was not included among the critical success factors, it ranks very high in the hierarchy of success factors, occupying 9th place.

In a comparative context, it can be noted that the results obtained are consistent with the findings of international studies, in which financial and risk factors also play a key role in the success of infrastructure projects, regardless of the region or scale of the project (Yamany et al. 2024; Chan et al., 2004; Ika et al., 2012; Gunduz, Almuajebh, 2020). It is also worth noting that the study confirms the importance of the project manager's competence as one of the most important success factors. This is consistent with the research of Ika and Pinto (2022) and Musioł-Urbańczyk (2010), who indicate that the role of the project leader is crucial for team integration, risk management, and ensuring that activities are consistent with the strategic objectives of the project. In infrastructure projects, where the number of stakeholders and the level of formalization are exceptionally high, this role takes on particular importance.

6. Summary

The article assesses the success factors in infrastructure project management in Poland. Based on a review of the literature, 31 factors were identified and assigned to specific stages of project management. Two factors were assigned to the project initiation stage, 10 factors to the project planning stage, 13 factors to the project implementation stage, and 3 factors to the monitoring and control stage.

In order to find answers to the research questions posed in the article, which aimed to identify success factors in infrastructure projects and indicate critical success factors, a literature review was conducted, followed by a survey of 104 respondents working in companies located throughout Poland who are involved in the implementation of infrastructure projects. The literature review allowed us to identify success factors in infrastructure projects, while the survey allowed us to indicate the importance of individual success factors in project management. In the survey, the largest group consisted of project team members, followed by project managers and members of Project Board.

The results obtained made it possible to develop a hierarchy of success factors in infrastructure project management and identify those that are most important (critical factors). The critical factors included two factors assigned to the initiation stage, three factors assigned

to the planning stage, and one factor each from the implementation and monitoring and control stages, i.e.:

- Accurate identification and clarification of customer requirements before starting the project.
- Accurate identification of the main objectives of the project before starting implementation.
- Appointing a project manager with appropriate competences, high authority and experience.
- Ensuring the availability of financial resources throughout the duration of the project.
- Establishing a project team with appropriate competencies, extensive experience and skills.
- Risk management.
- Monitoring and control of expenditure in relation to the planned budget.

The results of the study are largely consistent with research on critical success factors in Poland. The similarities stem primarily from the fundamental principles of effective project management, while the differences result from different research contexts and the specific nature of the infrastructure industry, where financial challenges, risk management, and precise definition of customer requirements play a key role in infrastructure projects. Research on success factors in infrastructure projects confirms that factors related to ensuring stable project financing and effective risk management are crucial regardless of the region in which the infrastructure project is implemented (Yamany et al., 2024; Chan et al., 2004; Osei-Kyei, Chan, 2015; Gudienė et al., 2014; Gunduz, Almuajebh, 2020; Ika et al., 2012).

The study achieved its research objective and answered the research questions, and the results of the research open up the field for further analysis and deepening of knowledge on infrastructure project management. In particular, the following areas for future research are worth noting:

- the impact of digitization and automation of management processes (including the use of artificial intelligence) on the implementation of infrastructure projects,
- infrastructure project management in the context of sustainable development – taking into account environmental and social aspects.

The results of the study have important practical implications. For organizations implementing infrastructure projects, they provide a basis for developing project management models focused on precise planning, proper resource allocation, and early risk identification. For policymakers and public institutions, these results can support the development of infrastructure investment management policies in which financial stability and transparency of decision-making processes play a key role.

From a theoretical perspective, the study contributes to the development of knowledge in the field of project management by confirming that, despite the global nature of the concept of critical success factors, their hierarchy and importance may vary depending on the national

context and type of project. The results suggest that in Poland, where infrastructure projects are often co-financed from public and EU funds, aspects related to financing, planning, and budget control play a greater role than in other countries.

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DETERMINANTS OF THE DEVELOPMENT OF GREEN INVESTMENT BANKING IN POLAND IN THE FIELD OF CORPORATE DEBT SECURITIES ISSUANCE

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Purpose: The aim of this article is to identify the key factors determining the development of green investment banking in Poland in the field of corporate debt securities issuance during the years 2020–2024. The study also assesses the level of banks' involvement in the issuance of sustainable debt instruments for corporate clients within this period and analyzes the structure of sustainable bond issuances across different market sectors.

Design/methodology/approach: The article employs the method of in-depth literature studies, the document analysis method and the synthesis method. The empirical verification was conducted based on data derived from the consolidated annual financial statements of the examined commercial banks, management reports and ESG reports for the years 2020-2024.

Findings: The results of the study indicate that during the years 2020-2024, the activity of banks in issuing sustainable bonds for corporate clients was markedly differentiated, with Bank Pekao S.A. playing a dominant role. The research identified determinants of green investment banking development encompassing institutional and regulatory, market-related, strategic and business-oriented, environmental and reputational factors. The study demonstrated that the primary corporate clients of commercial banks in Poland in the field of green debt securities issuance were enterprises from the energy sector.

Research limitations/implications: The main research limitation should be considered the availability of detailed reporting information from banks concerning issuances carried out for corporate clients.

Practical implications: Based on the conducted research, a set of practical recommendations has been formulated aimed at broadening the participation of additional market sectors in green bond issuances, thereby actively contributing to the advancement of sustainable development objectives.

Originality/value: Previous studies concerning green banking have focused primarily on bank–client relationships in the field of lending activities. This article introduces a new perspective by analyzing the hitherto unexplored role of banks as intermediaries in the issuance of sustainable debt securities. The study fills a gap in the analysis of factors determining issuances carried out by banks for corporate clients.

Keywords: green investment banking, corporate banking, green debt securities.

Category of the paper: Research paper.

1. Introduction

In the financial market, there is a steadily growing interest in the ESG concept, particularly its environmental component and the pursuit of sustainable development goals. This necessitates the mobilization of substantial capital resources at both the global and local levels. It is estimated that between 2016 and 2040, global investments in clean energy will require expenditures of approximately USD 27 trillion (National Green Bank, 2017, p. 12). The investment gap in this field cannot be bridged without the support of the private sector and the use of debt instruments in the financial market, for example through the issuance of green bonds. Banks are increasingly engaging in the achievement of sustainable development goals by integrating ESG considerations into their business strategies. In addition to their core deposit and lending activities, banks, acting as issuers or investors, offer advisory services to the real sector related to capital acquisition, management, and underwriting of debt securities, the proceeds of which are invested in projects with a positive environmental impact. Such banking activities fall within the domain of so-called green investment banking, the development of which holds a long-term prospective outlook.

The existing literature rarely addresses the role of the bank as an agent and guarantor of sustainable debt instruments. Therefore, the aim of this article is to identify the key factors determining the development of green investment banking in Poland in the field of corporate debt securities issuance during the years 2020-2024. The study also assesses the level of banks' involvement in the issuance of sustainable debt instruments for corporate clients during this period and analyzes the structure of sustainable bond issuances across different market sectors.

The article adopts a theoretical-empirical approach, employing the following research methods to achieve its objective: in-depth literature review, method of document analysis, method of observation and method of synthesis. The empirical verification was conducted based on data derived from the consolidated annual financial statements of the examined commercial banks, management reports and ESG reports for the years 2020-2024.

2. Literature review on green investment banking

For several decades, one of the global megatrends in the world economy has been sustainable development, which is defined as development that meets the current needs of societies without compromising the ability of future generations to meet their own needs. Sustainable development requires a joint effort in the areas of economic growth, social inclusion, and environmental protection (UNI Warsaw, 2025). Undertaking initiatives of this nature requires substantial financial capital, the acquisition of which is increasingly facilitated

through the issuance of debt instruments, particularly bonds. In the context of promoting the advancement of environmentally oriented projects, sustainable debt instruments are employed. These instruments can be broadly categorized into two distinct groups:

- those financing specific projects with a positive environmental and social impact, and
- those linked to the issuer's performance regarding ESG criteria (Loumioti, Serafeim, 2022, p. 35).

The first group includes green bonds, social bonds, and sustainable bonds (Schmittmann, Chua, 2021, p. 8), as well as bonds issued by the European Investment Bank, known as Climate Awareness Bonds (Banga, 2019, p. 3). The second group comprises sustainability-linked bonds, also referred to on the financial market as ESG-linked bonds (Machado, Sousa, Branco, 2025, p. 5), and bonds linked to ESG ratings (Kölbel, Lambillon, 2022, p. 10). All of these types of bonds represent the latest innovations in sustainable financing and can be issued by corporations, banks, local government units, governments or international institutions.

The creation of an innovative financial instrument for financing environmental needs is necessary but not sufficient. A crucial condition is the active involvement of financial institutions, primarily banks, whose role extends not only to that of an investor and, in some cases, issuer, but above all to that of a financial intermediary – organizing the issuance and performing functions adapted to the nature of the issuance (van der Wansem, Jessen, Rivetti, 2019, p. 16). The issuance of green bonds by banks may stem from the need to decarbonize their own loan portfolios, whereas investing in such instruments serves an income-generating purpose. Representatives of financial institutions emphasize that the primary task of the institutions they represent is to maintain a stable and profitable business model, not necessarily to support the development of green technologies. ESG considerations are important only insofar as they do not hinder profit generation (Żelisko, Juszczak, 2025, p. 23). Some studies indicate that banks engaged in sustainable development activities achieve, on average, better financial results than those that do not devote significant attention to this area (Weber, 2017, pp. 380-383). In addition to improved financial performance, these practices enhance the institution's public image and credibility (Muszyński, 2025, p. 127). An increase in bank reputation facilitates the acquisition of new clients and the expansion of market share (Torre Olmo, Cantero Saiz, Sanfilippo Azofra, 2021, pp. 1-2).

The offering by banks of financial instruments focused on environmental, social, and governance factors, while simultaneously ensuring profits from their operational activities, is referred to as “sustainable banking.” In contrast, “green banking” focuses exclusively on aspects of environmental protection (Kiertowicz, Węgrzyn, Zaremba-Janukowicz, 2025, p. 32).

While a bank's activity as a lender, issuer, or investor in financing sustainable development is increasingly well-known among market participants, its role in organizing debt securities issuances is less frequently addressed in the literature. A bank can act as an organizer, co-organizer, guarantor, agent, dealer, depository or financial advisor. It should be noted that,

due to their know-how and technical and organizational capabilities, banks most often combine these roles, providing comprehensive services to the issuer (Gradoń, 2014, p. 99).

The roles outlined above constitute functions performed by banks within the scope of their investment banking activities, which can be defined as a specialized banking activity involving the trading of securities in money and capital markets, financial advisory services, asset management, risk management, and the execution of complex transactions in capital markets (Gradoń, 2009, pp. 20-21). These investment banking functions are not reserved solely for investment banks; they can also be provided by universal banks (in Poland), brokerage houses or investment funds. This distinction is particularly relevant in the context of sustainable finance, where, in addition to “green investment banking”, there are also “green investment banks”. Green investment banking is defined as a specialization within investment banking that focuses on financing projects and companies with positive environmental, social and corporate governance impacts. In contrast, “green investment banks” are not commercial or traditional investment banks. They are specialized, publicly capitalized financial institutions operating in national markets, created specifically to attract private capital for investments in climate-resilient infrastructure (Sims, Dougherty, Bergöö, 2017, p. 6). Currently, twelve green investment banks operate worldwide at the national level (Australia, Japan, Malaysia, Switzerland, and the United Kingdom), state level (Connecticut, Hawaii, California, New Jersey, New York, Rhode Island in the USA), local level (Montgomery County, Maryland, USA) and municipal level (United Arab Emirates) (OECD, 2017, p. 2).

As of today, the sources reviewed by the authors of this study do not indicate the existence of green investment banks in European Union countries. Within the domestic banking market, such a role could potentially be fulfilled by the state-owned Bank Gospodarstwa Krajowego and Bank Ochrony Środowiska S.A., which, although listed on the Warsaw Stock Exchange, remains under the control of the National Fund for Environmental Protection and Water Management (NFOŚiGW), holding a 58.05% share in its share capital (bosbank.pl). Both banks possess market credibility, an appropriate product offering and the economic potential to attract private capital to help reduce the investment gap in the green economy.

The absence of such banks in the Polish market does not hinder the effective support of sustainable development by the largest domestic banks, which possess well-developed investment banking departments and actively participate in organizing debt securities issuances. Their further development, and particularly the development of investment banking in the field of green transformation, may depend on multiple factors.

The first determinant of this development is the European Union’s legal framework, including the EU Taxonomy and the Green Bond Standard, which are expected to positively influence banks’ ability to attract clients interested in incorporating environmental aspects into their operations. Environmentally sustainable bonds constitute a significant instrument for financing investments in ecological technologies, improving energy efficiency, promoting the efficient use of resources and developing sustainable transport infrastructure. The introduction

of such a standard ensures comparability in the green bond market, which benefits issuers and provides investors with an effective means of allocating capital (Kmita, 2024, p. 37).

The second determinant that may influence the development of green investment banking is the necessity of incurring financial expenditures for the decarbonization of the Polish economy. It is estimated that by 2050, USD 105 billion will be required in the energy sector and USD 449 billion in total, encompassing transportation, industry, agriculture and forestry. Ninety-four percent of these investments are already included in the current policy framework, regardless of the pace of decarbonization, due to the need to address issues related to aging power plants and buildings, as well as inefficient industrial and transport fleets. It is assessed that more than half of the required funds will have to originate from private sources, namely from the own resources of enterprises and financial institutions (Kotecki, 2025, pp. 40-42).

The next determinant arises from the previous one. The domestic banking sector constitutes the primary source of financing for enterprises and local governments; however, its financial capacity is insufficient to bridge the gap in funding for green investments. Although banks possess financial surpluses, the scale of the required capital is immense and the activation of such large amounts by banks would necessitate an increase in their own funds in order to comply with existing prudential standards. The issuance of debt securities serves as an alternative to credit financing, enabling the mobilization of market investors without increasing the bank's credit risk. In this context, public capital is indispensable.

The fourth determinant of the development of green investment banking is the reintroduction of transitional bonds into Polish legislation. By design, these bonds, similar to green bonds, were intended to finance Poland's infrastructural needs, but their issuance was subject to fewer formal requirements. Transitional bonds were deleted from the Bonds Act (Dz.U. 2015, item 238), and Articles 27p-27r of the Act were repealed.

The fifth factor driving development is the requirement to limit the financing of projects with a negative impact on the natural environment. By performing their traditional functions (deposit, credit, and settlement), banks can influence the volume, pace, and direction of capital allocation, entrepreneurs' investment decisions, and methods of capital acquisition. Key activities in this regard are undertaken by banks in two main areas: financial products and services and risk management (Kulińska-Sadłocha, 2022, p. 322).

Additional determinants of green investment banking development in the field of debt securities may include increasing environmental awareness among issuers and investors, technological progress and partial automation of the issuance process, as well as corporate and investor activism. Shareholder activism involves compelling companies to adopt more sustainable practices, while investors, using the power of their voice, advocate for greater transparency and accountability on ESG matters (Kotecki, 2024, p. 18).

The role of the public sector is also crucial, as it can create the legal and economic conditions necessary to attract capital in the financial market and assume risks in sectors where private capital is either unwilling or unable to fully participate.

3. Research methodology

The research objective adopted in the article determined the selection of the study sample. The study deliberately focused exclusively on commercial banks, which was determined by the availability of reporting data. An analysis of the financial statements of cooperative banks revealed that information concerning their investment activities in the field of sustainable debt securities issuance is notably limited. The primary criterion for sample selection was the size of the commercial bank, measured by the value of its assets. In the selection process, the asset values of commercial banks listed on the Warsaw Stock Exchange were verified as of December 31, 2024. Ultimately, for the purposes of the study, a research sample was established consisting of the ten largest publicly listed commercial banks in Poland as of December 31, 2024. The composition of the research sample is presented in Table 1.

Table 1.

Commercial banks included in the research sample, ranked by total assets as of 31.12.2024

No.	Name of the bank	Assets value (in thousands of PLN)
1	PKO BP S.A.	525 225 000
2	Bank Pekao S.A.	334 242 000
3	Santander Bank Polska S.A.	304 373 920
4	ING Bank Śląski S.A.	260 359 000
5	mBank S.A.	245 957 363
6	BNP Paribas Bank Polska S.A.	167 539 589
7	Bank Millennium S.A.	139 152 000
8	Alior Bank S.A.	93 293 487
9	Citi Handlowy S.A.	72 478 103
10	Getin Noble Bank S.A.	750 112

Source: own elaboration.

The study employed several research methods, including in-depth literature review, document analysis method, observation method and synthesis method. The empirical verification was conducted based on data derived from the consolidated annual financial statements of the examined commercial banks, management reports and ESG reports for the years 2020-2024. Additionally, data were collected from industry portals and the websites of the banks' corporate clients, who were issuers of the analyzed debt instruments.

The research procedure in this study consisted of several stages. The first step involved the identification of banks that, during the examined period, carried out debt securities issuances for corporate clients, with a distinction made for sustainable instrument issuances. Next, a detailed review of sustainable debt issuances conducted by these banks between 2020 and 2024 was performed. Based on this review, a comprehensive dataset of all issuances was prepared, including information on bank involved, year of issuance, corporate client, client's market sector, issuance value and the type of debt instrument. Finally, key groups of factors determining the development of green investment banking in Poland in the field of corporate debt securities issuance during 2020-2024 were identified.

4. Research results

The analysis conducted enabled the extraction of the most pertinent information regarding debt issuances executed by banks for their corporate clients. This information is presented in a consolidated format in Table 2.

Table 2.

Characteristics of sustainable bond issuances conducted by the examined banks for corporate clients during the years 2020-2024

Bank	Year	Client	Market sector	Issuance value in PLN	Type of the instrument
PKO BP S.A.	2021	Europejski Bank Inwestycyjny	finance	1.25 bn	Climate Awareness Bond
PKO BP S.A.	2022	Cyfrowy Polsat S.A.	media, telecommunications	2.67 bn	Sustainability-linked bonds
Bank Pekao S.A.	2020	PKN Orlen S.A.	energy	1 bn	ESG-linked bonds
Bank Pekao S.A.	2020	Tauron Polska energetyka S.A.	energy	1 bn	Sustainability-linked bonds
Bank Pekao S.A.	2021	PKN Orlen S.A.	energy	1 bn	ESG rating-linked bonds
Bank Pekao S.A.	2021	PKN Orlen S.A.	energy	500 m EUR	Green eurobonds
Bank Pekao S.A.	2021	PKN Orlen S.A.	energy	1 bn	ESG-linked bonds
Bank Pekao S.A.	2021	Famur S.A.	mining, energy	400 m	Green bonds
Bank Pekao S.A.	2023	media and telecommunications service provider	media, telecommunications	3.5 bn	Sustainability-linked bonds
Bank Pekao S.A.	2023	international financial institution	finance	1.4 bn	Eurobonds, including green eurobonds (Climate Awareness Bonds)
Bank Pekao S.A.	2023	Ghelamco Group	real estate	520 m	Green bonds
Bank Pekao S.A.	2024	Polenergia S.A.	energy	750 m	Green bonds
Bank Pekao S.A.	2024	Grupa Enea	energy	2 bn	ESG-linked bonds
Santander Bank Polska S.A.	2020	Cyfrowy Polsat S.A.	media, telecommunications	1 bn	Green bonds
Santander Bank Polska S.A.	2021	PKN Orlen S.A.	energy	1 bn	ESG-linked bonds
Santander Bank Polska S.A.	2024	Polenergia S.A.	energy	750 m	Green bonds
mBank S.A.	2021	R.Power S.A.	energy, photovoltaic	1 bn	Green bonds
mBank S.A.	2022	R.Power S.A.	energy, photovoltaic	275 m	Green bonds
mBank S.A.	2023	Ghelamco Group	real estate	520 m	Green bonds
mBank S.A.	2024	R.Power S.A.	energy, photovoltaic	610.7 m	Green bonds
mBank S.A.	2024	Polenergia S.A.	energy	750 m	Green bonds
mBank S.A.	2024	Ghelamco Invest sp. z o.o.	real estate	104 m	Green bonds
BNP Paribas Bank Polska S.A.	2020	Cyfrowy Polsat S.A.	media, telecommunications	1 bn	Green bonds

Cont. table 2.

BNP Paribas Bank Polska S.A.	2023	Grupa Polsat Plus	media, telecommunications	2.67 bn	Sustainability-linked bonds
Citi Handlowy S.A.	2021	Europejski Bank Inwestycyjny	finance	1.25 bn	Climate Awareness Bond

Source: own elaboration.

The analysis of the data presented in Table 1 indicates that, among the institutions examined, six banks were active in the issuance of green debt instruments and ESG-linked instruments. These were PKO BP S.A., Bank Pekao S.A., Santander Bank Polska S.A., mBank S.A., BNP Paribas Bank Polska S.A., and Citi Handlowy S.A. Between 2020 and 2024, a total of 20 issuances were carried out for corporate clients, with a combined value of PLN 25.39 billion. It should be emphasized that some sustainable bond issuances were arranged in a consortium format, meaning that the transactions were handled simultaneously by multiple banks rather than a single financial institution. Examples of such issuances include: Cyfrowy Polsat S.A. bonds (2020, PLN 1 billion, Santander Bank Polska S.A. and BNP Paribas Bank Polska S.A.), European Investment Bank bonds (2021, PLN 1.25 billion, PKO BP S.A. and Citi Handlowy S.A.), Ghelamco Group bonds (2023, PLN 520 million, Bank Pekao S.A. and mBank S.A.), and Polenergia S.A. bonds (2024, PLN 750 million, Bank Pekao S.A., Santander Bank Polska S.A. and mBank S.A.). Additionally, it is worth noting the issuance denominated in euros, namely the green eurobonds of PKN Orlen S.A., amounting to EUR 500 million. Table 2 provides an overview of sustainable bond issuances in which each bank participated on behalf of corporate clients, along with the total nominal value of these issuances. The data enabled an assessment of the activity levels of individual financial institutions involved in issuing sustainable instruments for corporate clients.

Table 3.

Total number and value of sustainable bond issuances carried out by the examined banks on behalf of corporate clients during 2020-2024

Bank	Total number of issuances	Total value of issuances in which the bank participated (PLN billion))	Share in total issuances
Bank Pekao S.A.	11	14,82	50%
PKO BP S.A.	2	3,92	13%
BNP Paribas Bank Polska S.A.	2	3,67	12%
mBank S.A.	6	3,26	11%
Santander Bank Polska S.A.	3	2,75	9%
Citi Handlowy S.A.	1	1,25	4%
Total	25	29,68	100%

* For issuances arranged in a consortium format, the full amount was counted for each of the participating banks; therefore, the total value of issuances in the table (PLN 29.68 billion) differs from the total nominal value of the bonds issued (PLN 25.39 billion).

Source: own elaboration

The analysis of the presented data indicates a clear differentiation in the activity of banks involved in the issuance of sustainable debt instruments for corporate clients between 2020 and 2024. Market leadership was held by Bank Pekao S.A., which participated in 11 issuances totaling PLN 14.82 billion, accounting for half of the total issuance value. Among the active banks in the analyzed area, the smallest scale of activity was observed for Citi Handlowy S.A., which conducted a single issuance valued at PLN 1.25 billion (4%). The remaining institutions – PKO BP S.A., BNP Paribas Bank Polska S.A., mBank S.A., and Santander Bank Polska S.A. – had a moderate market share, ranging from 9% to 13% of the total value of issuances carried out. A detailed analysis of the financial statements allowed for the identification of key groups of factors determining the development of green investment banking in Poland in the field of corporate debt securities issuance during 2020–2024. The following eight key groups of factors were formulated: (1) engagement of the largest financial institutions, (2) implementation of ESG strategies, (3) cooperation with international financial institutions, (4) compliance with regulations and certification, (5) energy transition of large enterprises, (6) demand from institutional investors, (7) effect of the pioneering issuances and (8) issuances arranged in a consortium format. Each group of factors has been separately described below.

4.1. Engagement of the largest financial institutions

The development of green investment banking in the field of debt securities issuance for corporate clients was largely determined by the activity of several leading commercial banks. These institutions played key organizational roles – coordinating issuances, acting as issuance dealers and supporting processes related to the distribution of securities. The reputation of major commercial banks significantly reduces transaction risk and enhances market credibility, which is an important factor in attracting institutional investors. Consequently, the engagement of the largest financial institutions not only influences market dynamics but also shapes its standards and investment practices.

4.2. Implementation of ESG strategies

Commercial banks in Poland are increasingly adopting ESG strategies by integrating them into their overall business operations. Bank Pekao S.A., in its 2021-2024 strategy, identified responsibility as one of its four key pillars, defined as conducting commercial and operational activities with greater consideration for environmental, social, and governance (ESG) aspects. Importantly, in the context of this study, Bank Pekao S.A. has committed itself to supporting the development of the economy through collaboration with its corporate clients. Similarly, mBank S.A., in its 2021-2025 strategy, has pledged to mobilize PLN 10 billion to finance green investments, including renewable energy, electromobility and waste management projects. Half of this amount comes from the bank's own capital, while the remaining PLN 5 billion is sourced externally – through green bond issuances and banking consortia. These strategies define the key directions of financial institutions, positioning green bond issuance as an integral

component of their business strategies and simultaneously signaling to institutional investors the long-term commitment of banks to ESG principles.

4.3. Cooperation with international financial institutions

The analysis indicates the involvement of international financial institutions in the implementation of investment processes. In 2020, the European Bank for Reconstruction and Development (EBRD) acquired 20% of Cyfrowy Polsat S.A.'s green bond issuance, valued at PLN 1 billion. Attention should also be drawn to the 2021 issuance of Climate Awareness Bonds by the European Investment Bank (EIB), amounting to PLN 1.25 billion. Cooperation with international financial institutions significantly strengthens the credibility of Poland's sustainable debt securities market. The engagement of such entities facilitates the transfer of specialized expertise, the enhancement of issuance process standards and the increased attractiveness of the market for foreign investors. Consequently, international collaboration serves as a key factor integrating the domestic financial market into the global sustainable finance ecosystem.

4.4. Compliance with regulations and certification

Banks and their corporate clients consistently indicate that their bond issuances comply with key regulatory frameworks, most notably the EU Taxonomy, as well as internationally recognized standards such as the *Green Bond Principles* developed by the International Capital Market Association (ICMA). Positive assessments issued by specialized expert institutions such as Sustainalytics, along with the linkage of bond coupons to ESG ratings, constitute essential mechanisms for building investor trust. The standardization of financial instruments based on these norms ensures procedural consistency, facilitates risk assessment and supports market development. Consequently, certification and alignment of issuance processes with EU regulations have become indispensable prerequisites for the sustained growth of the sustainable instruments segment in Poland. Attention should also be drawn to the environmental and social objectives embedded in the structure of the bonds. *Sustainability-linked bonds* are designed in a way that explicitly incorporates environmental and social targets into their framework. The inclusion of these objectives enables issuers to demonstrate the tangible impact of their activities on environmental protection and social development, thereby strengthening their market credibility.

4.5. Energy transition of large enterprises

The study involved the determination of sectoral structure of sustainable bond issuances carried out by banks for corporate clients. Figure 1 presents the results.

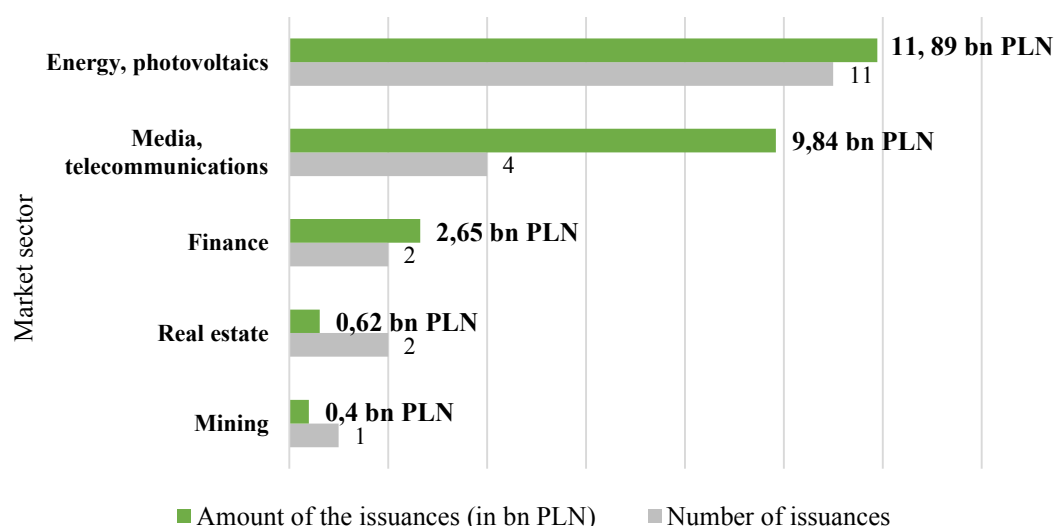


Figure 1. Sustainable bond issuances carried out by banks for corporate clients between 2020 and 2024, classified by market sectors.

Source: own elaboration.

Classification of issuances by market sectors indicates a clear concentration of capital in sectors most closely associated with the energy transition and the digital economy. The analysis shows that the main beneficiaries of financing through green bond issuances were companies from the energy sector. This sector accounted for the largest number of issuances and raised the highest amount of capital during the analyzed period (PLN 11.89 billion), confirming its leading role in the transition toward a low-carbon economy. Particularly significant were the issuances by companies such as PKN Orlen S.A., Tauron Polska Energia S.A., Polenergia S.A., Grupa Enea, and R.Power S.A. A characteristic feature of the energy sector was the high value of individual issuances, often exceeding PLN 1 billion and in the case of Grupa Enea, reaching PLN 2 billion. Importantly, this phenomenon was systematic –green bonds and ESG-linked bonds were issued every year of the analyzed period, demonstrating the sector’s long-term approach to raising capital for investments. Moreover, energy companies employed a wide range of financial instruments, including green bonds, ESG-linked bonds, sustainability-linked bonds, and green eurobonds, reflecting the maturity and comprehensiveness of their business strategies. The second most significant group consisted of media and telecommunications companies, which carried out four bond issuances, representing 20% of all issuances and raising PLN 9.84 billion. This high share indicates the growing role of digitalization and the development of ICT infrastructure as key factors supporting sustainable economic development. Although green bond issuances also occurred in other sectors, such as real estate (Ghelamco Group) and the financial sector (European Investment Bank), their number and total value were significantly lower than those in the energy sector. This underscores the dominant role of energy companies in the development of Poland’s sustainable debt instruments market. The analysis also highlights the strategic nature of banks’ cooperation with key energy sector

players. The largest market participants, such as Bank Pekao S.A., Santander Bank Polska S.A., and mBank S.A., regularly managed bond issuances for companies in this sector, confirming the critical importance of the energy sector for the development of investment banking in Poland, particularly in the area of financing sustainable projects.

4.6. Demand from institutional investors

The data indicate that sustainable development instruments were primarily targeted at institutional investors, including investment funds, banks and insurance companies. The growing attention to ESG criteria, combined with expectations of these entities, contributes to an increase in both the number and the value of issuances. This phenomenon suggests that demand from institutional investors is a fundamental factor driving market development, while also serving as a signaling mechanism that shapes issuance strategies among large corporate entities.

4.7. Effect of the pioneering issuances

During the analyzed period, certain instruments were issued for the first time on the Polish market. The pioneering green bond issuances were carried out in 2020 by Cyfrowy Polsat S.A., Orlen S.A., and Tauron S.A. and thus served as benchmarks for subsequent transactions. This can be described as a demonstration effect of these issuances, effective both financially and reputationally, which contributed to an increase in the number of issuers and helped to build investor confidence in subsequent issuances. This phenomenon indicates that early market successes have a significant impact on the direction of development of the sustainable debt instruments market in Poland.

4.8. Issuances arranged in a consortium format

Issuances of sustainability-linked bonds and ESG-linked bonds by the examined banks were arranged exclusively by banking consortia. Meanwhile, Climate Awareness Bonds and eurobond issuances were managed within international banking consortia. Establishing such consortia increases the capacity for placement and distribution of securities among institutional investors, thereby serving as an additional factor supporting the development of the sustainable financial instruments market.

5. Conclusions and Discussion

The conducted study revealed that between 2020 and 2024 the activity of banks in the field of sustainable bond issuances for corporate clients was clearly diversified. Only six out of ten examined banks participated in the issuance of such debt instruments. The market leader during the analyzed period was Bank Pekao S.A., which took part in half of all issuances, thereby enabling its clients to raise a total of PLN 14.82 billion in capital. The analysis of banks' reporting documents made it possible to identify eight key groups of factors shaping the development of green investment banking in Poland in the field of corporate debt instruments – institutional and regulatory, market-related, strategic and business-oriented, environmental and reputational. The study showed that, in the years 2020–2024, the main corporate clients of commercial banks in Poland in the field of green bond issuances were enterprises from the energy sector. The results indicate the dominant share of this sector in both the total number and value of issuances, as well as its crucial role in the development of the green debt instruments market during the analyzed period.

Based on the conducted research, several practical recommendations can also be formulated. First, banks should continue and expand their offer of sustainable financing instruments, particularly for the energy sector, which faces the challenge of implementing costly investments related to energy transition and greenhouse gas emission reduction. Second, further diversification of financial products is advisable to ensure that the type of instrument matches the specific characteristics of projects and environmental objectives of particular corporate issuers. Third, the role of banks in education and advisory services for corporate clients should be strengthened, especially in market sectors that have so far made limited use of green financing. This could contribute to increasing the participation of other market sectors in green bond issuances, thereby supporting the implementation of sustainable development goals. The main research limitation concerns the availability of detailed reporting data from banks on issuances conducted for corporate clients.

Based on the data presented in this study regarding the necessary global expenditures for the energy transition, it can be concluded that a further increase in banks' activities in supporting the financing of ecological projects is required. This includes a growing role for investment banking in the field of corporate debt securities issuance. Considering the findings, future research should include a comparative analysis of the activity of Polish commercial banks in the field of sustainable debt instruments relative to other EU member states. This could then allow to distinguish between international and Polish perspectives on green investment banking and reveal contextual specificities of the domestic market.

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ATTITUDES OF HR PRACTITIONERS TOWARDS CYBERVETTING IN MONITORING EMPLOYEES' ACTIVITY

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Purpose: The purpose of this article is to examine the HR practitioners' attitudes and approaches in big companies towards the use of cybervetting as a tool of monitoring the employees' activity in social media with the particular consideration of identified benefits, dangers and the influence of the respondents' seniority on the level of the acceptance of such a practice.

Design/methodology/approach: The survey test CAWI (n = 113) was applied among the representatives of big companies in the Lodz and Silesia Provinces. The questionnaire covered the one- and multiple-choice questions and statements assessed with the use of 4-grade Likert scale and the responses were analyzed with the consideration of the respondents' seniority.

Findings: Almost 65.5% of respondents regards cybervetting as a significant support of employees' monitoring and the acceptance is growing with the seniority – from the objection of the people with the shortest seniority to the highest support of the most experienced ones. The indicated benefits include mainly protection of goodwill and identification of competitive actions and dangers – infringement of privacy and fall of trust.

Research limitations/implications: The limitation of the conducted research is its pilot nature, limited geographical scope and possible overrepresentation of digitally active people. Further research of quantitative and qualitative nature covering deepened interviews and case studies in wider differentiated sample is necessary.

Practical implications: The research emphasizes the need of clear lawful cybervetting policies which limit the risk of privacy infringement and trust fall and at the same time make it possible to protect the organization interests and reputation.

Originality/value: The paper provides empirical data about the managers' and HR specialists' attitudes towards the use of cybervetting in monitoring employees. It shows the differences in the perception of this practice depending on the seniority, indicating the necessity of balance between the organization interests and the protection and autonomy of employees.

Keywords: cybervetting, employees' monitoring, social media, human resource management, privacy.

Category of the paper: research paper.

1. Introduction

Monitoring work processes and the activity of employees in modern organizations exceeds the traditional methods (video monitoring or control of phone conversations). At present, the monitoring methods allow to record keystroke logging, archive the contents of chats, analyze the visited websites as well as to use cybervetting to monitor the activity of company members in social media. Almost 40% of employees in the USA claim that the employer monitors their activity in the workplace and the number of big companies supervising their employees in a digital way amounted to 60% (data of November 2022 – pandemic period). It is anticipated that this percentage will increase to 70% by the end of 2025 (McNutt, 2024). Additionally, the empirical analyses emphasize the significant popularity scale of social platforms in the everyday communication practices. More than a half of adult population in the United States (53%) admits that they use social media regularly as a source of gathering actual information (*Social Media and News Fact Sheet*, 2025)¹. Additionally, according to the results of the research conducted by Pew Research Centre as many as 34% of employees admit that they use social media at work treating it as a break from professional duties (*Monitoring Employee Social Media Activity at Work*, 2025).

The purpose of this article is to examine the big companies HR managers', HR specialists', decision makers' attitudes and opinions towards using cybervetting as a tool of monitoring employees' activity in social media with the particular consideration of identified benefits, dangers and the influence of the respondents' seniority on the level of the acceptance of such a practice.

The answers to the following research questions may be helpful to perform the taken purpose:

- RQ1. What is the level of support provided by cybervetting in the process of employees' monitoring declared by the managers and HR specialists in big companies?
- RQ2. In which extent do the managers and HR specialists in big companies accept the use of cybervetting to monitor the employees' activity in social media?
- RQ3. What benefits and dangers do the respondents attribute to the use of cybervetting towards the employees the most often?

The exploration of the above research questions will allow to recognize the real scope of support which cybervetting provides in the supervision of employees, to specify the level of organizational permission to monitor the activity in the social media and to identify the most often perceived benefits and dangers.

¹ What is interesting, the analyses show that Facebook and YouTube take a dominant position: respectively 38% of adult Americans declare that they use Facebook systematically and 35% indicates YouTube to gather current information. Much lower percentage of respondents use other social media regularly to gather current information, respectively: Instagram (20%), TikTok (20%) or X (12%). Even less people indicate: Reddit (9%), Nextdoor (6%), WhatsApp (5%), Threads (3%), Rumble (2%), Truth Social (2%) and Bluesky (2%) (*Social Media and News Fact Sheet*, 2025).

This paper is an extension of the previous publication of the authors in which the HR staff's awareness and attitudes towards cybervetting in recruitment processes were analyzed (Pytel-Kopczyńska, Niedbał, 2025). The current paper focuses on using this practice to monitor the employees' activity in the social media.

2. Cybervetting as a practice in employees' monitoring

Functioning of an organization strictly connected with the advance of technological and communication technologies resulted in the presence of the monitoring technology of the employee's activity not only in the workplace (monitoring of communication and productivity of employees with the use of artificial intelligence, gathering biometric data with the use of sensors, algorithmic employees' management in the context of productivity) (Vitak, Zimmer 2023) but also left the boundaries of organizational life by using cybervetting in the processes of monitoring the employees' activity in the social media (Rahat, Nadeem, 2025). The labor future is more and more connected with the common gathering of digital data coming from social platforms (Nguyen, Mateescu, 2019). Gathering new categories of data referring to the employees allows to specify the activities and personal features in a quantitative way, which could not be monitored in the working environment before, intensifying scale and dynamics of data accumulation process², blurring at the same time the border between the public and private zone and modifying the set of forces between employers and employees (Nguyen, Mateescu, 2019). The research conducted by the organization Gartner in 2018 showed that over half of big corporations (from 239 tested) uses the digital forms of monitoring covering among others cybervetting of employees' activity in social media (Wartzman, 2019).

The empirical analysis with the participation of 2006 peopled full-time employed in the United States and the United Kingdom (Burlee, 2024)³ admitted in both cases that the digital methods are a dominant form of employees' monitoring (50% of respondents experience the monitoring of electronic correspondence, chats led with the use of such tools as Gmail, Microsoft Teams or Slack the most often). The most visible difference is that the monitoring of the network and data is used in the U.S. 39% more often than in the UK. What is interesting,

² The pandemic strongly contributed to the increase in the quantity, scope and diversity of information gathered by employers. These data (so called digital footprint) constitute the basis to draw up employers' digital profiles and implement algorithms which order these data in specific categories and perform assumed analyses of connections between accumulated information (Leonardi, 2021).

³ As it results from the empirical research (Burlee, 2024) numerous dangers and risks connected with digital monitoring of employees in the virtual space affect the mental health in a negative way (indications of almost 40% of respondents, respectively: U.K. 37.6%; U.S. 36.7%), lower job satisfaction (indications of three out of four surveyed, respectively: U.K. 77.5%; U.S. 74.7%). Moreover, a significant conclusion drawn up from the analyses is perceiving the monitoring of employees' activity in the digital world as an unethical activity (respondents' indications, respectively: U.K. 70.6%; U.S. 59%).

only 30% of workers in the USA and 27% in the United Kingdom were formally informed about the active monitoring in the workplace.

The above issues constitute an important argument for the necessity to document practices concerning the use of cybervetting in an organization not only in respect to potential employees (in a recruitment process) but at first to the current employees in the process of monitoring their activity in the social platforms.

From the employer's point of view, there are a lot of justified reasons for implementing cybervetting to monitor employees, starting from the verification of submitting sensitive, confidential or covered with the company secret data to the confirmation of potential unlawful activity (Mikkelsen, 2011). Whereas, from the employees' point of view, the use of unclear or inconsistent practice of cybervetting in the employees' monitoring process⁴ may result in the feeling of injustice, lowering the engagement level, job satisfaction and trust towards the organization as well as the increase in stress and negative influence on mental condition (Akbulut et al., 2024; Mikkelsen, 2011; McNutt, 2024; Burlee, 2024).

3. Research method

The survey research was conducted with the use of the CAWI method (Computer Assisted Web Interview) in the period from November 2024 to March 2025. The questionnaire was presented to the big companies from the Lodz and Silesia Provinces, obtaining 113 complete responses. The participation in the research was voluntary and its results should be regarded as pilot observation. The respondents were managers and specialists dealing with employees' recruitment processes who represented big subjects of two key sectors of economy – industry and services (with the exclusion of financial institutions).

The research questionnaire consisted of 18 questions in total: 7 of one-choice questions, 4 multiple-choice questions and 7 statements assessed with the use of even four-grade Likert scale without neutral point. The questions were divided into 4 sections: (I) experience and awareness about cybervetting, (II) legal and ethical aspects, (III) cybervetting in the context of

⁴ The analysis of Secure Data Recovery Services of April 2022 covering 998 full-time employees in the United States indicates that over half of the surveyed is against the supervision at work. The main reason is the fall of job satisfaction and almost 60% assessed the supervision as unethical. Many employees were not certain whether they are monitored at all; only 30% were informed about it and 53% indicated the lack of transparency provided by the managerial staff. The increase in the transparency could cover among others the possibility to have an insight into monitoring data, which is expected by 25% of respondents. Moreover, one third of respondents regarded the supervision as harmful for mental condition and 45% indicated the infringement of privacy. Additional consequences cover the fall of trust, growth of stress and fall in productivity. What is really interesting, over 25% of respondents declares taking actions in order to avoid monitoring including manipulation of work indicators or engaging office space in such a way that they pretend being active (McNutt 2024). The analysis of the research results presented above shows that both practices of monitoring employees' activity as well as using cybervetting may contribute to the creation of false picture of a given entity. These actions may be directed on shaping the employee's image in order to create the impression of greater loyalty and productivity.

employees' monitoring, (IV) cybervetting and information tools and artificial intelligence (Artificial Intelligence – AI).

This paper constitutes the continuity of the research presented in the publication *Recruitment in the Digitalization and AI Era – Awareness and Attitudes of HR Practitioners Towards Cybervetting* (Pytel-Kopczyńska, Niedbał, 2025). Both texts are based on the results of the same research survey but due to the amount of the material, the analyses were divided into two complementary parts. Whereas the first paper focused on the awareness and attitudes of HR specialists and recruiters towards cybervetting in the recruitment processes – including the information sources, perceived risks of privacy infringement and possibilities of using artificial intelligence tools – this paper presents the analyses referring to the use of cybervetting to monitor the employees' activity in the social media with the particular consideration of assessed benefits and dangers and the influence of seniority on the level of acceptance.

4. Cybervetting in employees' monitoring – results of empirical research and discussion

The research sample consisted of 46.8% of respondents ($n = 53$) with the over 20 years of experience in recruitment, 26.6% of surveyed – persons with the experience of 11-20 years ($n = 30$). The experience in the groups to 5 years and 6 – 10 years was represented by the same number of respondents – 13.3% of all tested ($n = 15$ each). In the research sample 54.0% of respondents ($n = 61$) represented the companies of the industry and 46.0% of respondents ($n = 52$) were from the sector of non-financial services.

The analysis of responses given by HR managers and specialists in big companies to the questions referring to the declared level of support which cybervetting provides in the process of monitoring the employees indicates generally positive assessment of this practice (Table 1).

Almost two thirds of respondents (65.5%) claimed that cybervetting may constitute a significant support in employees' monitoring whereas 25.7% gave the assessment '5' (very high support) and 39.8% - assessment '4'. These results suggest that the majority of respondents notices the real potential of this practice concerning the supervision over employees, independently of the fact whether it is used in their organizations or not.

It is worth noticing that the assessment of the usefulness of cybervetting is growing with the seniority of employees. In the group of employees with the seniority 11-20 as many as 73.3% regarded that cybervetting is a clear support in monitoring and among the people working over 20 years this percentage amounted to 79.3%.

Table 1.*The level of support provided by cybervetting in the process of monitoring the employees*

<i>In which extent, in your opinion, cybervetting may support the process of monitoring employees?*</i>	Seniority				Total
	Up to 5 years (n = 15)	6-10 years (n = 15)	11-20 years (n = 30)	Over 20 years (n = 53)	Number of indications of all the respondents (%)
Level of support	Number of indications in a given group of respondents (Number of indications in a given group of respondents, %)				
5	6 (40,00)	-	9 (30,00)	14 (26,42)	25,66
4	2 (13,33)	2 (13,33)	13 (43,33)	28 (52,83)	39,82
3	7 (46,67)	9 (60,00)	7 (23,33)	9 (16,98)	28,32
2	-	4 (26,67)	1 (3,34)	-	4,43
1	-	-	-	2 (3,77)	1,77

* Assessment in the scale from 1 (no support) to 5 (very high support).

Source: own study.

It shows that the growing conviction that digital tools may be useful in keeping organizational standards and control of employees' behavior. In the group with the lowest job experience (up to 5 years), the assessments were also positive but less unequivocal – 53.3% of indications were included in the values 4 or 5. The clearly more ambivalent attitude was observed among the respondents with the work experience of 6 -10 years. In this group the moderate assessments were dominant (60.0% indications at level 3) and there was relatively high percentage of low assessments (26.7% of indications at level 2). Only 13.3% in this group selected the assessment at the high level (4), which may show the increased caution about the control tools among people who are engaged in the team management processes but do not participate in shaping staff policy at the strategic level. The extremely low assessments (at level 1) appeared only in the group with the greatest job experience (over 20 years), which may suggest that part of the experienced employees do not have trust to the methods of digital supervision, especially if they disagree with the regarded privacy standards or employee's autonomy. Despite this fact, the percentage of this assessment was marginal and did not affect the general picture of high level of acceptance.

Summing up and at the same time referring to the research question RQ1 – cybervetting is perceived by managers and HR specialists as a practice which may support the monitoring of employees in a significant way. The level of declared support is growing together with the respondents' seniority and the highest indicators of approval were noticed in the group with the longest seniority. Although there are some differences in the assessments, the general picture is clearly beneficial – cybervetting seems to be a useful tool, worth considering in the modern practices of organizational supervision.

The next stage of the survey research was an attempt to identify the respondents' opinions about the justification to use cybervetting to monitor the employees' activity in social media (e.g. to protect the company image). There may be a discrepancy between the assessment of the usefulness of this practice and its acceptance – the respondents may perceive it as useful and declare a high level of support in the scope of monitoring the employees but due to various aspects (e.g. the ethical ones connected with the privacy or bidding law) they may not accept it and be ready to implement it in their organization. The obtained results are presented in Figure 1.

The respondents' attitudes towards using cybervetting to monitor employees indicate clear differentiation depending on the seniority. The clearest objection was expressed by the employees with the smallest work experience – as many as 80% of people in the group up to 5 years regarded this practice as completely unacceptable and the next 13% declared the response “rather no”. It shows the strong sensitivity of this group in the matter of privacy and protection of personal life in the digital area. Only 7% of respondents in this group supported the use of cybervetting fully. A different approach took the respondents with the job experience of 6-10 years among whom over half (54%) expressed the acceptance for monitoring. However, the exceeding part of this group (47%) were for the limited form – used only in specified cases. It can be assumed that these people start joining the responsibility for the image of an organization with the need to maintain moderation in using the control measures.

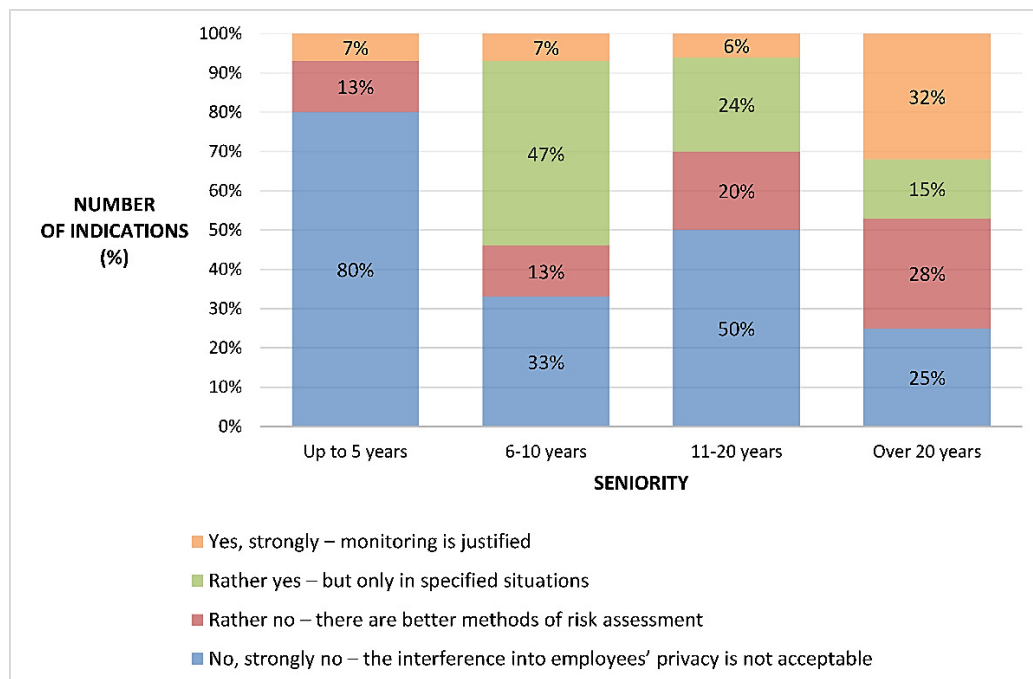


Figure 1. Monitoring the activity of employees in social media.

Source: own study.

Having worked for about ten years of seniority, in the group 11-20 years, the clear fall in acceptance is observed – as many as 70% of respondents rejected the use of cybervetting and half of them firmly. It may suggest stronger attachment to autonomy and greater experience in using alternative tools of the reputation risk assessment which do not interfere with a private

employees' activity directly. When it comes to employees with the work experience of over 20 years, the trend was partially reversed – almost one third (32%) declared the full support to the use of cybervetting and in total 47% were for any form of its implementation. Although some critical opinions appeared also in this group (28% of indications to the answer “rather no”), the increase in the readiness to accept this form of monitoring was visible. Probably it resulted from the stronger identification with the interest of an organization and greater awareness of risks connected with the employees' activity in the online public space.

Summing up, the opinions of managers and HR specialists in big companies about the importance of using cybervetting to monitor the employees are clearly polarized. Whereas, the people with low seniority clearly reject this practice and the employees with middle work experience show moderate acceptance, the ones with the longest work experience turn to be the most eager to regard cybervetting as the tool worth using. In the context of the research question RQ2 referring to the rate of acceptance of this practice, it is possible to notice that the acceptance of cybervetting among respondents is differentiated and conditional – depends on the seniority and the perception of relations between control and privacy. It is not possible to talk about the unanimous acceptance but about the segmentation of attitudes – from the clear objection through conditional acceptance to full support in selected professional groups.

The next two questions in the questionnaire referred to the identification of potential benefits (Figure 2) and risks (Figure 3) for the company arising from the use of cybervetting towards employees. Both had the form of multiple-choice questions (the respondents could choose more than one answer).

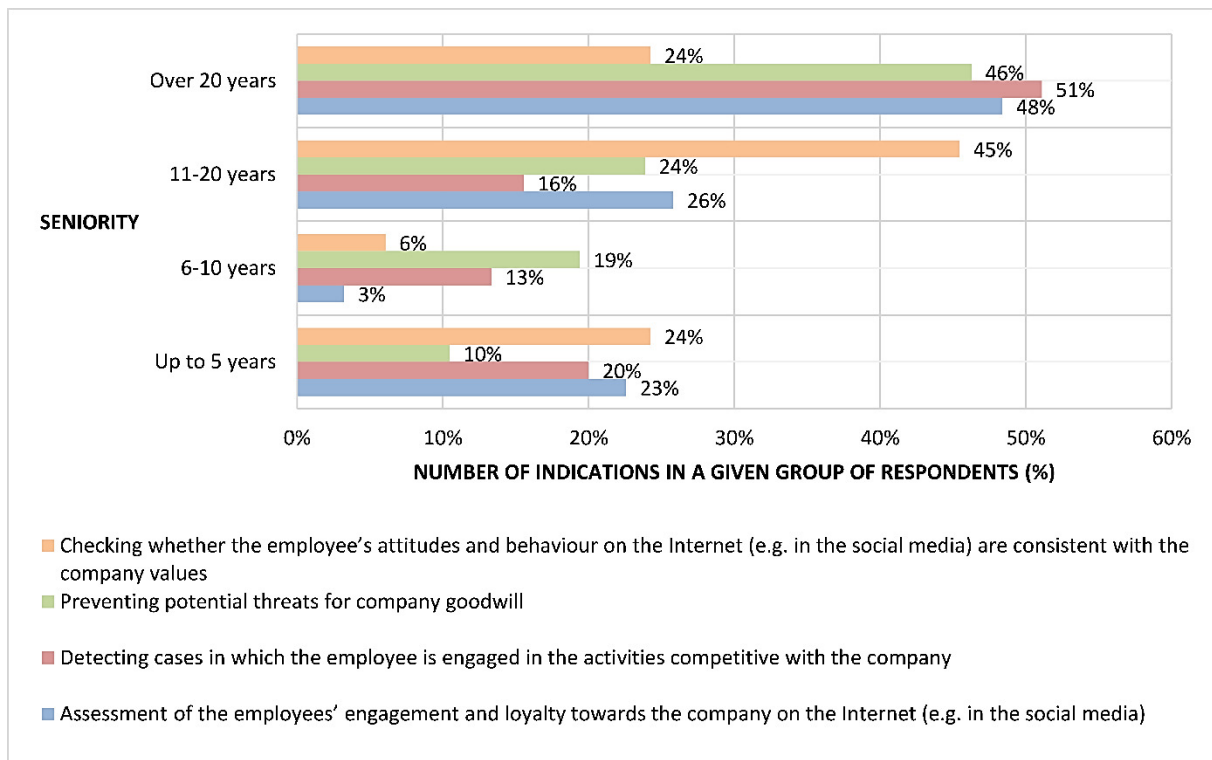


Figure 2. Benefits for the company arising from the use of cybervetting towards employees.

Source: own study.

The research results clearly show that the attitudes of managers and HR specialists towards the use of cybervetting to monitor the already employed workers are ambiguous – they see both particular benefits as well as significant threats arising from this practice (RQ3). On the one hand, cybervetting is perceived as a useful tool supporting the management in an organization, on the other hand - as an activity burdened with serious ethical, psychological and legal dangers.

When it comes to potential benefits, the possibility to prevent dangers for the company goodwill was the cybervetting function which the respondents chose most often. Such answer was chosen by 59.3% of all respondents whereas the highest percentage of indication was noticed in the group of respondents with the work experience over 20 years.

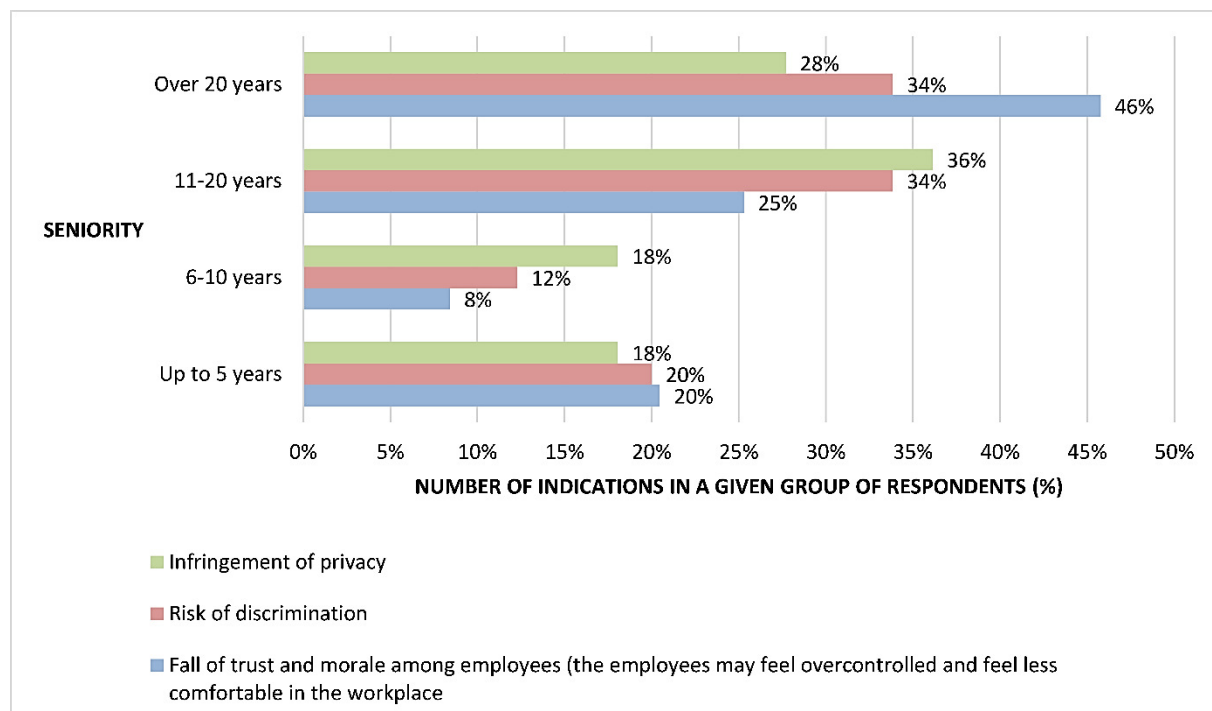


Figure 3. Dangers for companies arising from the use of cybervetting towards employees.

Source: own study.

This result suggests that people with the higher work experience appreciate the significance to protect the organization image in a particular way and are more sensitive to reputation risks connected with the employees' activity in the digital area. The possibility to identify the competitive actions taken by employees was the second most often selected aspect – it was indicated by 39.8% of respondents also mainly from the group with the longest work experience. Whereas 27.4% of respondents noticed the value of cybervetting in the assessment of employees' loyalty and engagement and 29.2% regarded that the analysis of activity on the network may be useful to check the cohesion of employee's attitudes with the organization values. The above results show that according to the respondents – especially the ones with the highest work experience -cybervetting may play the function of a tool supporting the control of organizational risks and cultural adaptation of the staff.

At the same time, the respondents' answers show the set of dangers which are clearly expressed. The worries which were indicated the most often referred to the infringement of privacy and fall in the morale among employees – both these dangers obtained 73.5% of indications. The infringement of privacy was often identified by people with the work experience of 11 – 20 years and over 20 years, which may indicate that they are sensitive to the border between professional and private life strongly. On the other hand, the fall in trust – interpreted as the possible effect of excessive control – was indicated by the respondents with the longest work experience. It may result from their attachment to the management model based on trust and autonomy. The risk of discrimination was the next significant danger (57.5% of indications). It was also perceived by the people with the longest work experience. It may show that they are more aware of the consequences arising from the subjective interpretation of contents published online and that they are more sensitive to the infringement of the rules of equal treatment.

Referring to the research question RQ3 formed in the introduction it is possible to claim that the respondents attribute to cybervetting towards employees both particular functions supporting the protection of the organization interests – especially when it comes to reputation, loyalty and consistence of attitudes with the company values – as well as significant dangers connected with the infringement of privacy, fall in trust and possibility of discrimination. In a consequence, cybervetting seems to be a tool with big potential but requiring a lot of caution, clear rules of use and sensitivity to ethical and social aspects.

The key element describing the rules of proceedings in the scope of cybervetting to monitor employees should be the standardized approach, performed both in the form of clearly formed internal use policies (Mikkelsen, 2011) or by the set of consistent and transparent procedures to monitor the employees' online activity (Akbulut et al., 2024). The documents drawn up in this way should specify that the activity in the social media and online activities are monitored for business purposes and the improper use of digital tools may lead to disciplinary consequences including the dismissal from work. These documents should also specify which disclosures of confidential information referring to the employer are allowed and which are prohibited, should also forbid publishing false information about the employer, co-workers or customers. They should also indicate the person responsible in the organization for the issues connected with the use of social media and remind the employees about the necessity to maintain common sense and personal responsibility for the published contents. The organization should set boundaries of monitoring guaranteeing clearly that it is consistent with the binding provisions of law, justified, proportional, transparent and respects employees' rights (Mikkelsen, 2011). These are the actions in order to eliminate or minimize dangers and generated numerous risks (prejudice, discrimination, infringement of privacy, infringements of labor agreement) referring to the practices of cybervetting towards employees of an organization.

5. Conclusion

Cybervetting constitutes a significant element of HR practices at present. The conducted research confirms that it is perceived by managers and HR specialists as a tool with big potential supporting the supervision over employees – especially in such areas as the protection of company goodwill, identification of risk behavior and assessment of the cultural adaptation. At the same time, the respondents express clearly dangers connected with this practice and in particular the infringement of privacy, fall of trust in the organization and risk of discrimination. The attitudes towards cybervetting turned out to be strongly differentiated depending on the seniority which may show the influence of work experience on the way of perceiving the border of available control.

The obtained results provide important indications for the management practice; however, they should be interpreted with the consideration of several important limitations. Firstly, the research was of a pilot nature and covered only big companies from two provinces (Lodz and Silesia), which limits the possibility to generalize the results to other regions. Secondly, the use of CAWI method may affect the composition of the sample – most probably the representant who were more active digitally gave their responses. Thirdly, although the differentiation of the seniority was considered, the impact of other significant factors such as taken position, level of responsibility in the organizational structure or the specific of company culture was not analyzed in this stage.

Taking the above into consideration, the presented results should be regarded as the preliminary picture of attitudes towards cybervetting which requires further deepened research – both quantitative as well as qualitative ones covering among others in-depth interviews and case studies.

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DIFFERENT APPROACHES TO MEASURING THE CIRCULARITY OF BUSINESS MODELS

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Purpose: Since the circularity concept gained momentum while business is involved, the issue of measuring progress towards it has become more and more significant. There is still a lack of a single coherent and standardized approach towards measuring the circularity of businesses, and different methodological options are available here. The objective of the paper is to evaluate existing methodological options to measure *circularity* from the perspective of its usefulness for business units, their business models, and their reporting capabilities.

Design/methodology/approach: The objective is realized through a review of existing literature and solutions to measure circularity in business.

Findings: There is still no commonly recognized circularity measurement system, but several different metrics are used. Despite the active ongoing development of circularity measures, the recommendation could be to combine existing evaluation frameworks. Such an adaptive assessment framework could focus on using existing circularity, environmental performance, and sustainability metrics and combine them for a specific organizational context and scope of its use.

Practical implications: Practical implications of the circularity metrics review could be the development of an adaptive assessment framework that would use existing metrics and adjust them to specific cases. The desired mode of its use could be related to existing guidance and quality standards, while specific methods and metrics are concerned.

Originality/value: The paper critically assesses the need to develop circularity-specific complex metrics. The paper presents the circularity assessment framework that could be used for the purpose of assessing business models and directing them towards more circular performance.

Keywords: circular economy, circularity metrics, business circularity, circular business models, sustainability indicators, circulation and recycling rates.

Category of the paper: viewpoint, literature and general review.

1. Introduction

Circularity might be defined as a fraction of a product that comes from used products (from closed or open-loop cycles) (Linder et al., 2017). But there are some other important aspects like environmental burdens and social gains, which could be included in CE scope. Thus, CE could be experimented in an ecosystem working, sharing values for all stakeholders involved (Zucchella, Previtali, 2019). Moreover, several works emphasize the need to create CE metrics at the micro level (Elia et al., 2017; Linder et al., 2017; Lonca et al., 2018), including the link with sustainability (Geng et al., 2012; Mesa et al., 2018).

Previous papers show that CE aims to reach sustainability (Franklin-Johnson et al., 2016; Mesa et al., 2018). But these indicators only addressed the material aspects (Virtanen et al., 2019). The majority of studies also involved specific CE indicators focused in end of life strategies (Di Maio, Rem, 2015; Figge et al., 2018; Jensen et al., 2019), and eco-efficiency (Laner et al., 2017, Yin et al., 2023) instead of economic (Di Maio et al., 2017; Scheepens et al., 2016), environmental (Huysman et al., 2015; Nitkiewicz, 2021), and social indicators (Geng et al., 2012).

Circular business models (CBM) formulate sustainable business strategies. To evaluate sustainable business strategies, it is necessary to be able to measure the actual performance of all processes in a circular business model (Vegter et al., 2020). Research on integrating circular business models with the business model canvas has led to several framework adaptations. Scholtysik et al. (2023) developed a Circular Business Model Canvas (CBMC) that enriches existing Business Model Canvas elements and adds five new components, including reverse logistics, to guide systematic circular business model development. Similarly, Lewandowski (2016) identified two additional components—take-back systems and adoption factors—creating an extended circular business model canvas framework. Islam & Iyer-Raniga (2023) proposed the "Circular Business Model Value Dimension Canvas" for innovation and validation, while Jamadagni et al. (2024) introduced the Circular Business Ecosystem Model Canvas for ecosystem-level circular value chains. Mentik et al. (2014) created the Business Cycle Canvas to support closed-loop material systems, and Lauten-Weiss & Ramesohl (2021) developed the Circular Business Framework based on circular economy principles. These adaptations address the limitations of traditional business model canvases in capturing circular economy requirements (Reim et al., 2019; Upadhayay, Alqassimi, 2020).

Recent research has focused on developing metrics to measure circularity in business models. Various approaches have been proposed, including circularity measurement indices and assessment tools applicable at micro, meso, and macro levels (Barros et al., 2024). Some studies introduce novel metrics like RCE, SCI, and KSI to quantify circularity in open innovation-enabled business models (Geetha et al., 2024). Others suggest linking circular economy principles with business models and sustainability pillars (Rossi et al., 2020).

Common challenges include a lack of standardization and data availability (Das et al., 2022). Researchers have also proposed frameworks connecting circular economy strategies and material flows (Brändström, Eriksson, 2022), and identified six strategic approaches to circular business models (Bocken, Ritala, 2022). Additionally, studies have conceptualized supply chain processes and performance objectives in circular business models, identifying eight key processes and various performance metrics (Vegter et al., 2020). These developments aim to help businesses assess, compare, and improve their circularity.

On the macro level (global or regional), circularity is often referred to as the ratio of cycled material at EOL, or circulation (Wit, Haigh, 2022). The system level below macro is called meso and mostly targets eco-industrial parks and industrial symbiosis (Linder et al., 2017). Metrics on this system level commonly measure recycling rates, reuse rates, and maintenance aspects and generate circularity results based on multiple dimensions (Saidani et al., 2019). Existing research on micro and nano level (product or company) C-metrics shows that many metrics on this system level are either focused on economic aspects (Kristensen, Mosgaard, 2020) or are heavily focused on resource efficiency (de Oliveira, Oliveira, 2023). Resource efficiency C-metrics tend to focus on the circulation of material, or closeness of loops, such as the ratio of circulated input (Linder et al., 2017) or material flows at EOL (Di Maio, Rem, 2015). What's more important, these criteria need an adequate measuring and assessment framework that is done within specific and standardized tools and frameworks, including such tools as life cycle assessment or carbon footprint assessment (Nitkiewicz, 2021). The different levels and their respective circularity metrics are shown in **Figure 1**. It is clear that getting to the lower levels leads to the diversification of assessment metrics and their scopes.

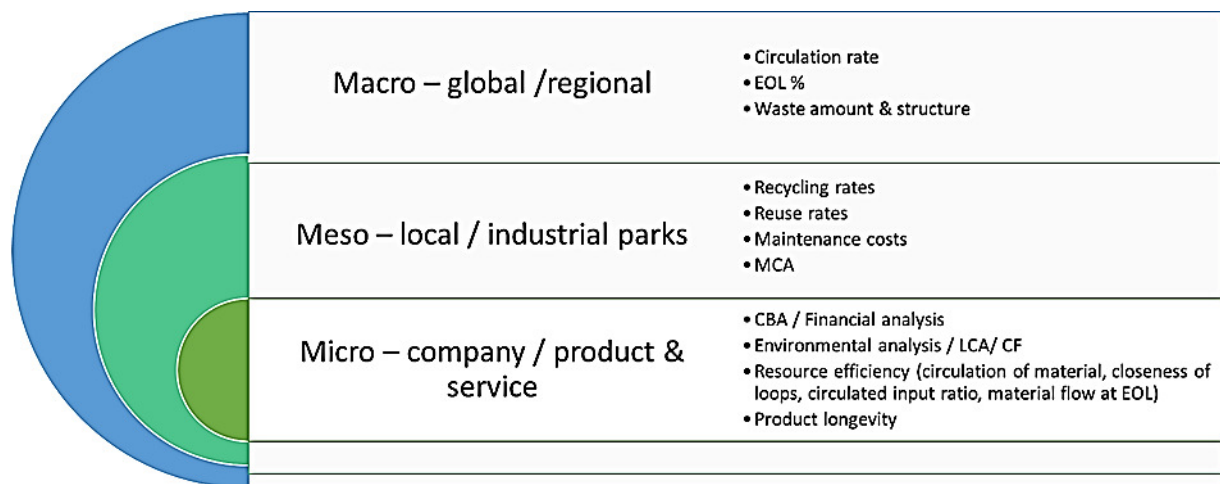


Figure 1. Circularity levels and their metrics.

CBM assessment criteria encompass recycling measures, efficiency improvements, use phase extensions, intensifying use phases, dematerialization, material flows, product lifecycles, and production efficiency (Nitkiewicz et al., 2024). These criteria are crucial for businesses to measure and enhance their circularity performance in alignment with circular economy principles, but also generate key information for communication with external

stakeholders and non-financial reporting. The circularity concept has highly dematerialization-oriented priorities and therefore any product or packaging manufacturing issues gain additional importance (Wojnarowska et al., 2022).

There are, however, those who also consider longevity aspects in the use phase (Franklin-Johnson et al., 2016). The most commonly cited metric, the Material Circularity Indicator (MCI), developed by the Ellen MacArthur Foundation, is a quantitative C-metric that considers both circulation and longevity aspects by calculating the linearity of material flows over time (Goddin et al., 2019). A similar metric, Product Circularity Indicator (PCI), can be used to assess circularity on the product level based on MIO throughout the product life cycle (Bracquené et al., 2020). Both MCI and PCI generate a circularity value by calculating a Linear Flow Index (LFI) and a utility factor (X) (Bracquené et al., 2020). The LFI is a factor that measures the fraction of material flowing in a linear fashion compared to a fully linear system, while the utility factor is used to calculate the expected lifetime and use rate compared to a fully linear system (Bracquené et al., 2020). The most prominent difference between these metrics is that PCI captures material losses in multiple production stages, while manufacturing production losses are summarized in one value in MCI. Both MCI and PCI are quantitative material flow-based C-metrics that can capture both closeness and slowness of loops.

Since the diversity of approaches in defining CBM leads to the development of quite diversified business circularity metrics, the issue at hand is to provide a commonly recognized framework for reliable and transparent circularity assessment. The objective of the paper is to evaluate existing methodological options to measure *circularity* from the perspective of its usefulness for business units, their business models, and their reporting capabilities. The research questions are:

1. What is the coverage of business circularity within existing circularity metrics? and
2. Does it satisfy the needs of business organizations and fit their reporting capabilities?

The objective of the paper, and its research questions, are aimed at relating the research to the underlying issue of the need to develop new complex circularity metrics for business.

2. Methods

The methods used for the assessment are organized within a two-step process. Firstly, the literature review is performed. The focus is on circularity metrics and existing circularity assessment indicators and frameworks. Secondly, the existing metrics are examined from the perspective of complexity. The complexity is approached from the perspective of CBM and business in general. The complexity of CBM metrics is based on distilling assessment areas from existing circularity metrics and matching the areas with the most common assessment frameworks and indicators.

The construction of almost every circularity metric, at least those that aspire to be complex enough to cover circularity in its holistic understanding, starts with the 3R strategy (Reduce, Reuse and Recycle) as proposed by Ellen MacArthur Foundation (EllenMacArthur Foundation, 2013), or one of its further extensions (Wojnarowska et al., 2022). As shown in **Figure 2**, the idea is to follow the hierarchy and to prioritize the most valuable and feasible for CE strategies (Reduction over Reuse and Reuse over Recycle).

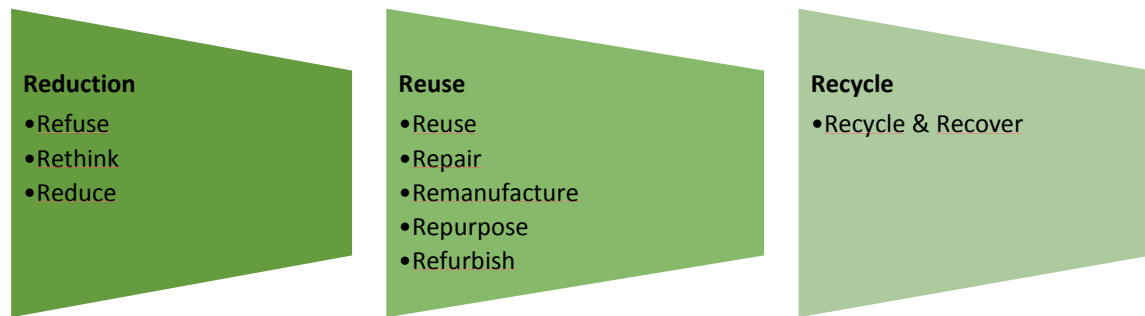


Figure 2. Strategies of 3R and 9R for setting circularity priorities.

3. Results

The importance of adjusting circularity metrics to CBM is related to the sector, size, target group, or technology, but also could be sensitive to the CBM archetype used. The most commonly recognized CBM archetypes are (Woldeyes et al., 2023):

1. Product-as-a-Service.
2. Resource Recovery Models.
3. Sharing Platforms.
4. Life-extension models.

The scope of each one of the archetypes suggests the metrics that could be dominant within circularity evaluation. The Product-as-a-Service type will be focused on the change of general material flow and will have a strong competitive advantage orientation. The Resource Recovery Models will be oriented on finding an appropriate way for material and waste recovery scenarios. Sharing platforms will be focused on the manufacturing and use phase, progressing towards dematerialization of the product life-cycle and providing a strong boost to customer empowerment, aimed at rethinking the demand for products and their use models. Life-extension models will be searching for increasing product durability and longevity, and avoiding overproduction and overconsumption.

For more than a decade, the CE concept has been equipped with complex metrics and indicators. For example, the Material Circularity Indicator (MCI) focuses on the restoration of material flows at product and company levels and is based on the following six principles (EllenMacArthur Foundation, 2013; Goddin et al., 2019):

- a. Sourcing biological materials from sustainable sources.
- b. Using feedstock from reused or recycled sources.
- c. Keeping products in use longer (e.g., by reuse/redistribution/increasing durability).
- d. Reusing components or recycling materials after the use of the product.
- e. Making more intensive use of products (e.g. via service, sharing or performance models).
- f. Ensuring biological materials remain uncontaminated and biologically accessible.

The approach presented in MCI is also common for the Product Circularity Indicator (Bracquen   et al., 2020), Material Efficiency Metric (MEM) (Br  ndstr  m, Eriksson, 2022) or Resource Circularity Efficiency (RCE) (Geetha et al., 2024) indicators. The coverage for the CE concept is focused and, somehow, limited to the material flow within existing value chains.

The issues that remain out of the scope of material-oriented metrics, like customer or market-related issues, tend to be covered within some extra indicators and metrics. Geetha et al. (2024) proposed to combine the Stakeholder Collaboration Index (SCI) and the Knowledge Sharing Index (KSI) with RCE to measure aspects of open innovation-enabled circular business models. While environmental impact is concerned, the circularity metrics are supplemented or developed on the basis of life cycle-based metrics, like life cycle assessment (LCA), carbon footprint (CF) or even its extensions to measure sustainability, like life cycle sustainability assessment (LCSA), or social aspects, like social life cycle assessment (S-LCA). The reference to the life cycle remains valid also for economic aspects of circularity and CBMs (Nitekiewicz, Cappelletti, 2022). An example of it is the use of the life cycle costing (LCC) framework to assess circularity (Kambanou, Sakao, 2020). But the list of economic and market-related measures that could contribute to circularity metrics is long and diversified among sectors or even business units, and could hardly even be mapped within the framework of this paper. On the most general level, the assessment and analytical instruments should provide market performance indicators, as well as some financial and cost-benefit related insights. Cost-benefit analysis (CBA), which is discussed later in the text, should be understood as a measure to balance the potential benefits and costs of introducing CBM, including also profits that are lost due to the strategic switch towards circularity.

As explained above, if the business perspective is taken into account, it seems that the material focus is often not enough to feed circular business models. In the literature on CBMs a few common circularity criteria for business models have been identified:

1. Degree of Circularity: CBMs are classified based on the degree of adoption of circularity principles, particularly in the customer value proposition and interface (Urbinati et al., 2017). CBMs tend to prioritize end-of-life management strategies, such as recycling and recovery, to ensure that remaining materials are reused or repurposed rather than treated as waste (Stewart, Niero, 2018).

2. **Value Creation Logic:** A key aspect of CBMs is the conceptual logic for value creation, which involves utilizing the economic value retained in products after their initial use to produce new offerings (Kanda et al., 2021). Another essential aspect of CBMs is to emphasize circular product design. This involves designing products that are easily recyclable, reusable, or compostable to minimize environmental impact (Stewart, Niero, 2018).
3. **Resource Efficiency:** CBMs aim to improve resource efficiency by extending the lifespan of products and their parts, leading to environmental, social, and economic benefits (Frishammar, Parida, 2019).
4. **Orchestrating Circular Networks:** Effective CBMs often involve a focal actor orchestrating a circular ecosystem that includes suppliers, customers, research centers, and public authorities (Koszevska, Bielawska-Zakrzewska, 2024; Zucchella, Previtali, 2019). Establishing collaborative ecosystems within the manufacturing industry, involving stakeholders such as suppliers, manufacturers, and waste management companies, is essential for the successful implementation of CBMs (Nitkiewicz et al., 2024).
5. **Loop Closure Strategies:** CBMs are characterized by strategies that close, narrow, slow, intensify, and dematerialize material loops to reduce material inputs and waste leakage (Voukkali et al., 2023). CBMs often incorporate the use of reverse logistics systems to facilitate the collection and recycling of used materials, contributing to a more closed-loop system (Guarnieri et al., 2020).
6. **Innovation and Differentiation:** CBMs can help organizations increase differentiation, reduce costs, generate new revenues, and mitigate risks associated with resource scarcity (Husain et al., 2021). Developing innovative product designs that promote circularity, such as incorporating recycled materials or designing for easy disassembly and recycling, is a key aspect of CBMs (Liu et al., 2023).
7. **Communication Strategies:** Effective communication with consumers regarding the disposal and end-of-life pathways of product remaining, construction materials or packaging is integral to CBMs. Clear communication can guide consumers in proper waste disposal practices (Baskoro et al., 2024).

Table 1 presents key characteristics of metrics that are related to specific circularity criteria.

Table 1.
Circularity criteria and their characteristics

Circularity Criteria [Acronym]	Characteristics
Degree of Circularity [DC]	Share of material volume that is recovered at every life-cycle phase
Value Creation [VC]	Relative economic value retained in products after their initial use to produce new offerings
Resource Efficiency [RE]	Decrease of materials use in manufacturing, extending the lifespan of products and parts, leading to environmental, social, and economic benefits
Loop Closure [LC]	Share of closed loops within life cycle; implementing strategies that close, narrow, slow, intensify, and dematerialize material loops to reduce material inputs and waste leakage
Innovation and Differentiation [ID]	increase of differentiation, reduction of costs, generation of new revenues, and mitigation of risks associated with resource scarcity
Communication Strategies [CS]	Effective communication with consumers regarding the disposal and end-of-life pathways of packaging materials is integral to circular business models in the packaging industry
Circular Networks [CN]	orchestrating a circular ecosystem that includes suppliers, customers, research centers, and public authorities

After identifying circularity criteria that could be used to drive CBMs, they are evaluated vs. their potential significance for CBM archetypes. The assessment is made with a simple 3-star scale where a 1-star mark denotes relatively weak significance, while a 3-star mark denotes strong significance. As **Table 2** shows, the technical circularity, as mapped by DC, RE and LC criteria, is not always the most significant for specific CBM types. Only Resource Recovery Models have a definite material circularity orientation, while life-extension models are very sensitive to product types, and Product-as-a-Service and Sharing Platform CBM are heavily dependent on communication and networking activities.

Table 2.
Evaluation of the significance of circularity criteria for CBMs archetypes

Circularity criteria	Product-as-a-Service	Resource Recovery Models	Sharing Platforms	Life-extension models
DC	★	★★★	★	★
VC	★★★	★	★★	★★★
RE	★★	★★★	★★	★
LC	★	★★★	★★	★★
ID	★★★	★	★★	★★
CS	★★	★	★★★	★★
CN	★★	★★	★★★	★

It seems that metrics dedicated to CE and CBMs, which usually have a more technical focus, are not capable enough to cover all the circularity criteria. They certainly contribute to the assessment of any CBM type, but in most cases, only to some extent. Therefore, the use of additional metrics and indicators can significantly contribute to making the assessment more complex and better cover the CE concept in its holistic form.

4. Discussion

Since the current developments in the field of CE metrics are directed towards getting more complex measures of circularity, it is important to map the coverage of all CBMs assessment criteria within existing tools and frameworks. Geetha et al. (2024) proposes a novel set of metrics to cover the complexity of CE, while some authors (Brändström, Eriksson, 2022; Rossi et al., 2020) propose to combine the typical CE metrics with existing metrics and frameworks. In order to have an overview of the coverage of circularity criteria with CE dedicated and external metrics, the mapping process is shown in **Figure 3**. The metrics are divided into four categories: CE-oriented metrics (CE), environmental metrics (ENV), economic and business-specific metrics (ECON), and social metrics (SOC). The list of metrics that are applicable is limited to some commonly recognized items in each of the categories. We could observe that the group of CE-oriented metrics has a limited range of use, while the circularity criteria are considered. This conclusion is shared by several different researchers (Bracquené et al., 2020; Brändström, Eriksson, 2022; Geetha et al., 2024; Jerome et al., 2022; Kambanou, Sakao, 2020) and confirms the limited scope of the currently developed metric and the CE-specific toolbox.

Instead of proposing new metrics or arguing for using more complex metrics, we suggest focusing on what is available and combining CE metrics with existing, preferably business-oriented metrics, that could contribute to showing the complexity of CBMs, but without engaging business owners in further development of monitoring and reporting schemes. It seems that referring to business-specific KPIs together with existing ESG reporting data should enable quite complex fulfilment of circularity criteria for any CBM.

Circularity Criteria [Acronym]	Metrics	
Degree of Circularity [DC]	MCI LCA / CF MEM	CE Material Circularity Indicator (MCI) Material Efficiency Metric (MEM) Resource Circularity Efficiency (RCE)
Value Creation [VC]	KPI LCC CBA	ENV Life cycle assessment (LCA) Carbon Footprint (CF)
Resource Efficiency [RE]	KPI RCE / MCI / MEM LCA / CF	ECON Key Performance Indicators (KPI) Life cycle costing (LCC) Cost-Benefit Analysis (CBA)
Loop Closure [LC]	MCI MEM LCA	
Innovation and Differentiation [ID]	KSI CBA	SOC Net Promoter Score (NPS) Social LCA (S-LCA) Knowledge Sharing Index (KSI) Stakeholder Collaboration Index (SCI)
Communication Strategies [CS]	KPI SCI NPS	
Circular Networks [CN]	KPI SCI / KSI S-LCA	

Figure 3. Application of existing metrics to CBM circularity criteria.

The authors suggest that for the current reporting needs of CE, its current toolbox is enough. The reasoning for that is twofold. Firstly, CE-related reporting still remains voluntary and is only occasionally determined by some market-driven circumstances. In the case of an existing specific need, business units could use their own and ESG-originating metrics and reporting schemes. Secondly, the role of business circularity and the concept of CE seems to be still subordinate to the concept of sustainable development and business sustainability, and it provides a specific path towards sustainability. Bearing that in mind, the existing toolbox of sustainability metrics could be used to complement the adaptive assessment framework and should allow for a complex assessment of CBMs.

5. Summary

Traditional indicators could not express CE in its totality, because they are not designed for the systemic, closed-loop, feedback features that represent CE. Comprehensive evaluation of CBM is highly determined by the profile and scope of the unit under evaluation. Designing comprehensive integrated metrics may lead to evaluation overprocessing and could bias the results, especially on macro and meso levels. The recommended approach is to develop an adaptive assessment framework and possibly to engage it within sectoral evaluation. Another approach could simply use a combination of existing ESG reporting schemes or sustainability metrics and incorporate them with CE metrics.

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ADVANCED DATA MINING TECHNIQUES IN KNOWLEDGE MANAGEMENT

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Purpose: The research shows a strong link between strategically using advanced data mining tools and improving Knowledge Management processes. It suggests that machine learning and social network analysis help organizations shift to proactive, personalized, data-driven strategies. The results highlight how these tools can reveal hidden knowledge, improve knowledge flow, and enhance organizational learning and decision-making. It also suggests that utilizing advanced data mining tools strategically and ethically can improve knowledge management by addressing limitations of traditional methods and enhancing core organizational processes.

Design/methodology/approach: This article uses a mixed methods approach to examine academic literature on data mining techniques used in knowledge management. A rigorous review of previous studies published by IEEE Xplore, ACM Digital Library, Scopus, and Web of Science to pinpoint well-established and cutting-edge techniques in knowledge management and data mining was conducted. To further highlight the application of KM strategies, elements of a previous work were integrated.

Findings: This study offers a detailed analysis of how knowledge management and modern data mining interact to benefit researchers and experts aiming to enhance their strategies in a data-driven world. The study outlines benefits, challenges, and methods, making it a valuable resource for maximizing success. The study shows that advanced data mining techniques greatly improve knowledge management through knowledge discovery, knowledge acquisition and structuring, knowledge sharing and collaboration, and knowledge utilization.

Research limitations: Reliance on published materials, which omitted the newest breakthroughs, results being skewed by publication bias, direct comparison being hampered by different research quality, academic emphasis ignoring the subtleties of the actual world, and constraint in data gathering time in a dynamic field such as knowledge management are the limitations of this study.

Social implications: When advanced data mining is used effectively in Knowledge Management, organizations can gain insights from a variety of datasets, and data-driven knowledge management (KM) fosters quick innovation. Enhanced knowledge management (KM) through data mining can help governments make better policies and provide better healthcare and education for their people. Data mining also makes it easier for interdisciplinary teams to work together to solve difficult societal problems.

Practical Implications: Despite limitations, this study offers useful information for organizations. It shows the significant potential of leveraging advanced data mining techniques to enhance knowledge understanding and efficiency. Also shows how organizations can begin

to explore their KM-related data using accessible data mining tools. This study suggests integrating data mining into current knowledge systems strategically. Organizations can then identify key use areas by discussing specific techniques and their benefits. It also goes to emphasize the importance of data-driven strategies for better decision-making.

Research Contribution: The main research contribution is the creation of a structured framework that successfully combines the capabilities of advanced data mining with well-established knowledge management processes. This research goes beyond a purely theoretical discussion by providing a practical assessment of the tangible impact of data mining techniques - namely, machine learning (ML), natural language processing (NLP), and social network analysis (SNA) - in crucial organizational functions. By looking into real-world applications and analyzing existing literature, this research shows how these techniques directly impact organizational knowledge flow, operational efficiency, and, ultimately, the caliber and efficacy of strategic decision-making. For organizations looking to leverage the potential of data mining to maximize their knowledge management strategies and attain measurable improvements in their operational and strategic outcomes, this framework, which is based on the research findings, offers a concrete approach.

Originality/value: This article incorporates knowledge from various academic areas and offers a thorough overview of the use of modern data mining techniques in Knowledge Management. It adds to the continuing discussion on the function of data mining in knowledge management and provides helpful guidance for organizations looking to improve their knowledge management strategies.

Keywords: Data Mining, Knowledge Management, Machine Learning, Natural Language Processing, Social Network Analysis.

Category of the paper: Research paper.

1. Introduction

In today's digital era, knowledge management is vital. It drives innovation and boosts competitive advantage. However, traditional systems struggle with the vast amounts of complex data generated by modern organizations. This calls for a new approach that embraces flexible and dynamic Knowledge Management methods. Automating knowledge discovery, organization, and usage through advanced data mining techniques can help organizations use their intellectual capital effectively. Davenport (1998) defines knowledge as a blend of experience, values, context, and expert insight. This definition stresses the need for systems that adapt to the changing information landscape. Nonaka & Takeuchi (1996) also emphasized the importance of organizational processes in turning implicit knowledge into explicit knowledge. As larger data sets become more common, the demand for automated Knowledge Management systems that can analyze and extract valuable information has grown. The McKinsey Global Institute supports this trend. Advanced data mining techniques, such as clustering, outlier analysis, regression, data integration, and decision trees, are effective tools. They help organizations gain insights and enhance decision-making. Nowadays, knowledge management is crucial for organizations all over the world to get a competitive edge and expand. The problem

with the availability of data is that it has gotten harder to glean insightful information from this data, creating a "data blind spot" where important information is frequently overlooked. This paper addresses the current problem by examining the connection between data mining methods and knowledge management strategies. Industry reports and trends for 2024 and 2025 stress the importance of this topic, especially in knowledge management systems for artificial intelligence. The demand for intelligent KM systems to derive insights from extensive data is crucial for businesses navigating real-time decisions and remote work models. This study aims to help researchers, IT strategists, leaders, and knowledge management specialists by providing practical frameworks and recommendations to improve knowledge assets, communication, employee performance, and promote a learning culture. The article also explores leveraging technological skills to maximize organizational knowledge value.

1.1. Data Mining

Many terms relate to data mining. These include knowledge mining from data, knowledge extraction, data archaeology, and data dredging. However, the most often used of these terminologies is Knowledge Discovery from Data (KDD). The primary objective of KDD in databases is to extract relevant information from extensive datasets. Applying different methods and algorithms to find and extract patterns from recorded data is one of data mining's primary tasks. As depicted in *Figure 1*, the flow of data, from raw data through the process of extracting valuable knowledge through data mining processes. Databases, data warehouses, the internet, other information repositories, and data that enters the system dynamically are some of the sources of this raw data.

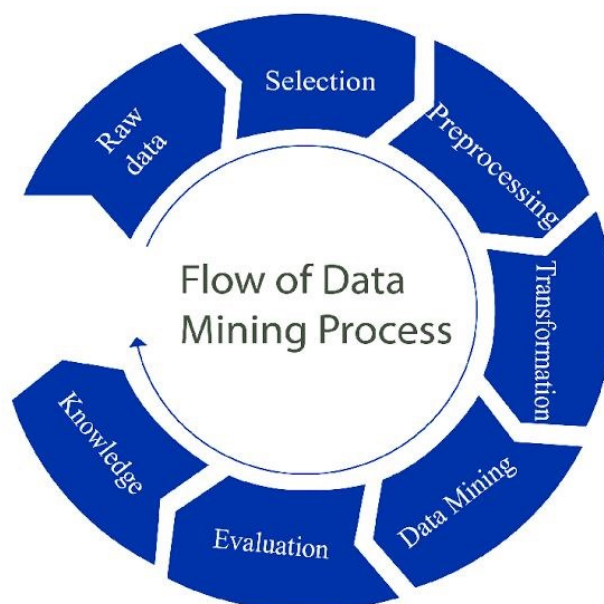


Figure 1. Flow of the data mining process.

Source: (ResearchGate, 2023).

An iterative sequence method is used in the data mining process, and they are as follows:

1. Data cleaning: merging data from many sources and eliminating noise and inconsistent data.
2. Integrating data: Merging various data sources.
3. Selecting Data: Choosing pertinent information that is obtained from the database and required for analysis.
4. Data Transformation: Converting information into formats that are suitable for data mining.
5. Data mining: Selecting an algorithm for data mining based on patterns found in the data.
6. Evaluation of patterns: Identifying interesting patterns that provide information.
7. Knowledge presentation: Converting practical patterns into language that people can comprehend.

To find hidden patterns, organize unstructured data, and identify trends, organizations can use advanced data mining techniques like Social Network Analysis (SNA), Machine Learning, and Natural Language Processing (NLP), which is vital for extracting valuable information from large datasets. Han et al. (2022) note that data mining reveals important information hidden in vast data sets. By applying these techniques, organizations gain a competitive edge in today's data-driven world. Effective decision-making, big data, and data science are related. Davenport et al. (2010) demonstrate that analysts can lead to better decisions and outcomes, highlighting the need for analysts in modern organizations. My earlier work, "The Effects of Information Technology on Organizational Culture and Management in the Banking Sector - Case Study" by Obi & Guminski (2024), highlighted the importance of Organizational culture and IT infrastructure as essential for efficient knowledge management. This work aims to build on those findings by analyzing the role of advanced data mining techniques in knowledge management. Thus, this study evaluates advanced data mining techniques in knowledge management, analyzes their capabilities, and identifies their limitations in real-world applications.

1.2. Knowledge Management

There are numerous definitions of knowledge management (KM) in various works of literature authored by numerous research scholars. Gaining a deeper comprehension of knowledge management requires first comprehending what knowledge is. Knowledge is a broad concept with significant effects on an organization's ability to act efficiently. It can be divided into two types: explicit and tacit knowledge. According to Gloet & Terziovski (2004), information management means formalizing and making accessible experience, information, and expertise. This process fosters innovation, enhances customer value, boosts performance, and develops new skills. The authors identify several interrelated elements under "knowledge management", including knowledge generation, value and measurement, mapping and indexing, transport, storage and distribution, and sharing. The knowledge management process,

as noted by Mohapatra et al. (2018), mainly focuses on information acquisition, application, generation, capture, sharing, and dissemination. Information technology supports acquiring, creating, sharing, distributing, and applying knowledge. *Figure 2* shows the knowledge management cycle, depicting the process of knowledge creation to utilization, necessary for the proper utilization of knowledge. Information technology helps in the process of acquiring, creating, sharing, distributing, and applying knowledge.

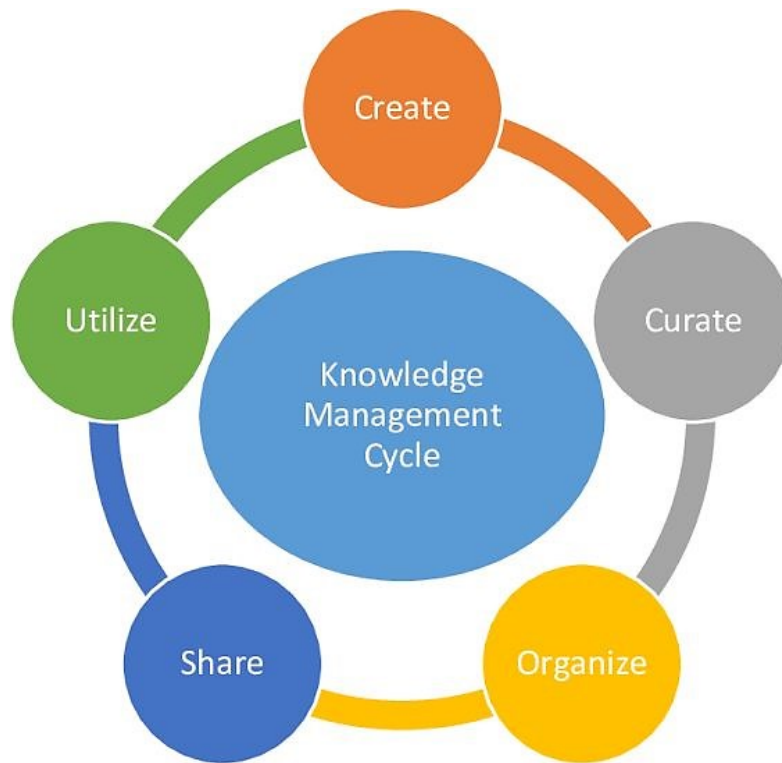


Figure 2. Illustration of the knowledge management cycle.

Source: (ResearchGate, 2023).

Figure 3 also shows the evolution of KM systems, referencing the development and transformation of technologies, strategies, and practices used to capture, organize, share, and utilize knowledge within organizations.

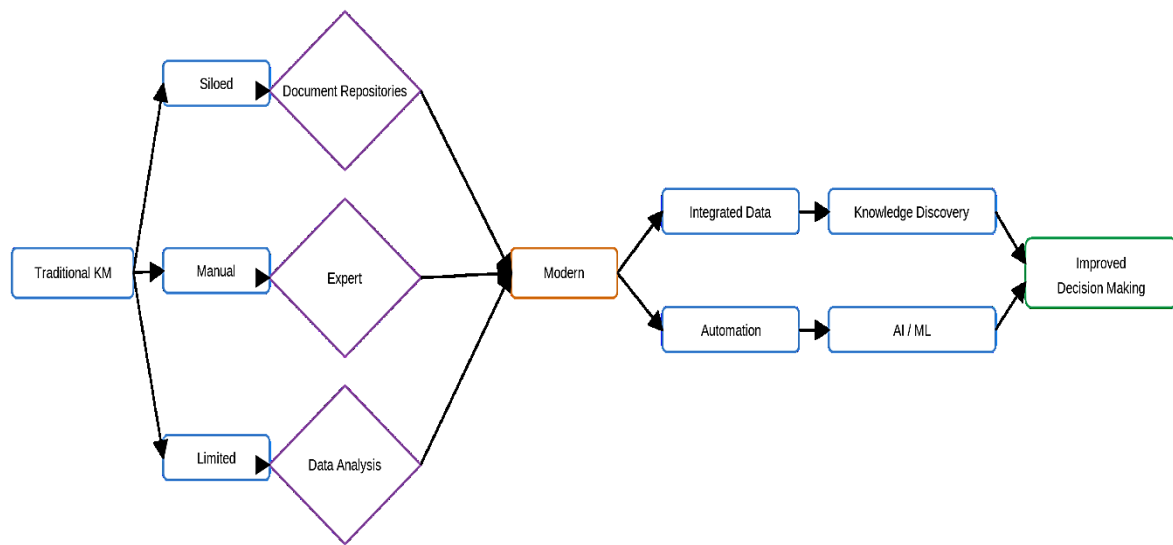


Figure 3. The Evolution of Knowledge Management Systems.

Source: (Illustration by the author, 2025).

Various knowledge management (KM) technologies have been used as a means of generating and capturing knowledge. The mining of customer information for the product line and brand extension in retailing can be divided into seven categories:

- a. The KM Framework.
- b. Knowledge-based systems.
- c. Data Mining.
- d. Information and Communication Technology.
- e. Expert systems and artificial intelligence (AI).
- f. Database Technology.
- g. Modeling.

Data mining is one of the tools used in the knowledge management process. According to H. Wang & S. Wang (2008) Knowledge Management can benefit from data mining in the two primary areas:

1. To give data miners a shared understanding of the business intelligence context.
2. To employ data mining as a powerful instrument to expand human knowledge.

Figure 4 shows data mining methods, with each method serving a unique purpose in the data mining process, leading up to extracting valuable knowledge at the end of the process. A closer look at the methods and how they are used in knowledge management is as follows.

Clustering: This method reveals underlying patterns and structures in datasets by putting similar data points together. Its application in knowledge management includes classifying documents, identifying knowledge domains, and assembling users with related interests.

Outlier Analysis: This method finds data points that substantially depart from the norm, which may indicate errors or anomalies. Its use in Knowledge management includes spotting discrepancies in existing knowledge, spotting possible knowledge gaps, and highlighting odd user behavior.

Regression: This is using the values of other variables to predict the value of a target variable, and its application in knowledge management includes recognizing patterns in user behavior, forecasting knowledge demand, and estimating the efficacy of knowledge resources.

Data Integration: Data integration is the process of merging data from multiple sources to create a single data collection. It is used in knowledge management in combining information from multiple sources, including documents, databases, and social media, to create an extensive knowledge base.

Decision Trees: This method, which may be applied to categorization and prediction, represents decisions and their potential outcomes using a tree-like structure. It is used in establishing decision-guiding knowledge frameworks, categorizing documents or knowledge resources, and forecasting user requirements.

Association Rule Mining: finds connections between various data set components. It is used in finding connections between information resources, locating pertinent documents, and proposing linked knowledge topics are examples of applications in knowledge management.

Data visualization: It uses visual representations to investigate and communicate data findings. It is applicable in using dashboards and reports to monitor knowledge utilization, visualize knowledge structures, and share findings with stakeholders.

Deep Learning: This is a technique used in extracting knowledge by analyzing intricate data patterns using artificial neural networks. Its knowledge management application includes automating knowledge discovery, customizing access to knowledge, and developing intelligent knowledge systems.

Predictive analysis: This forecasts future events by utilizing data mining and machine learning. Its applications in knowledge management include recognizing patterns in user behavior, forecasting knowledge demand, and estimating the efficacy of knowledge resources.

Data cleaning: This method eliminates flaws and inconsistencies from data to get it ready for analysis. Applying it in knowledge management makes sure that knowledge resources are accurate and dependable.

Data normalization is a technique that improves the usability of data by standardizing it. It is employed to make integrating and comparing data from various sources easier.

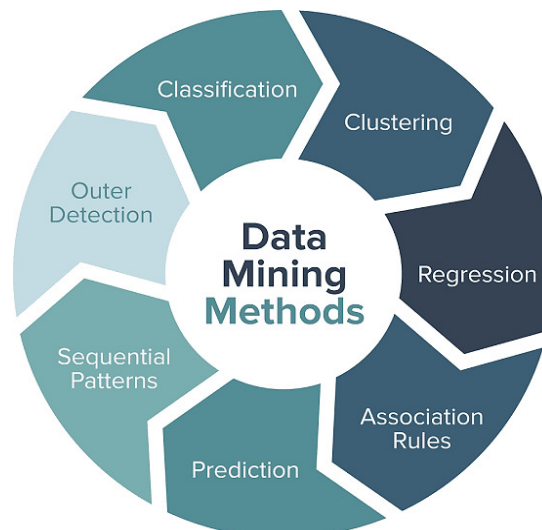


Figure 4. Image showing the data mining methods.

Source: (Jaro Education, 2025).

The more efficient data mining-enabled KM includes automated knowledge discovery/extraction to save time/resources. Intelligent knowledge organization/retrieval for faster/accurate information access. Proactive knowledge sharing/recommendation for relevant knowledge delivery. Data-driven identification of expertise/communities for collaboration, and scalable analysis of knowledge needs/gaps organization-wide. Also, the less efficient traditional KM includes manual curation and incomplete indexing, reactive knowledge sharing, subjective knowledge needs identification, and limited scalability due to managing large volumes effectively. Its limitations include dependencies on data quality, the need for contextual interpretation, privacy concerns, and technical complexities of integrating various data sources and tools. While Challenges include building interdisciplinary skills by collaborating between KM professionals and data scientists. Then, fostering a data-driven culture for decision-making in KM, and managing tool complexity and costs by selecting appropriate data mining tools. Key elements in KM to support include knowledge discovery, organization, sharing, creation, utilization, expertise management, learning, development, retention, and measuring impact using data.

With the role of advanced data mining techniques in knowledge management established, the objectives of this research outlined, the efficient and less efficient data mining-enabled KM listed, and the subsequent limitations and challenges in using KM, the subsequent section details the methodology used to analyze these techniques and their impacts.

2. Methodology

This research used a mixed-methods approach to examine the use of advanced data mining tools in knowledge management, through an exhaustive literature study.

2.1. Literature Study

A comprehensive review of peer-reviewed publications, conference papers, and industry reports from 2010 to 2024 was conducted. Web of Science, IEEE XPLORE, ACM Digital Library, Google Scholar, and Scopus were the databases used. Search terms included "data mining", "knowledge management", "machine learning", "natural language processing", "social network analysis", "discovery of knowledge", and "organizational learning". Each study's methods and relevance were examined to follow the established methodology. Guidelines provided by Kitchenham (2004) for systematic literature reviews, ensuring a reliable and unbiased analysis, were adhered to. Papers were organized under headings like "Machine Learning for KM", "NLP for KM", and "SNO for KM" for better data management. *Figure 5* shows the systematic literature review as undertaken, showing the structured approach to identifying, evaluating, and synthesizing existing research on a specific topic or research question. The collected data was analyzed using qualitative methods. Thematic analysis of the literature review data revealed recurrent themes, theoretical frameworks, and key points on advanced data mining in knowledge management.

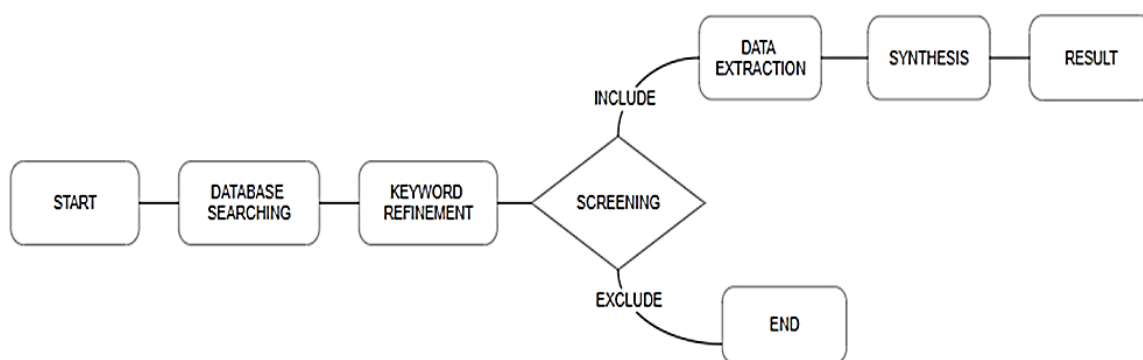


Figure 5. Systematic literature review.

Source: (Illustration by the author, 2025).

2.2. Data Analysis

The gathered data underwent rigorous examination through computational performance and theoretical synthesis. Thematic analysis of the literature study data identified patterns using a widely accepted qualitative approach. This systematic procedure proceeded in phases.

Data Familiarization: To understand the data better, all selected literature was read thoroughly to gain insights into knowledge management and data mining.

Initial Code Generation: During the familiarization phase, intriguing traits from the dataset were systematically coded, including the initial reflections on data mining techniques, knowledge management processes, their interactions, observed benefits, and recognized challenges. The coding approach was a combination of inductive and deductive methods.

Searching for Themes: After collating, the original codes were categorized into possible subjects by searching for patterns, grouping related codes. For example, codes like "predictive analytics", "recommended system", and "pattern recognition" fell under the topic of "discovery of knowledge through machine learning".

Reviewing Themes: The themes were examined against coded extracts to ensure accuracy and distinctiveness. This process involved refining topic definitions and potentially adjusting subject divisions.

Defining and Naming Themes: Each topic was defined precisely with characteristics and detailed data parts. Subjects were named succinctly to reflect their original meaning.

All these made it easy to identify and evaluate important discoveries on knowledge management and data mining by facilitating the study of the full literature for data analysis.

2.3. Integration of Previous Work

Additionally, findings from “Effects of Information Technology on Organizational Culture and Management in a Banking Sector - A Case Study” by Obi & Guminski (2024) were integrated to contextualize the impact of IT infrastructure and organizational culture on the implementation of advanced data mining techniques. This allowed the research to build on earlier findings and provide a more comprehensive view of the topic.

The main conclusions from the review are presented in the next section, following an explanation of the research methodology. It emphasizes the usefulness and results of advanced data mining approaches in knowledge management.

3. Results

The findings of the study highlighted key data mining techniques relevant to Knowledge Management, including machine learning (e.g., clustering, classification), natural language processing (e.g., subject modeling, emotion analysis), and social network analysis (e.g., centrality measures, community detection). These techniques were assessed for their alignment with KM challenges. Making it possible to extract useful and actionable insights from data using algorithms that learn from data and improve over time, machine learning (ML) is essential to knowledge discovery (KDD), as shown in Figure 6. By using machine learning in knowledge discovery, there have been noteworthy outcomes. Cluster algorithms like K-Means and hierarchical clusters have successfully uncovered underlying patterns and

correlations within large data sets. Data was categorized and future outcomes were anticipated by classification techniques such as support vector machines (SVM) and decision trees (Quinlan, 1986). For instance, machine learning has effectively been used to identify common issues and patterns and to categorize client comments into several groups. By offering tailored suggestions, recommendations have also been utilized to boost the application of knowledge. Provost & Kohavi (1998) was used to explain the terms used in machine learning.

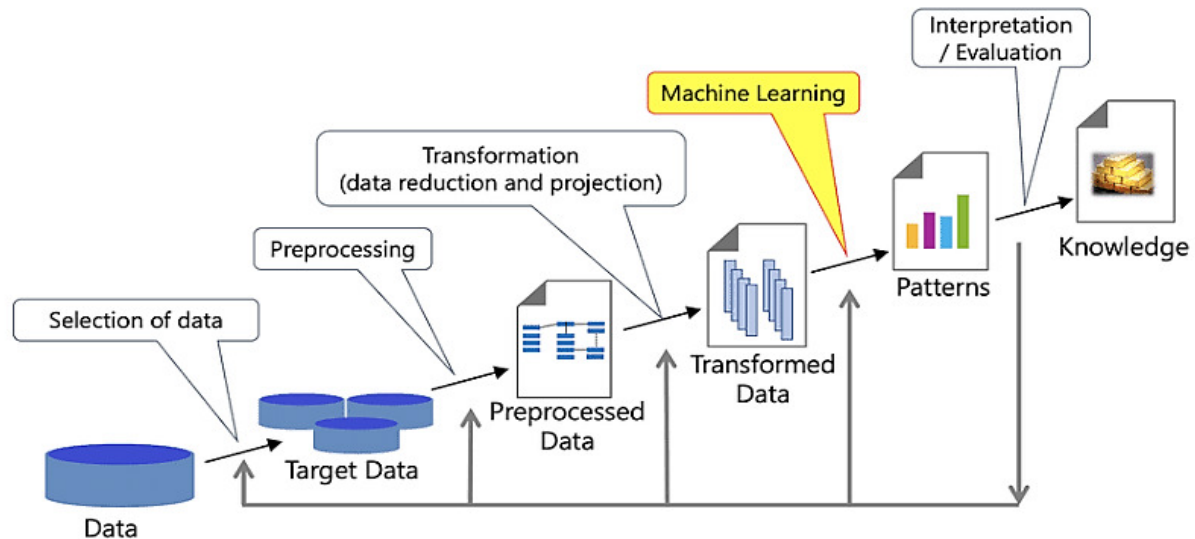


Figure 6. Knowledge discovery (KDD) through machine learning.

Source: (ResearchGate, 2021).

Natural Language Processing (NLP) methods significantly influenced the organization of knowledge. To extract significant topics from unstructured text data, modelling themes was done using techniques such as latent allocation Dirichlet (LDA) (Blei et al., 2003). Sentiment analysis was used to spot new trends and analyze consumer sentiment (Liu, 2022; Pang, Lee, 2008). Automated linking of related documents was made possible by semantic analysis. Concerning contemporary NLP methodologies, the fundamentals of information retrieval as described by Salton (1983) are still applicable. The thorough introduction to text data mining given by Hearst (1999) was a useful resource for this area of study. According to Newman (2018), social network analysis (SN) has demonstrated efficacy in mapping knowledge networks and finding critical knowledge within organizations. To find prominent people and information brokers, network measures, including international centrality, were employed (Borgatti et al., 2024). By identifying the silos of knowledge and facilitating cooperation, she was able to solve the possible barriers to the flow of knowledge. The mechanics of knowledge flow in social networks were examined, highlighting the significance of comprehending the dissemination of positive ideas. It is determined that to guarantee a seamless flow of knowledge, data mining technologies must be integrated with current KM systems. As stressed in Obi & Guminski (2024), the influence of organizational culture and IT infrastructure was crucial to the effective application of these strategies. The effectiveness

of the system was significantly impacted by the quality of the data, demonstrating the significance of both data and quality control. Additionally, it was shown that business analytics and intelligence are crucial, according to Chen et al. (2012). McAfee et al. (2012) claim that big data completely changed their management style.

3.1. The Precise Connection Between Data Mining Tools and KM: What is Possible

Use of advanced data mining tools for KM makes several transformative possibilities a reality. Such realities are:

Automated Knowledge Discovery: Analyzing extensive organizational data to uncover overlooked correlations, patterns, and trends in both structured and unstructured formats.

Enhanced Knowledge Organization: Utilizing NLP approaches to automatically classify, label, and organize knowledge assets. This helps learning by reducing overload and facilitating the creation of semantic knowledge networks.

Personalized Knowledge Delivery: Using machine learning algorithms, specialists are recommended based on staff members' projects, positions, and interactions, saving time and improving knowledge application.

Identification of Key Knowledge Holders: Analyzing communication patterns to identify key personnel and subject-matter experts within an organization through social network analysis. This makes it easier to locate experts and share knowledge.

Understanding Knowledge Gaps and Needs: Studying search queries and requests helps identify knowledge gaps for developing new resources and focused programs.

Predictive Knowledge Management: By anticipating future knowledge needs, organizations generate and manage crucial knowledge effectively by analyzing trends, projects, and employee skills.

Improved Decision-Making: Decision-making can be improved at all levels through data-driven insights.

Measuring KM Effectiveness: To improve organizational performance, data mining techniques are used to analyze knowledge utilization, contributions, and impact initiatives.

Basically, the integration of knowledge management (KM) and advanced data mining techniques brings in a new era of organizational intelligence. These technologies offer transformative capabilities such as identifying expertise, tailoring information, and enhancing organizational performance. This integration empowers organizations to effectively handle knowledge, bridge gaps, make data-driven decisions, and improve the efficiency of their knowledge management strategies with precision and a strong competitive advantage.

3.2. Operational Mechanisms: How it Works

Data mining tools and KM connect by applying specific techniques to knowledge-related data systematically. First is to gather data from organizational sources like document repositories, communication logs, project databases, expert directories, and employee profiles.

After that, this data is processed, cleansed, and ready for analysis. It is then important to select and apply the appropriate data mining tool based on the specific KM objective:

Algorithms in machine learning cover clustering (e.g., K-Means) for grouping knowledge, classification for categorizing data, and recommendation systems for offering relevant information. Natural language processing methods can then be involved in entity recognition for extracting data, sentiment analysis for opinion assessment, and topic modeling (e.g., LDA) for identifying key subjects in texts. Social network analysis then examines network data (e.g., emails, project collaboration) to identify experts, practice communities, and traffic patterns. Knowledge extraction and interpretation are then employed to extract relevant information for data analysts to interpret and discover patterns and algorithms to achieve organizational goals. The extracted knowledge is incorporated into existing systems like directories, teaching platforms, and knowledge bases, aligning them with organizational processes for production, sharing, and utilization. User input and organizational outcomes drive continuous improvement of methods and process mining, alongside ongoing monitoring of integrated KM-based solutions. This breakdown shows how data mining uses organizational data to generate valuable insights. The information is then integrated into knowledge management systems and processes to enhance knowledge utilization. Data mining methods and integration strategies are tailored based on observed outcomes, with continuous evaluation of the impact of these initiatives.

4. Discussion

There are problems associated with implementing modern data mining techniques in knowledge management. Three key issues have been noted: data quality, privacy and security, and ethics, as *Figure 7* shows a pictorial depiction of these problems. One of the biggest problems with data mining is the quality of the data used. Inaccurate results usually arise from mistakes, omissions, duplication, or inconsistencies in the data. Hence, the precision of the outcomes is influenced by completeness, correctness, and consistency. Furthermore, it can be difficult to fully comprehend the data if certain qualities or values are missing, which is known as incomplete data. Errors in data transmission, data storage, data integration, and data entry are only a few of the causes of problems with data quality. Improving the quality of data will go a long way in solving these challenges. Data quality must be improved using pre-treatment and cleaning techniques. Data pre-processing prepares the data for data mining, and data cleaning identifies and fixes flaws in the data.

Another major issue in data mining is data security and privacy. Having data that is private, sensitive, or confidential means that gathering, saving, and examining a large amount of such data increases the likelihood of data breaches and counterattacks. Organizations and data

mining professionals must inculcate data encryption and anonymization and also adhere to the stringent guidelines on the collection, use, and sharing of data that are enforced by data privacy laws, including the CCPA, GDPR, and HIPAA. Professionals have to use encryption methods to encode the data so that unauthorized users cannot access it, and also anonymize the data to delete personally identifiable information (PII) from the data. Data mining brings up ethical questions about data gathering, use, and sharing. The information could be used to reinforce pre-existing biases, breach private rights, or discriminate against particular groups. Furthermore, it may be difficult to identify biases or prejudice due to opaque data mining technologies. It is clear that skilled professionals who could use these methods successfully are needed (Witten et al., 2005). Furthermore, ethical considerations are important when it comes to security and privacy. Nevertheless, there are quite a good number of chances for more inventions and wider choices. It is more advantageous for companies with strong IT infrastructure and support networks to adopt these technologies, as ‘better-formed’ organizations are those with a data-controlled culture. Marwick (2001) noted the significance of technological infrastructure in knowledge management, emphasizing that the right technology can have a big impact on the flow of knowledge.

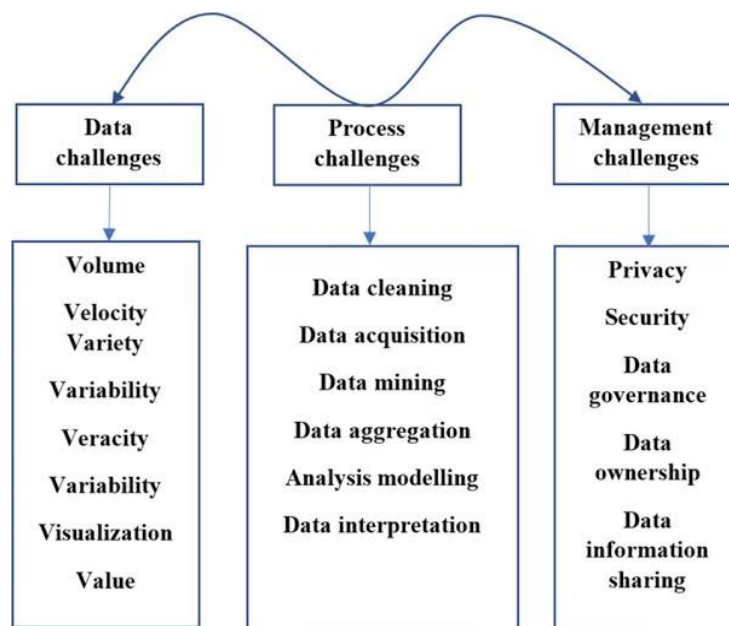


Figure 7. Challenges of data mining and its categorization.

Source: (ResearchGate, 2021).

The main objective of future research should be to incorporate standardized frameworks involving data mining into existing systems. Analyzing the ethical implications of advanced data mining in knowledge management, specifically concerning security and personal information, is paramount. Evaluating how recently developed technologies like deep learning and time-series databases affect knowledge management is also crucial. The long-term impacts of these technologies may be better understood through longitudinal research. As Domingos (2015) explains, the continuous efforts to improve machine learning algorithms are probably going to result in more advancements in knowledge management.

5. Summary

This study has demonstrated the revolutionary potential of advanced data mining techniques to improve knowledge management. The study found a strong link between knowledge management and advanced data mining techniques, showing potential for strategic integration changes. Basic methods identified include machine learning (ML), natural language processing (NLP), and social network analysis (SNA), with various applications in KM. According to the review's conclusions, data mining helps organizations move from static repositories to dynamic knowledge management systems. Making use of machine learning algorithms facilitates the effective extraction of patterns and insights from huge datasets. Intelligent knowledge organization is promoted by natural language processing (NLP), which automates classification, summarization, and semantic analysis. Social network analysis is crucial for tracking informal knowledge flow and identifying key expertise areas within a firm's human network. Notwithstanding the transformative potential, organizations must overcome challenges, including learning data science, handling ethical and privacy issues, cultivating a data-driven culture, and satisfying the need for high-quality data. According to Obi & Guminski (2024), organizational culture and IT infrastructure play a crucial role. Organizations have to place a core focus on implementing knowledge management-based systems and funding training initiatives to improve staff data literacy. To successfully deploy, adopting a data-driven culture is important, and ensuring that the data is of high quality is also crucial. Organizations can gain a competitive advantage by utilizing data mining to improve their KM strategies.

Benefits of applying Data Mining in Knowledge Management include:

Better Decision-Making: Organizations may make better judgments based on facts rather than gut feeling by revealing hidden patterns and linkages.

Improved Knowledge Discovery: Data mining methods can uncover best practices, insights, and knowledge that were previously undiscovered within the company.

Improved Knowledge Sharing: By recognizing knowledge links and dependencies, departments and teams may share knowledge more successfully.

Predictive Knowledge Management: Proactive knowledge management techniques can be made possible by anticipating knowledge gaps, resource allocation, and knowledge needs.

Personalized Knowledge Delivery: Knowledge access and utilization can be enhanced by customizing knowledge delivery to each user's needs.

Enhanced Efficiency: Time and resources can be saved by automating knowledge finding and management procedures.

This study demonstrates how sophisticated data mining transforms contemporary knowledge management and enables organizations to make efficient use of their intellectual property. Employing these strategies may provide organizations with a competitive edge, encourage innovation, improve work flexibility, and simplify operations. For knowledge management to be effective in the future, data must be used strategically.

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FROM RESPONSIBILITY TO RESILIENCE: HOW CSR SPARKS INNOVATION IN ORGANIZATIONS?

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Purpose: The study aims to identify the role of Corporate Social Responsibility (CSR) in fostering innovation and building organizational resilience. The rationale for research in this area stems from the limited number of academic studies that combine these three constructs.

Design/methodology/approach: The analysis of the issue was carried out based on a review of the literature on the subject, including both international and Polish sources.

Findings: This publication focuses on the links between CSR practices, innovation processes, and organizations' ability to adapt and survive in conditions of uncertainty.

Research limitations/implications: The study highlights the lack of universal definitions of CSR, innovation, and organizational resilience in the literature. Although each of these areas has been studied, relatively few studies examine their interconnections. This article attempts to discuss the relationship between CSR, innovation, and organizational resilience, identifying factors that may strengthen this relationship. It also presents examples of CSR practices that stimulate innovation processes and contribute to building organizational resilience, underlining the importance of a responsible approach to management.

Originality/value: The research in this matter is crucial because CSR increasingly serves not only as a tool for building reputation and trust. It is also treated as a catalyst for implementing innovative solutions within organizations, which leads to an increased ability to cope with crises. Implementing strategies based on social responsibility fosters a culture of continuous improvement, anticipating challenges, and responding flexibly and quickly to change. As a result, organizations can more effectively adapt to a dynamic environment, ensuring stability, competitive advantage, and long-term development.

Keywords: Organisational resilience, innovation, CSR-driven innovation, corporate social responsibility, CSR.

Category of the paper: Literature review.

1. Introduction

The challenges that modern organisations face and operate under include uncertainty, volatility, and increasing stakeholders pressure and expectations. The conventional method of managing an entity may not be enough in light of fast changing social expectations, climate change, and technology advancements. With this in mind, strategies that combine social responsibility with the implementation of innovative solutions that contribute to building organisational resilience are becoming increasingly important.

Corporate Social Responsibility (CSR) activities undertaken by modern entities not only shape and strengthen their reputation in the market in which they operate, but also build lasting trust among stakeholders. What is more, initiatives of this kind support innovation processes that influence adaptation and resilience to crises and unforeseen challenges that the organisation will have to face in the future. CSR takes into account social, environmental and ethical interests in the functioning of an entity. At the same time, it creates conditions for the development and implementation of innovative solutions. The integration of CSR with the implementation of innovation can strengthen organisational resilience. Entities can gain the ability to anticipate future threats, respond quickly to changes in the environment, and maintain a competitive advantage by cooperating with stakeholders and creating a culture based on responsibility.

The aim of this article is to examine the relationship between CSR, innovation implementation and organisational resilience. This analysis will allow to understand whether the actions taken by entities as part of corporate social responsibility can be considered as a factor stimulating the implementation of innovation and leading to the development of organisational responsibility, which is crucial in conditions of uncertainty and environmental change. The aim is pursued with the following research questions:

- How are the concepts of innovation, CSR-driven innovation, corporate social responsibility, and organizational resilience defined and interpreted in the literature?
- What is the role of corporate social responsibility in fostering innovation processes?
- How can CSR practices influence an organization's ability to adapt and survive under conditions of uncertainty?
- What are the conceptual connections between corporate social responsibility, innovation, and organizational resilience?

The questions are addressed through a literature review of international and Polish sources.

2. Methods

The literature review focused on determining the role of CSR in stimulating innovation and building organisational resilience. The review was based on a systematic literature review (Czakon, 2020), which aimed to identify the level of knowledge in the presented subject areas. As part of this method, basic literature on the subject was selected using databases such as Scopus and Web of Science.

The next step was to select publications, taking into account the following keywords: ‘innovation’, ‘CSR’ and ‘organisational resilience’. The list of publications was supplemented using the ‘snowball’ method. The criteria for selecting the literature were the language of the publication (Polish and English) and the time period of publication (2004-2024). As a result of this selection, a database of publications was developed. Bibliometric analysis techniques were also used, limiting the analysis to keywords, fields (business, management and accounting, and social sciences) and document type (articles, conference publications, books and book chapters).

Figure 1 presents an analysis of the number of publications from 2004 to 2024 on the construct of innovation, based on the Scopus and Web of Science databases.

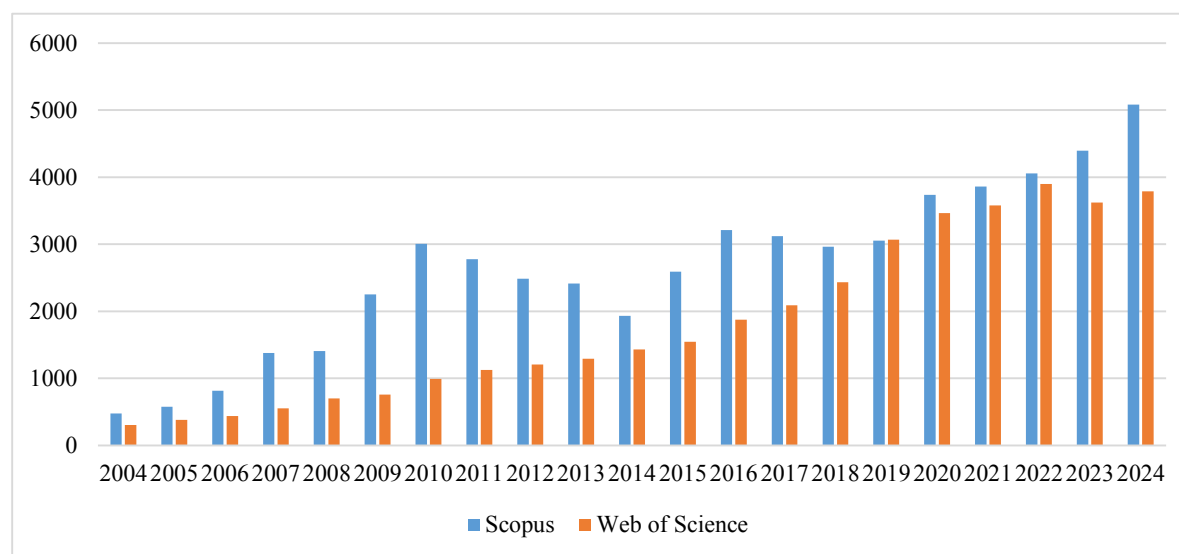


Figure 1. Number of publications on innovation from 2004 to 2024.

Source: Scopus and Web of Science databases.

Based on Figure 1, an upward trend in interest in innovation among researchers can be observed from 2004 to 2024. A steady upward trend can be observed in both databases, but the increase in publications varies from year to year. In the Scopus database, the number of publications in the field of innovation increased from 476 in 2004 to 5083 in 2024. This indicates a more than tenfold increase during the period analysed. The Web of Science database also recorded a significant increase, from 306 publications in 2004 to 3788 in 2024. It should be noted that between 2004 and 2010, the growth rate of publications was higher in

the Scopus database. In contrast, in the Web of Science database, the number of publications began to grow steadily from around 2012. This has led to a reduction in the difference between the databases. The largest increase in publications in the databases can be seen in the Scopus database in 2009-2010 and 2023-2024, while in the Web of Science it occurred in 2017-2020.

Figure 2 shows an analysis of the number of publications in the period 2004-2024 on the concept of CSR, based on the Scopus and Web of Science databases.

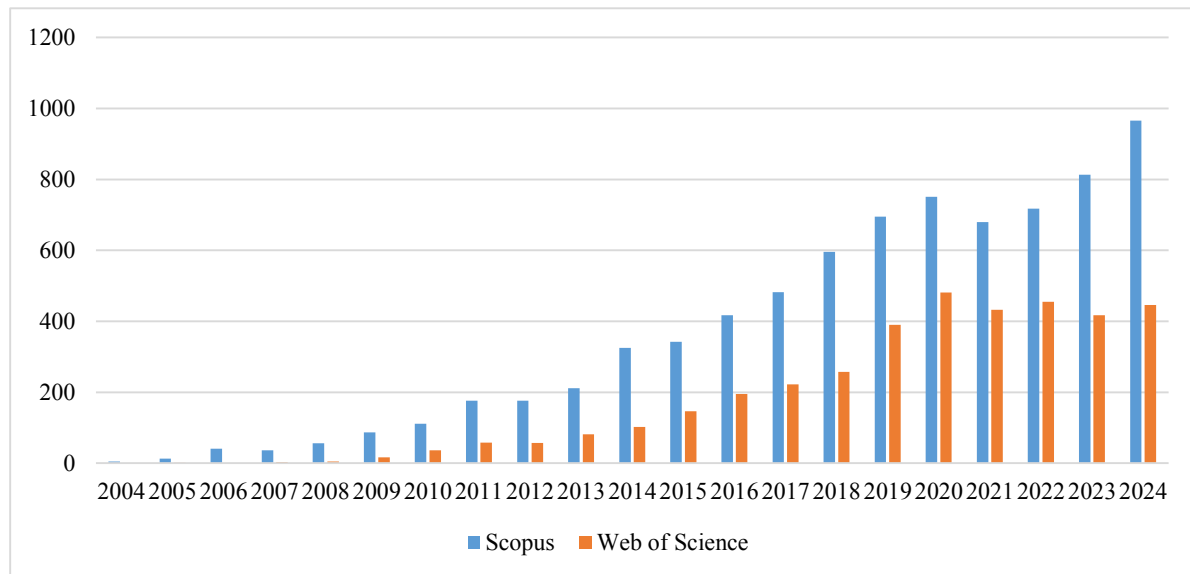


Figure 2. Number of publications on Corporate Social Responsibility from 2004 to 2024.

Source: Scopus and Web of Science databases.

Based on Figure 2, there is a clear increase in interest in the concept of corporate social responsibility among researchers. In the Scopus database, the number of publications rose from just 5 in 2004 to as many as 966 in 2024. A similar trend can be observed in the Web of Science database, although the initial number of publications was significantly lower. Initial interest in CSR can be observed in the years 2004-2007, when the increase in publications was quite slow. In the Scopus database, a significant increase in published works has been visible since 2009, with a clear interest in the period 2014-2020. The highest growth rate of publications in the Web of Science database occurred between 2015 and 2020, followed by a stabilisation of published studies between 2021 and 2024. Analysis of Figure 2 leads to the conclusion that CSR can be considered an increasingly important area of scientific research. This proves not only the growing interest in CSR, but also its importance in the activities undertaken by organisations and the role of this construct in their strategies.

Figure 3 shows an analysis of the number of publications in the period 2004-2024 on the organisational resilience, based on the Scopus and Web of Science databases.

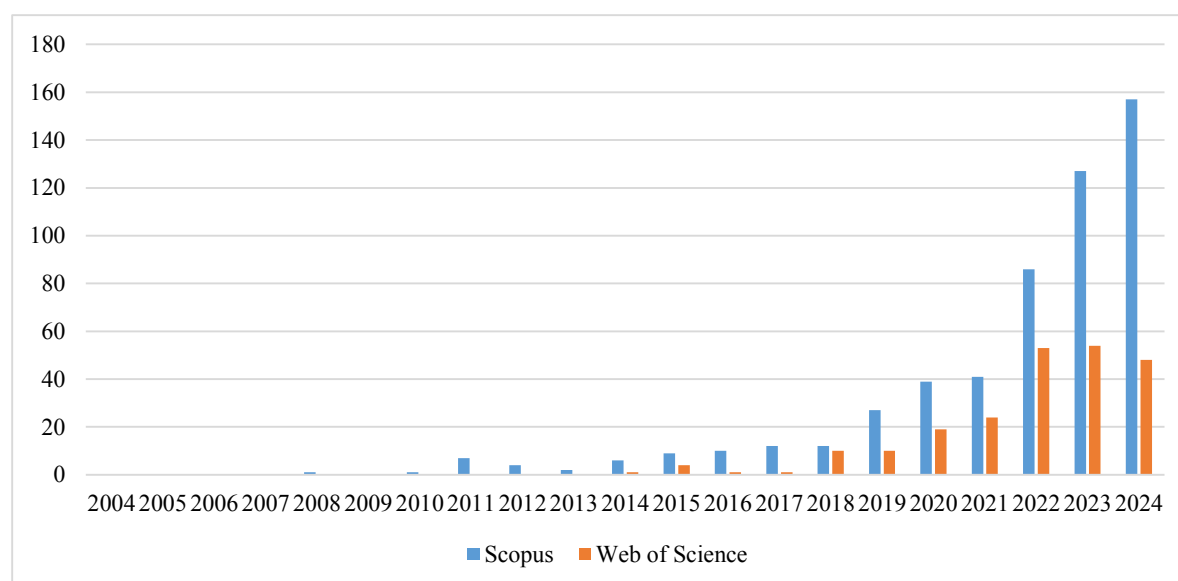


Figure 3. Number of publications on organisational resilience from 2004 to 2024.

Source: Scopus and Web of Science databases.

An analysis of the data presented in Figure 3 indicates that interest in organisational resilience among researchers, within the search criteria used, has grown in recent years. Based on an analysis of publications in the Scopus database, it can be concluded that the number of studies has increased significantly over the last decade. It should be noted that publications on this topic appear sporadically in the Web of Science database. It can be seen that the largest increase in the number of studies published in the Scopus database dates back to 2019-2024, and in the Web of Science database to 2018-2022. This indicates that organisational resilience is becoming an important area of scientific research. This is particularly important given the global uncertainty faced by economic entities and the associated need to adapt to change.

3. Results

3.1. Corporate Social Responsibility as a Strategic and Cultural Driver

Corporate Social Responsibility (CSR) has undergone a paradigmatic shift, evolving from a peripheral organizational function to a central determinant of strategic orientation and cultural foundation (Porter, Kramer, 2019). This transformation reflects the growing recognition that sustainable corporate performance is intrinsically linked to responsible business practices (Eccles et al., 2014). CSR has multidimensional nature and it is important in generating organizational capital (Fatima, Elbanna, 2022), and enhancing adaptive capabilities through improved stakeholder responsiveness (Du et al., 2023).

The conceptualization of CSR has progressed through distinct developmental phases, marking a clear transition from a peripheral, supplementary activity to a core strategic component. The Evolutionary Development commenced with philanthropic and ethical frameworks, where CSR represented discretionary charitable activities or moral obligations. This progressed toward strategic integration models, positioning CSR as instrumental for achieving competitive advantage through alignment with business objectives (Porter, Kramer, 2019). The contemporary perspective advances a transformative paradigm, wherein CSR becomes embedded within fundamental business models as a necessity for addressing systemic global challenges (Bocquet et al., 2023). This evolution directly informs the strategic dimension of CSR, which serves as a mechanism for proactive risk mitigation and opportunity identification. It necessitates comprehensive environmental scanning to anticipate regulatory shifts, supply chain vulnerabilities, and evolving market expectations toward sustainability (Eccles et al., 2014). This forward-looking approach enables organizations to minimize potential disruptions while accessing emerging markets for environmentally and socially preferable offerings (Nidumolu et al., 2009), with the fundamental strategic objective of dissociating economic growth from adverse socio-environmental impacts, thereby ensuring long-term viability (Khan et al., 2021).

Parallel to its strategic function, the normative dimension of CSR finds its foundation in stakeholder theory (Freeman, 2010), which asserts corporate accountability to all entities affected by organizational operations. This extends to principles of corporate citizenship, positioning corporations as societal actors with inherent responsibilities toward the public good. This ethical underpinning provides legitimate justification for CSR initiatives beyond purely instrumental rationales (Gillan et al., 2021). The practical convergence of these strategic and normative views is crystallized in the interconnection with ESG and sustainability. While CSR establishes the philosophical groundwork for corporate citizenship, Environmental, Social, and Governance (ESG) criteria provide a standardized framework for performance measurement and evaluation by investors and regulators (Brook, Oikonomou, 2018). Collectively, they operationalize the principles of sustainable development—satisfying present requirements without compromising future generational capacities (Brundtland Report, 1987). Thus, ESG constitutes the operational pathway through which corporations contribute to sustainable economic systems (Dong, 2023).

CSR functions as a critical source of intangible yet essential organizational assets that underpin long-term success. As an articulator of organizational values, CSR, when authentically institutionalized, translates ethical principles into a concrete organizational value system that guides managerial decision-making and operational conduct (Maon et al., 2017). This value infrastructure addresses fundamental questions of organizational purpose beyond profit maximization, actively shaping the firm's ethical climate (Simha, Cullen, 2012). For organizational members, this process cultivates a shared purpose and collective identity, which serve as powerful motivational drivers that enhance talent attraction and retention,

particularly among employees who prioritize social consciousness (De Roeck, Farooq, 2018; Glavas, 2016). The values solidified through CSR directly contribute to the Foundation of Organizational Legitimacy, which represents the generalized perception that organizational actions conform to socially constructed norms, values, and belief systems (Suchman, 1995). Through demonstrable commitments to social and environmental welfare, organizations establish pragmatic legitimacy (by providing stakeholder utility), moral legitimacy (through ethical conduct), and cognitive legitimacy (via institutional alignment) (Bitektine, 2011). Consequently, robust CSR implementation is a primary mechanism for securing and maintaining an essential social license to operate, a critical factor for ensuring long-term resource access and organizational survival (Fatima, Elbanna, 2022).

Furthermore, the legitimacy and value-system fostered by CSR act as a Catalyst for Relational Trust, which embodies the willingness to accept vulnerability based on positive expectations of another's behavior (Mayer et al., 1995). Through consistent, transparent, and ethically grounded interactions with diverse stakeholders, CSR generates relational trust, which acts as a protective buffer in organizational crises and enhances resilience.

A genuine commitment to CSR fundamentally enhances organizational capabilities for environmental adaptation and internal transformation by necessitating systematic stakeholder engagement processes (Greenwood, 2007). This ongoing dialogue functions as an advanced sensing mechanism, providing early detection of emerging social trends, potential conflicts, and evolving expectations (Du et al., 2023). Organizations proficient in stakeholder dialogue develop heightened dynamic capabilities for environmental scanning, enabling agile adaptation of products, policies, and processes in response to external changes (Mkonda, 2022).

The complex nature of CSR challenges organizational insularity by necessitating cross-sector collaboration with NGOs, government entities, and industry partners (Selsky, Parker, 2005; Sharma, Bansal, 2017). It breaks down internal silos and exposes organizational members to diverse perspectives and knowledge systems, fostering absorptive capacity—the ability to recognize, assimilate, and apply external knowledge (Bridoux, Stoelhorst, 2022). Internally, the pursuit of CSR objectives requires employee empowerment for sustainable innovation, fostering cultures of psychological safety where challenging established paradigms and proposing novel solutions becomes institutionalized (Edmondson, 2018). This cultural permeability establishes the necessary preconditions for organizational learning and adaptation that underpin sustained resilience (Williams et al., 2023). Essentially, a CSR-oriented culture functions as a learning organization, continuously evolving through interaction with its broader ecosystem (Hsu, Lamb, 2020).

In summary, CSR constitutes not an ancillary function but a pervasive influence that shapes strategic direction, defines cultural parameters, and generates essential intangible capital. By fostering cultural permeability and enhancing environmental responsiveness, CSR establishes the foundational conditions that initiate the causal sequence progressing through innovation toward organizational resilience.

3.2. CSR-Driven Innovation and Organizational Resilience

In the past, CSR could be treated by companies as limited solely to charitable activities or appropriate image management. Nowadays, CSR activities go beyond ensuring compliance with applicable laws. This concept can be seen as the main driver of organisational strategy and innovation. This is because the business models of entities focus on achieving competitive advantage and thereby creating long-term economic, social and environmental value for the entity. Therefore, it can be considered that they act as a catalyst for innovation processes (Zhou et al., 2020; Khan et al., 2021). This may be mainly related to the multidimensional challenges faced by modern organisations, which go beyond issues of competition or profitability.

Among these, particular mention should be made of challenges related to the environment and sustainable development (Carmeli et al., 2020; Weber, 2023; Mutua et al., 2025), social issues (Rashkova et al., 2023), ethical issues (Baker et al., 2006; Beeri et al., 2013) and market challenges (Kihlström, Elbe, 2021; Candelo, 2019). Technological changes are also extremely important (Wilson et al., 2020; Imran et al., 2022; Awad, Martín-Rojas, 2024; Sibassaha et al., 2025), cybersecurity threats (Sharif, Mohammed, 2022; Saeed et al., 2023) and organisational and cultural challenges (Yeo, Ajam, 2010; Dong, 2023; Elliott et al., 2023). The uncertainty associated with global crises should also not be forgotten (Mukherjee, D., Mukherjee, D., 2021; Islam, 2023; Newman et al., 2023). Therefore, stakeholder expectations of modern organisations go beyond the provision of products or services or the generation of profits. Stakeholders expect these organisations to take action to balance their profits with social, environmental and ethical outcomes (Axjonow et al., 2018; Fatima, Elbanna, 2022; Awa et al., 2024).

Therefore, it is extremely important to properly manage innovation processes aimed at implementing new or significant changes in the products or processes currently offered by a given organisation (Taylor, 2017; Singh, Aggarwal, 2021; Kochetkov, 2023). It should be emphasised that no universal definition of innovation has yet been developed in the literature on the subject, as this construct is treated very broadly by researchers (Kamiński, 2018; Matysik, 2024). This is mainly due to the fact that various sciences have had a significant influence on the development of this concept. Due to the difficulties associated with clearly defining innovation, researchers distinguish between many types of innovation in the literature. Among the most commonly used typologies in research, the one presented in the Oslo Manual 2018, which takes into account product and business process innovation, should be highlighted (Oslo Manual, 2018). Innovations introduced by organisations are not only about achieving competitive advantage or efficiency. By implementing such solutions, entities seek to secure legitimacy in their social and regulatory environment (DiMaggio, Powell, 1983). It should be emphasised that interest in this construct and the popularity of implementing innovation is constantly growing, as new or improved solutions can be applied in any field.

In the context of stimulating innovation through CSR activities in organisations, in addition to the approximate expectations of stakeholders, regulatory pressure and cross-sector cooperation are also important (Sharma, Bansal, 2017). In this area, trust between partners in cross-sector cooperation, which is considered a constantly evolving feature of every organisation (Malewska, 2010), is extremely valuable. Therefore, it can take on a variety of values (Wicks et al., 1999). Cross-sector cooperation can leverage the unique characteristics that are the strengths of each sector. The private sector can be associated with resources that enable the implementation of innovative solutions (Cankar, Petkovsek, 2013; Hooli, 2021). In turn, cooperation with third sector organisations allows for familiarisation with social needs and expectations, as these entities are characterised by determination in achieving their goals (Teneta-Skwiercz, 2016). The public sector, on the other hand, mainly refers to regulatory and decision-making powers (Wojciechowski, 2007; Kargol-Wasiluk, 2011; Raczyńska, Krukowski, 2020). M. Blowfield and A. Murray (2011) point out that cross-sector cooperation undertaken as part of CSR initiatives promotes greater effectiveness and sustainability of implemented projects. It also increases their scale and overall impact (Blowfield, Murray, 2011). Furthermore, management based on cooperation leading to the achievement of common goals is essential in ensuring stakeholder satisfaction, which leads to long-term success (Fonseca et al., 2016; Maqbool et al., 2020; Derakhshan, Turner, 2022).

The term ‘CSR-driven innovation’ is commonly used in the literature on this subject. It refers to innovations that arise from activities undertaken as part of corporate social responsibility, combining economic goals with social and environmental needs. Table 1 presents selected definitions of CSR-driven innovation.

Table 1.
Selected definitions of CSR-driven innovation

Author/Authors (year)	Definition
A. Little (2006)	Taking into account social, environmental or sustainability aspects in order to create new working methods, new products and services, and processes that enable new international markets to be tapped.
C.B. School et al. (2008)	An innovative process aimed at designing a profitable product or service in an innovative and user-oriented manner that will benefit the environment and society.
S.P. MacGregor, J. Fontrodona (2008)	Creating products and services with a specific social purpose. They are driven by values related to the creation of social products and services.
Nordic Innovation Centre (2010)	An innovative process aimed at designing a profitable product or service that, in an innovative and user-oriented way, can prove beneficial to the surrounding environment and society.

Source: Own study.

Based on the definitions presented in Table 1, it can be concluded that the essence of CSR-driven innovation is primarily a combination of economic and socio-environmental goals. These innovations combine the profitability and competitiveness of an organisation with concern for society and the natural environment. Another feature that can be attributed to

CSR-driven innovation based on the definitions presented is its focus on users and stakeholder needs. The innovations implemented are designed to meet the needs of the community, rather than just drawing attention to technological improvements. Furthermore, social and environmental values can be treated as a source and driving force for innovation aimed at developing new and improving existing products, services and processes. CSR-driven innovation is a process embedded in an organisation's strategy, rather than individual actions in this area. This process not only enables the implementation of innovative solutions, but also the acquisition of new markets and the building of competitive advantage.

It should also be emphasised that CSR-driven innovation leads to strengthening the resilience of organisations in terms of survival and development in a changing environment. Entities that implement CSR-driven innovation in the form of, for example, environmentally friendly products and processes can build their reputation on the market. In crisis situations, this can result in greater support from customers, investors and the local community (Ortiz-de-Mandojana, Bansal, 2015). CSR-driven innovation, which relates to social responsibility and sustainable development, leads to an increase in an entity's adaptability (Klewitz, Hansen, 2013). CSR-driven innovation can also promote long-term responsiveness through early risk identification (Teece et al., 2016). It can therefore be concluded that CSR and innovation can create a synergy effect, in which social responsibility acts as an initiator of innovation creation and implementation, and innovation forms the foundation of organisational resilience (Wereda, Jończyk, 2020).

The analysis of the literature on the subject leads to the conclusion that CSR-driven innovation can be considered the foundation of long-term organisational resilience. Table 2 presents selected definitions of organisational resilience.

Table 2.
Selected definitions of organisational resilience

Author/Authors (year)	Definition
D.L. Coutu (2002)	Ability to respond to pressure conditions or changes.
United Nations (2007)	The ability of a system or society that is exposed to a threat to adapt to a new situation through resistance or by introducing changes in order to maintain an acceptable level of functioning.
N. Ortiz-de-Mandojana, P. Bansal (2015)	The company's ability to detect and correct abnormal trends and deal positively with unexpected situations.
L. Xiao, H. Cao (2017)	The ability of an organisation to restore its original state or even develop new skills in disruptive conditions.
A. Williams et al. (2017)	The process by which an individual, organisation or community builds and utilises its capacity to interact with its environment in a way that positively adapts and sustains functioning before, during and after adversity.
S. Duchek (2020)	The organisation's ability to anticipate potential threats, effectively deal with adverse events and adapt to changing conditions.
Organisational Resilience: Good Practice Guide (2024)	Key to adapting to a changing global marketplace and coping with short-term disruptions such as natural disasters, cyber-attacks, physical threats or supply chain issues.
R.K. Dickson (2025)	The ability of an organisation to anticipate, respond to, cope with and adapt to difficulties while maintaining its core functions and achieving its long-term goals.

Source: Own study.

Based on an analysis of the definitions presented in Table 2, it can be concluded that organisational resilience, due to its interdisciplinary nature, can be analysed in various contexts and at various levels (Linnenluecke, 2015). Although the issue of organisational resilience has been the subject of interest among researchers in recent years, no universal definition of this concept has been developed in the literature (Duchek, 2020). This may be due to the complexity of the term and the different factors influencing its interpretation by different authors (Linnenluecke et al., 2011). Based on the definitions presented in Table 2, it should be emphasised that organisational resilience is not limited to returning to the state prior to the disruption. It also includes the ability to develop and learn in the face of challenges faced by the entity. Moreover, resilience is not only a response to crises, but also the ability to identify warning signs. This allows for risk analysis and adequate preparation for potential threats. Organisational resilience is therefore not a one-off activity. It is a process that enables the continuous development of competencies, processes and mechanisms.

In summary, implementing innovation, taking into account CSR-driven innovation and properly managing innovation processes is extremely important in building organisational resilience. This increases an entity's ability to adapt to changing conditions and its operational flexibility.

3.3. CSR as a Catalyst for Innovation and Resilience – case studies

Empirical evidence from leading global companies strongly reinforces the theoretical connection between CSR, innovation, and organizational resilience, demonstrating a universal and applicable virtuous cycle. In this cycle, CSR commitments introduce new constraints and reveal unmet stakeholder expectations, which act as key drivers for innovation across products, processes, and business models. The resulting innovations, as illustrated by the following case studies from diverse industries, generate fresh value offerings and operational approaches that directly strengthen an organization's capacity to anticipate, endure, and adapt to disruptions, thereby building robust resilience (Ortiz-de-Mandojana, Bansal, 2015; Duchek, 2020).

Table 3.

Case studies of CSR-driven innovation and organizational resilience

Company (HQ)	CSR Initiative / Challenge	Innovation Developed	Resilience Outcome
Patagonia (USA)	A key challenge was waste from its own products and the broader apparel industry (Schillmann, 2020).	A dedicated platform for repairing, re-selling, and recycling Patagonia garments – the Worn Wear program (Patagonia, 2023). Patagonia also has developed a unique supply chain for recycled materials, including turning plastic bottles into polyester for fleece and using recycled nylon and cotton (Denkes, 2020).	Built a fiercely loyal customer base and a distinctive, authentic brand identity immune to fast-fashion competition (White et al., 2019). It provides a stable demand even during economic downturns. The circular economy model mitigates long-term risks from virgin material price volatility and supply chain disruptions, future-proofing the business (Bocken et al, 2021).

Cont. table 3.

Unilever (UK/Netherlands)	The Unilever Sustainable Living Plan (USLP), launched in 2010, aimed to decouple growth from environmental impact by halving the footprint of its products while improving health and well-being for millions (Unilever, 2021).	Developed concentrated laundry detergents (e.g., Persil Small & Mighty) that require less water, packaging, and energy for transportation. Created water-efficient products like dry shampoo (Unilever, 2022).	By 2020, Unilever's 'Sustainable Living Brands' were growing 69% faster than the rest of the business (Unilever, 2022). This portfolio future-proofed the company against water scarcity regulations and consumer shifts towards eco-friendly products, ensuring market relevance and growth (Eccles, 2014).
Ørsted (Denmark)	Radical transformation from a fossil-fuel-intensive energy company to a renewable energy leader, driven by the ethical imperative to combat climate change (Ørsted, 2022).	Transformed its core business model from fossil fuels to renewable energy, pioneering the commercial-scale development of offshore wind power. This included significant innovations in turbine foundation design and the development of advanced commissioning vessels, which were critical to scaling the technology efficiently and reducing costs (Ørsted, 2022). The company has also been a leader in integrating biodiversity protection into project planning, such as creating artificial reef structures around wind farm foundations to enhance marine ecosystems (Ørsted, 2024).	Successfully navigated the global energy transition. From deriving 85% of its energy from fossil fuels in 2009, it now generates over 90% from renewables (Ørsted, 2022). This pivot shielded it from stranded asset risks and price volatility in fossil fuels.
Tesla, Inc. (USA)	The challenge was making electric vehicles (EVs) desirable and practical, overcoming range anxiety and high costs (Mangram, 2012).	Revolutionized EV battery technology, performance, and software (Over-the-Air updates). Built a proprietary, global Supercharger network to solve the charging infrastructure problem (Kley et al, 2011).	Created an insurmountable technological and infrastructural moat. Dominates the EV market, making it highly resilient to fossil fuel price crises and stringent emission regulations. Its direct-to-consumer sales model also proved resilient during pandemic-related dealership closures (Yang, 2023).
Nike (USA)	"Move to Zero" initiative aiming for zero carbon and zero waste to combat the apparel industry's significant environmental footprint (ThisRock inc, 2024).	Created Nike Grind, a program that recycles old shoes and manufacturing scrap into new products. Developed Flyknit technology, which reduces material waste by an estimated 60% compared to traditional cut-and-sew methods (Nike, Inc., 2025).	Mitigates significant reputational risks related to labor and environmental practices. Secures a sustainable, circular material supply, reducing dependency on virgin materials and insulating against future resource scarcity and cost inflation (Lund-Thomsen et al., 2014).

Source: Own study.

The case studies presented in Table 3 collectively demonstrate a consistent pattern wherein CSR objectives stimulate innovation that directly contributes to organizational resilience. Several key insights emerge from this analysis revealing the mechanisms through which this transformation occurs.

A primary insight is that the nature of innovation varies according to industry context and CSR challenge, yet consistently addresses core vulnerabilities. Patagonia and Nike, operating in the resource-intensive apparel industry, focused on circular economy innovations (Bocken et al., 2021) through their Worn Wear and Nike Grind programs. These initiatives not only reduce environmental impact but also build operational resilience by mitigating dependence on volatile virgin material markets and creating alternative revenue streams. Similarly, Ørsted's business model innovation, transitioning from fossil fuels to renewable energy, directly addresses strategic vulnerability to climate regulations and fossil fuel price fluctuations, future-proofing the company against energy transition risks (Ørsted, 2022).

Furthermore, the resilience outcomes manifest across multiple dimensions simultaneously. Each case shows that CSR-driven innovation builds resilience in an integrated manner. For instance, Tesla's technological innovations created not only competitive resilience through its technological moat but also supply chain resilience by vertically integrating critical charging infrastructure (Kley et al., 2011). Unilever's product innovations simultaneously achieve market resilience through growth in sustainable brands and regulatory resilience by preemptively addressing water scarcity concerns (Eccles et al., 2014). This multidimensional resilience reflects the comprehensive nature of the capabilities developed through CSR-oriented innovative processes.

The pathway from CSR commitment to tangible resilience is characterized by strategic, long-term orientation. The transformations undertaken by Ørsted and Unilever were not quick initiatives but sustained multi-year strategic investments. This extended timeline supports the theoretical proposition that resilience is an emergent outcome of deeply embedded sustainable practices, accruing over time as innovations mature and their cumulative impact is realized (Ortiz-de-Mandojana, Bansal, 2016). Ultimately, these cases powerfully challenge the perceived trade-off between corporate responsibility and competitiveness. They illustrate that CSR-imposed constraints can act as powerful catalysts for innovation, simultaneously generating environmental and social value while building business resilience. By reframing challenges like waste reduction and carbon neutrality as opportunities for value creation, these organizations have turned potential limitations into sources of durable competitive advantage.

In conclusion, these case studies provide empirical evidence that strategically embedded CSR serves as a powerful driver of innovation that builds organizational resilience. They illustrate the theoretical pathway from responsibility to innovation to resilience in practice, showing how companies can convert social and environmental challenges into business opportunities while enhancing their long-term viability in an uncertain world.

4. Discussion

The interplay between CSR, innovation, and organizational resilience can be conceptualized as a logical, causal pathway where each construct enables the next. The sequence ‘Responsibility → Innovation → Resilience’ illustrates that CSR provides the motivational and strategic context stimulating innovation, which then serves as the vehicle through which organizations build the adaptive capacities that constitute resilience (Ortiz-de-Mandojana, Bansal, 2016).

The causal pathway from responsibility to resilience is initiated by CSR as the starting point, which establishes the foundational intentions and cultural context for organizational action (Aguilera et al., 2004). A genuine commitment to social and environmental goals creates a unique set of constraints and challenges. Rather than being perceived as limitations, these challenges, driven by stakeholder expectations and strategic CSR objectives, act as a powerful stimulus for creativity and problem-solving (Nidumolu et al., 2009; Bocken, Geradts, 2019). This ‘CSR-driven’ mindset fosters a culture of openness, where exploring novel solutions to complex socio-business problems becomes institutionalized (Edmondson, 2018; Wu et al., 2021).

The cultural and intentional foundation provided by CSR directly fuels innovation as the mechanism. To meet its responsible objectives, an organization is compelled to develop new dynamic capabilities for learning and resource reconfiguration (Teece, 2022). This necessity leads to tangible innovative outputs across multiple domains, including:

- product innovation, which involves developing goods with reduced environmental impact in response to stakeholder pressures (Varadarajan, 2015),
- process innovation, entailing the creation of more efficient, less wasteful manufacturing methods to achieve circular economy goals (De Marchi, 2012), and
- business model innovation, which involves designing entirely new value creation and delivery systems that embed sustainability at their core (Lüdeke-Freund et al., 2022).

This constitutes CSR-driven innovation directed by a purpose beyond profit, which often leads to more disruptive and sustainable market solutions (Hansen et al., 2009; Boons, Lüdeke-Freund, 2013).

The cumulative effect of these innovation mechanisms culminates in resilience as the emergent effect. The generated innovations represent more than new market offerings. They are manifestations of enhanced organizational capabilities that collectively build resilience. These outcomes manifest in several dimensions:

- operational resilience is achieved through efficient processes and circular models that reduce dependency on scarce resources and mitigate supply chain disruptions (Ivanov, 2023; Geissdoerfer et al., 2017),

- financial resilience stems from diversified revenue streams and strong brand loyalty that provide a buffer during economic volatility (Albuquerque et al., 2020; Eccles et al., 2014),
- reputational resilience is built through a track record of responsibility that creates a reservoir of goodwill and trust, offering protection during crises (Bundy, Pfarrer, 2015),
- adaptive resilience is enabled by the dynamic capabilities developed through continuous, purpose-driven innovation, allowing the organization to anticipate and shape its environment more effectively than competitors (Teece et al., 2016).

In conclusion, CSR provides the "why", in terms of the motivating purpose and cultural foundation. Innovation is the "how", treated as the transformative process that addresses this purpose. Finally, resilience is the "what", so the resulting organizational state of robustness and adaptability that ensures long-term survival and success in a volatile world (Ortiz-de-Mandojana, Bansal, 2015; Duchek, 2020). This causal linkage underscores that building resilience is not an isolated goal but the ultimate benefit of strategically embedding social responsibility into the heart of an organization's innovation activities.

5. Conclusion

Current research indicate the existence of a relationship between Corporate Social Responsibility (CSR), the emergence and implementation of innovation, and organizational resilience. CSR has evolved from marginal philanthropic activities to the role of a strategic pillar of competitive advantage. When its principles are permanently embedded in strategy and organizational culture, it becomes a driver of CSR-driven innovation (Carrol et al., 2010; Porter et al., 2019). Activities undertaken in this area relate to the development of new products, processes, and business models that respond to social and environmental challenges. At the same time, they constitute the foundation for building long-term organizational resilience (Teece et al., 20216).

Enterprises engaged in CSR activities perceive social and environmental requirements not as constraints but as stimuli for implementing innovative solutions (Nidumolu et al., 2009; Hansen et al., 2009). Product innovations involve creating sustainable solutions, opening up new market opportunities (Varadarajan, 2017). Process innovations focus on implementing efficient technologies and closed supply chains that reduce waste and lower costs (Ortiz-de-Mandojana et al., 2015). Business model innovations, in turn, consist of designing new ways of creating and capturing value (Lüdeke-Freund et al., 2018).

The result of these activities is the strengthening of organizational resilience. CSR initiatives contribute to reducing operational and financial risk by limiting dependence on rare or unstable resources, thereby minimizing threats related to supply chain disruptions and price fluctuations (Ortiz-de-Mandojana, Bansal, 2015). Moreover, they enable the building of reputation and customer loyalty by creating an ethical brand image, which enhances attractiveness even under crisis conditions (Luchs et al., 2010). They also allow for securing regulatory compliance, as a proactive approach to environmental and social regulations helps avoid costly compliance issues and provides a first-mover advantage (Sharma, Bansal, 2017).

CSR strategies also support revenue diversification and the development of new markets by providing access to socially conscious consumers and ESG-oriented investors. In addition, they foster revenue generation from circular economy models, which increases financial stability (Khan et al., 2021). This study shows that the integration of CSR with key business processes promotes innovation and organizational resilience. In practice, this means that managers should treat CSR as a strategic tool rather than merely a reputational exercise. For organizational leaders, it is crucial to promote authentic values and create an environment that fosters experimentation. From an academic perspective, the results open the space for further research on causal mechanisms and the standardization of organizational resilience measurement.

The analysis presented in this article leads to the conclusion that the integration of CSR with a company's core strategy not only promotes responsible business practices but also stimulates innovations that enhance adaptability and organizational resilience. By developing dynamic capabilities, building stakeholder trust, anticipating risks, and improving operational efficiency, CSR transforms into both a protective mechanism and a growth engine, ensuring long-term competitiveness for enterprises in an environment characterized by volatility and uncertainty.

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LEAN GAMIFICATION AS A LEVERAGE FOR INNOVATIVE ORGANIZATIONS

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Purpose: The paper aims at investigating the issue of low engagement and innovativeness within organizations. It introduces the lean gamification concept and investigates its impact on innovativeness and employees engagement.

Design/methodology/approach: In order to achieve the research objectives a literature review is conducted followed by a case study of real life implementation of lean gamification.

Findings: Lean gamification can be an effective method of increasing innovativeness within organizations. A successful application of this concept can be achieved by following the POMPA model (Problem, Offtakers, Mechanics, Pilot, Adjustments).

Research limitations/implications: In order to confirm presented findings it is recommended to conduct bigger number of case studies of lean gamification application.

Practical implications: The research has a big impact on business by introducing a new concept, which can be leveraged to increase employees engagement and innovativeness within organizations.

Originality/value: The paper expands the theoretical knowledge in terms of social sciences by combining two popular concepts – lean management and gamification, consequently creating a new concept of lean gamification. The article introduces also a standardized method of the lean gamification application through the POMPA model.

Keywords: lean management, gamification, innovation, continuous improvement.

Category of the paper: Research paper.

1. Introduction

Game elements accompany us today in almost every aspect of life. They are so widespread and embedded in our everyday reality that we often fail to notice them, treating them as a natural part of the environment in which we function. When we go shopping, we collect points for our purchases, we receive badges and rewards for our physical activities, even in an area that might seem inherently serious-personal finance-we are encouraged to achieve our savings goals by game-typical progress bars and rankings.

The concept of using game elements in a context unrelated to games is called gamification, and is one of the fastest-growing management trends of the twenty-first century. Its popularity is hardly surprising. Companies use it to strengthen customer engagement, increasing loyalty and attachment to the brand. Thus far, it's the end users of goods and services that have been primary recipients of gamification solutions.

What, however, about applying game-like elements inside, rather than outside, the organization? Can gamification be equally effective in building corporate innovativeness by enhancing employees' capacity to generate new and creative solutions? Numerous studies indicate that it may be the case.

According to a survey conducted by the TalentLMS portal in 2019, 89% of American employees stated, that gamification makes them feel more productive, while 87% reported that they are more engaged in their tasks when game elements are applied. Additionally, 88% of respondents confirmed that using gamification simply makes them feel happier at work.

In traditional business environments, we have long been accustomed to a clear separation between entertainment and professional duties. Yet everything suggests that, along with generational changes in the labor market, the habits and practices prevailing in the office or on the shop floor will also evolve. Referring to data from the United States-which may be representative for most developed countries – 70% of people under the age of 18 play video games regularly and as many as 74% of teachers use digital game elements in their classroom practice. Today's youth are therefore accustomed to gamification being incorporated into their daily activities and there is a high likelihood that this habit will carry over into their adult working lives.

Given clear market trends and proven effectiveness of gamification, a wider spread of game elements in organizational management is only a matter of time. It is reinforced by the fact that gamification helps addressing one of the biggest challenges, which contemporary enterprises are facing -low employee engagement. Referring now to data from the Polish market, according to a 2022 study by ARC Rynek i Opinia, as many as 40% of individuals aged 18-24 and 44% of those aged 24–34, feel bored with their current tasks at work. Low motivation for proactive behaviors is also evident; for example, only 29.2% of employees reported submitting improvement suggestions in 2021 studies.

Companies dealing with the above-mentioned problems often lack an appropriate “toolbox” to address them effectively. Many members of managerial staff-despite sincere intentions-do not know how to encourage their employees to be proactive, innovative, or engaged in the innovation and improvements of their processes.

An answer to such challenges can be found in a new idea called lean gamification, which combines two leading contemporary management concepts: the gamification and lean management-a philosophy derived from the Toyota Production System that strives to maximize value added for the customer while simultaneously minimizing waste in processes.

Their synthesis-lean gamification-is a concept which is using game techniques and elements to support the application of lean management principles and to build a culture of continuous improvement and innovation within organizations.

The purpose of this article is to characterize the concept of lean gamification and to present possibilities for its use in the context of building innovativeness in organizations. To achieve this objective, the paper is structured in three parts. The first presents the origins of gamification and its theoretical foundations, drawing on the evolution of psychology and motivation science. The second characterizes the concept of lean gamification together with a description of the POMPA model, which indicates a sequenced pathway for implementing gamified solutions. Finally, the third part presents a case study of using lean gamification in a project to implement an employee suggestion system, thereby increasing an organization's ability to identify and implement innovations rapidly and to respond to changes in a dynamic business environment.

2. Gamification

Games have accompanied humanity since the dawn of history. From an anthropological perspective, they have been not only forms of entertainment but also important components of culture and community, exerting a profound influence on human development and social structures. They have also provided a space for learning the principles of cooperation, competition, and social hierarchy. Beginning with unstructured play within small, isolated hunter-gatherer groups, the practices gradually acquired more defined rules and standards with the Neolithic revolution, slowly resembling the games familiar to us today.

Despite the extensive history and significance of games in human affairs, their use for many years was largely confined to social and recreational aspects. The forms of play naturally differed across social classes and age groups; however, regardless of the form, games most commonly occurred in the context of leisure and fun. This state of affairs was changed only by the Industrial Revolution and the accompanying development of theories in psychology and motivation. Recognition of potential of games within the behavioral sciences was not immediate, as the earliest leading concepts in this field prioritized external motivators over the internal factors, which are typical to games. This applies primarily to two theories: Maslow's Hierarchy of Needs and, as part of Taylorism, the so-called "carrot-and-stick" method.

Despite initial domination of theories emphasizing external motivators, interest in other engagement factors, not necessarily related to rewards or punishment, grew within the scientific community over time.

The first breakthrough in this area was the research conducted by the American professor at the University of Wisconsin, Harry F. Harlow. In 1949, he launched an experiment on a group of eight monkeys concerning knowledge acquisition and learning. He used a simple

puzzle-like toy placed in the animals' cage. To the researchers' surprise, the animals immediately began to engage with the object with visible enthusiasm and joy, achieving very good solution times—all without any rewards. Such behavior contradicted the prevailing theories of primate motivation (including humans), which emphasized only two determinants: biological drives and external motivators (rewards and punishments). Based on his findings, Harlow identified a third factor, which he called intrinsic motivation, grounded in the joy of performing the task itself. Interestingly, when the researchers repeated the study, this time rewarding the monkeys for correctly solving the puzzle, the animals became more distracted and made more errors (Kopertyńska, 2009).

Similar conclusions were reached in 1969 by Edward Deci, who, seeking inspiration for his doctoral work, replicated Harlow's experiment—this time with humans. His findings indicated that external incentives, such as monetary or material rewards, motivate only in a short and limited scope and, when used over longer periods, may even lead to a decline in engagement. Continued research in this area led Deci, together with his former student Richard Ryan, to develop in 1985 the self-determination theory (SDT), which became one of the foundations of modern concepts of motivation. Their theory posits that people are most motivated and engaged when their actions satisfy three basic psychological needs: competence, autonomy, and relatedness. SDT suggests that intrinsic motivation is stronger and more enduring than extrinsic motivation; people perform most effectively when they feel in control of their actions, are competent in carrying them out, and have a sense of social belonging (Kopertyńska, 2009).

The final conclusion of the shift in motivation science from external to internal factors is Daniel Pink's concept of the Motivation 3.0. Presented in his 2009 book *Drive: The Surprising Truth About What Motivates Us*, this concept argues that traditional motivational methods (Motivation 2.0), such as rewards and punishments, are ineffective for tasks requiring creative thinking and problem-solving. Similar to Deci and Ryan, Pink identifies three fundamental elements that motivate people in the modern world: autonomy, mastery, and purpose. The theory suggests that providing people with greater control over their work, opportunities to develop skills, and participation in activities serving a higher purpose can lead to much better motivation and performance.

The above-described evolution of theories in psychology and motivation indicates a gradual decline in the significance of external motivational stimuli based on the traditional “carrot-and-stick” principle. In their place, internal drivers have become key—those based on setting well-designed goals, ensuring conditions conducive to collaboration, and enabling individual decision-making and independence. This evolution led researchers and management practitioners to recognize the potential of using game elements as a method of engaging both employees and the recipients of the products and services they create.

The earliest attempts to use simplified gamified solutions occurred in the 1970s and 1980s in the form of numerous loyalty programs, marketing campaigns, as well as training simulations and games. One of the pioneers in employing game elements is considered to be American

Airlines, which in 1981, as the first airline, launched its own loyalty program, AAdvantage, allowing passengers to collect points for miles flown (Christians, 2018). The effectiveness of such programs-leading to the attainment of increasingly prestigious tiers and privileges with accumulated distance.

Despite the gradually growing popularity of game elements in business contexts, the term “gamification” gained prominence only at the beginning of the twenty-first century. One of the originators is considered to be game designer Nick Pelling, who coined and popularized the English word gamification while developing game-based interfaces for ATMs and beverage machines (Kapp, 2012).

As a formal concept, gamification began to be widely discussed and examined in academic circles toward the end of the first decade of the twenty-first century. In 2008, Deterding, Dixon, Khaled, and Nacke published an article containing a definition of gamification, and a year later Byron Reeves and J. Leighton Read released the book *Total Engagement: Using Games and Virtual Worlds to Change the Way People Work and Businesses Compete*, in which they elaborated the concept. However, it was Daniel H. Pink’s aforementioned 2009 book *Drive: The Surprising Truth About What Motivates Us* that garnered greater attention from the scientific and business communities by linking gamification with Motivation 3.0.

Over the years, gamification has gained popularity as a business, educational, and social tool. Today, more and more companies employ game elements both with respect to their customers-embedding them in offered products and services-and to influence the motivation and engagement of their employees (Czerska, 2017).

The most common areas of application currently include (Werbach, Hunter, 2012):

- Marketing – brands and companies use gamification in advertising campaigns and loyalty programs. Elements such as contests, challenges, and points increase customer engagement and build stronger relationships with the brand.
- Innovation and product development – programs and applications incorporating games that encourage collaboration, innovativeness, team-based problem solving, and idea generation.
- Social behaviors – in some cities, gamification is used to promote pro-environmental behaviors, such as waste separation or the use of public transport, through point systems and rewards.
- Social networks – platforms use gamification to increase user activity, e.g., by introducing voting functions, activity badges, or ranking systems.
- Education and training – game-characteristic elements such as scoring, challenges, or difficulty levels are increasingly used in schools and training institutions. As a result, students and employees are more motivated to achieve educational goals, and materials become more accessible and engaging.

What, then, is gamification in essence? Being a relatively new idea in both business and academia, there is currently no single binding definition. Nevertheless, across existing descriptions, a set of common elements can be observed that point to three fundamental characteristics of gamification (Deterding et al., 2011):

- the use game-like elements and mechanisms,
- operation in a context not related to games,
- the pursuit of increased user motivation and engagement.

For an initiative to qualify as gamification in its full sense, all three of the above elements must be present. This is particularly important because, with rising popularity, the use of the term has become visibly “elastic”. Many companies or individuals familiar with gamification only superficially, label as such any program, training, or product with even a semblance of rankings, points, or levels. This is not a proper approach, since, as noted above, merely introducing game elements represents only one of the three essential characteristics of the concept.

A similar distinction is employed by Brian Burke in his book *Gamify: How Gamification Motivates People to Do Extraordinary Things*. He indicates a division in the use of game elements depending on the objective we wish to achieve (Figure 1). In doing so, the author emphasizes that the primary aim of gamification is not fun, but building of sustained emotional engagement among participants.

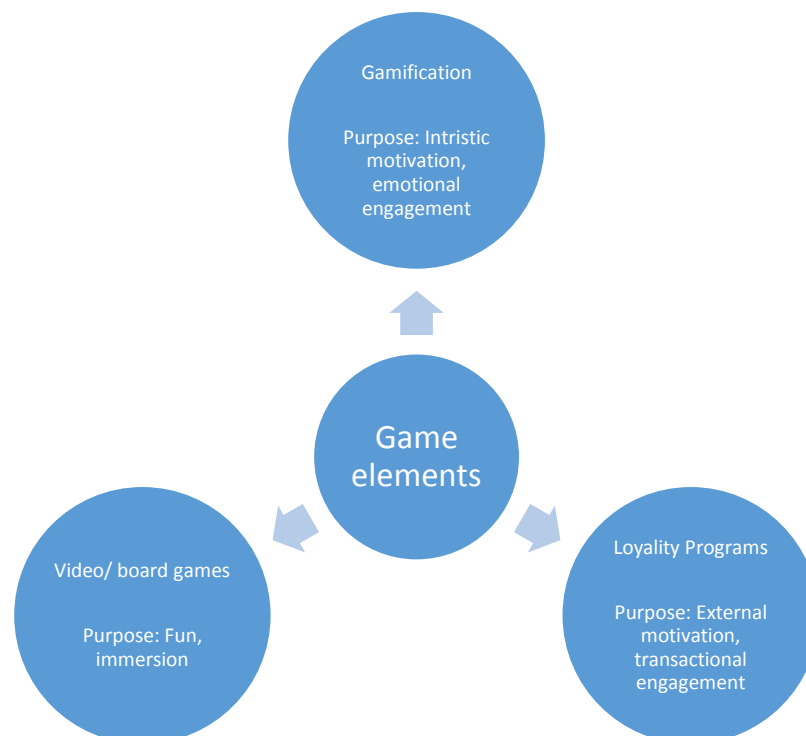


Figure 1. Application of game elements.

Source: (Burke, 2014).

To sum up, gamification can be defined as application of game elements in a non-game context to create a sustainable motivation and engagement among target audience. It accomplishes this by stimulating individuals' intrinsic motivators, creating conditions that confer purpose, support collaboration, and strengthen participants' decision-making and autonomy. The detailed elements and mechanics of gamification used in the context of process improvement and innovation are described in the second part of the article, which concerns the concept of lean gamification.

3. Lean Gamification

Getting to know the origins, theoretical foundations and benefits of gamification, it is worth asking how this concept can be used to increase innovativeness and operational performance of companies.

Lean management can be of assistance here. This management philosophy, derived from the Toyota Production System, places respect for people at the forefront while simultaneously aiming to achieve operational excellence in terms of cost, quality, and lead time for products or services. With the success of Toyota and many other enterprises applying its principles, lean management has become a leading paradigm for managing organizations of all kinds - from industry, through services, to the public sector.

Popularity, however, does not always translate into the effective and correct application of its principles. Many companies that consider themselves "lean" in practice implement lean management in a tool-centric manner, limiting themselves to isolated improvements while neglecting the "soft" aspects related to employee development, empowerment, and engagement. As a result, improvement initiatives are often executed in a top-down, coercive fashion, yielding only short-term business benefits. This is precisely why the foundation of an effective application of lean management is building a durable culture of innovativeness, based on the engagement and motivation of the workforce.

Achieving this objective is not straightforward. One reason is that the traditional lean "toolbox" does not contain ready-made solutions that rapidly increase employee motivation. Engagement is presented rather as a goal and a prerequisite, whereas attaining it is left to the organization itself.

This is where gamification comes in to play. To understand its role in fostering innovativeness in the spirit of lean management, an analogy is helpful. "Lean organizations" often use different dedicated tools and methods to solve specific problems: for poorly designed workplace they deploy 5S; for long changeover times - SMED; and for high machine failure rates - TPM. Similarly, when seeking to solve the problem of low motivation and proactivity among employees, the organization should reach for an appropriate tool - gamification.

Embedding game mechanisms and elements into existing organizational programs and processes creates conditions to enhance autonomy, strengthen purpose, and simply make work more enjoyable. Hence, gamification should be part of the “toolbox” of every organization working in the lean spirit (Feijóo, Hernantes, 2017).

In this part of the article, I present how the two concepts referenced above - lean management and gamification - can complement and reinforce each other. Their combination, referred to as lean gamification, can be defined as the use of game techniques and elements to strengthen a culture of continuous improvement and innovative behavior.

In line with the trends in motivation science and the needs of today’s labor market, the concept of lean gamification enriches the traditional set of managerial methods and techniques by addressing soft organizational problems, including low innovativeness or weak employee motivation. By weaving game mechanisms and elements into existing programs and processes, it creates conditions that elevate autonomy, sharpen purpose, and increase enjoyment at work.

Although the term lean gamification is not yet widely used in business and academic nomenclature, certain solutions that fall under this concept have been successfully employed by enterprises in Poland and around the world for many years. This pertains primarily to educational games and simulations that introduce participants to the theoretical aspects of lean management. Today, virtually every major company offering lean training has at least one product that explains its key principles or tools through gameplay. We refer to this area of lean gamification as the simulation environment.

An important niche in the application of lean gamification, however, is the real environment, which concerns the use of game elements for actual problems and processes carried out in the enterprise (Figure 2). In this case, the aim is not to facilitate knowledge acquisition for the user but to drive concrete behavioral change and obtain tangible results. It is precisely this second area which constitutes the scope of this article.

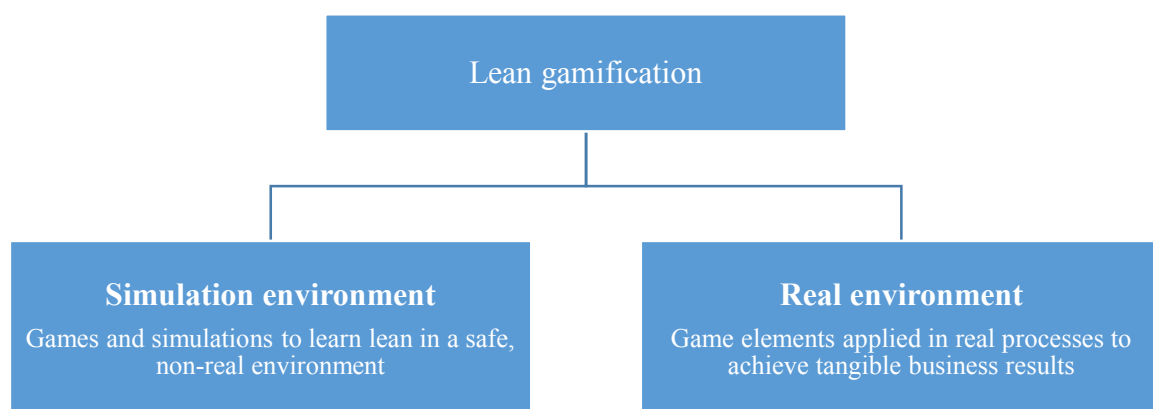


Figure 2. Areas of lean gamification application.

Source: Author’s own work.

The pathway leading to the effective application of lean gamification in real organizational environment is presented by the POMPA model. It provides a support to go through each of the lean gamification implementation steps: from problem definition, through game design and pilot deployment, to gathering feedback for further improvement.

The POMPA model (Figure 3) consists of five steps that should be executed sequentially:

- Problem – unambiguous definition of the problem and the business objective.
- Offtakers – identification of the target users of the lean gamification solution and their key needs, based on Bartle's taxonomy of player types (Bartle, 1996).
- Mechanics – design of the lean gamification concept, comprising elements of emotion, narrative, and rules.
- Pilot – pilot implementation of the lean gamification prototype.
- Adjustments – drawing conclusions from the pilot and improving the lean gamification solution.

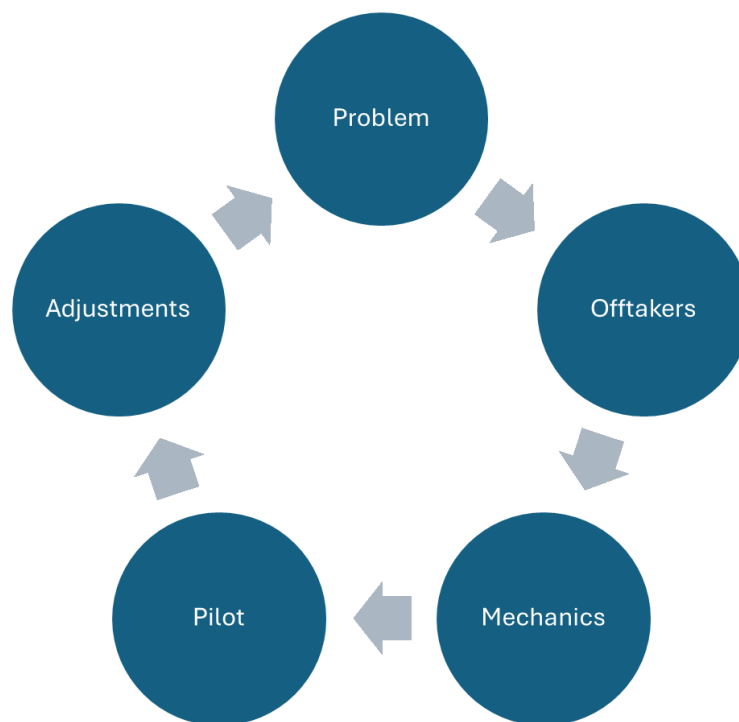


Figure 3. The POMPA Model.

Source: Author's own work.

The next part of the article presents a case study of using the POMPA model in a real business project aimed at increasing organizational innovativeness and engagement.

4. Case study

A branch of a global aerospace company was struggling with low motivation and innovativeness of employees. The enterprise had no formal engagement system and the management team aimed at building a new, creative solution, which could encourage the employees to improve their work. The company primarily targeted small, bottom-up innovations which could be quickly implemented by employees, but also expected tangible financial benefits from these efforts. An important target was also to build ownership among the workforce and to empower them as the decision-makers.

The first step, following the POMPA model, was to define problem and specific goals connected to desired effectiveness of the designed solution. The success metrics were defined as followed:

- Employee engagement level – measured as the percentage of employees submitting at least one improvement idea in a given calendar year; the target was $\geq 50\%$.
- Product and non-product savings – measured as annual savings resulting from reduced material consumption or avoided purchasing costs; the target was $\geq$ USD 50,000.

The intended audience (Offtakers) for the lean gamification solution comprised all non-managerial employees of the branch - approximately 100 people, mostly aged 25-40, though some were significantly older. To better detect the needs of future users, a randomly selected group of employees was surveyed to identify dominant player types based on the Bartle's Taxonomy. The analysis indicated a predominance of Socializers (38%) and Achievers (30%), with a meaningful representation of Explorers (20%). This information was used in the subsequent stage of designing the game mechanics to ensure application of emotionally engaging solutions aligned with employees preferences.

To achieve the intended goals and address the organizational challenges described above, the company decided to design an employee suggestion system. It took a shape of a board game. The premise was simple: employees submit and implement successive innovations, consequently earning points and moving along the board, winning various prizes.

The game was called sCORE - alluding both to "scoring" points and to the company's operational system named CORE (Customer Oriented Results and Excellence). To give the project an industry context, the board was designed with aeronautical motifs with scoring fields represented by the company's various overseas units.

Within the game, employees could submit improvements in four categories:

- Excellence – elimination of process waste, productivity gains, cost reduction, and shortening of operation times.
- Quality – reduction of the cost of poor quality, lowering defect rates, improving inspection effectiveness or error-proofing solutions.

- Safety – improving workplace ergonomics and identification of potential hazards.
- Culture – a peer-to-peer recognition token that one employee could grant another for behavior consistent with company values.

To promote cross-functional collaboration, participants could work on specific ideas in teams of up to three people. A crucial aspect was maintaining high autonomy, where it was up to players to decide with whom they would collaborate and which innovations they would implement. In addition, the typical pre-implementation idea evaluation step, present in many suggestion systems, was removed. In the designed game, teams obtained approval directly from area owners, securing the budget and time necessary for its application. Consequently, the program significantly reduced unnecessary administrative work.

Designing the game mechanics, the team defined submission criteria, which followed the same logic of simplicity. With a use of a basic one-pager, the implemented idea was documented and then forwarded to each category coordinator (usually the manager of the relevant function), who analyzed it and assigned a score from one to three. Based on this assessment, the employee(s) moved along the board by the corresponding number of fields. The farther they progressed, the more attractive rewards they received. Importantly, the rewards were not exclusively material; they also included opportunities such as participation in a training course, spending a day in a chosen department, receiving a parking space or organizing a team integration.

To add a competitive element, the end of the game was defined at the moment when the first person reached the 30th (final) field. In addition to the overall winners, category leaders—those who accumulated the most points in Excellence, Safety, Quality, or Culture—were recognized after the game. To involve managers, who according to the rules could not submit improvements themselves, there was also a special reward for team lead with highest number of total points.

After designing of the lean gamification mechanics, the pilot was carried out. It was scoped with a smaller group of people covering a limited area of the company. The purpose of such scoping was to obtain rapid feedback on whether the lean gamification solution would be attractive to employees and whether it would effectively engage them in improvements and innovation generation. The organization also expected first measurable financial benefits from the implemented ideas. These goals were defined with the following pilot hypotheses:

- At least 50% of employees will engage in improvement activities by participating in at least one implementation.
- Improvements will contribute to $\geq$ USD 5,000 in product cost savings.
- Improvements will contribute to $\geq$ USD 5,000 in non-product cost savings.

The company anticipated that the first, pilot edition would last about three months. In reality, the game generated such strong interest that it concluded in just under two months. The numerical summary of the first edition was as follows:

- 126 implemented improvements,
- 69% of employees engaged in at least one implementation,
- USD 14,000 in annualized product cost savings,
- USD 3,000 in annualized non-product cost savings.

Beyond the measurable effects reflected in the defined success metrics, the game also brought significant changes in employee behavior and mindset: people began to attach great importance to identifying waste and carrying out improvement actions. During the game, sCORE became a frequent topic of conversation in the canteen and corridors. Employees planned tactics, discussed new ideas and actively sought collaborators to help bring them to fruition. Many of the submitted improvements resulted from collaboration between production departments and support functions, which significantly improved internal communication. This also helped to gradually break down the invisible barrier that often separates “white-collar” and “blue-collar” staff.

After the pilot edition, management and a selected group of employees organized a retrospective session to summarize and further update the game mechanics. Despite the game’s overall success, several areas for improvement were identified. Firstly, employees pointed to a lack of transparency in the scoring of submitted improvements, which led to accusations of biased game coordinators. Secondly, some rewards proved difficult to deliver and sometimes required long waiting times, which significantly reduced their attractiveness. Thirdly, management noted that the vast majority of improvements concerned small, local changes, which did not translate into substantial savings. While not inherently negative, it was emphasized that the next edition should place greater emphasis on recognizing ideas that yield bigger financial benefits.

Based on the feedback, the coordination team proposed appropriate changes to the mechanics. These included creating an assessment committee to increase transparency and objectivity in scoring of improvements; introducing additional benefits and rewards for improvements that deliver measurable savings; and finally, adding mechanisms to introduce greater randomness and elements of surprise to further enhance the emotional engagement among players.

5. Conclusions

In order to react to ever-changing market conditions, growing complexity and increased customer requirements, motivated and capable staff is a key ingredient to sustain organizational innovativeness and consequently profitability. However, with ongoing technological, social and demographic trends, the well-established managerial solutions are increasingly often proving to be outdated and ineffective, forcing to experiment with new and creative ways of engaging

its employees. The lean gamification concept, which was described in this article, can be considered as one of the solutions to keep up with recent trends and answer the above-mentioned challenges.

By leveraging the strengths of both lean management and gamification, lean gamification constitutes an important tool for supporting the development of innovativeness in enterprises. Firstly, it supports creation of environment conducive to experimentation through simulations and enables testing of solutions under conditions of limited risk. This consequently leads to acceleration of organizational learning - a key capability necessary for generating innovation. Secondly, gamification mechanisms strengthen employees' intrinsic motivation, engagement in processes improvement and the search for new breakthrough ideas. In this way, lean gamification supports process transparency, facilitates knowledge sharing and promotes cross-team collaboration, shaping an organizational culture toward creativity and continuous improvement.

The lean gamification implementation should follow the standardized POMPA model, which starts with proper problem and users definition, continues with design of the game mechanics and concludes with a low-cost pilot to achieve quick feedback. This sequenced approach ensures a comprehensive diagnoses and custom-made deployment of a solution, addressing specific organizational challenges.

As a relatively new concept, it is recommended to continue more in-depth research on the lean gamification. The case study, which was described in this article, was limited to a production environment with a core purpose of increasing employees motivation and innovativeness. It is advisable to extend the scope of future researches to other business environments (e.g. service, administration) and different aspects of organizational processes. Additionally, there is a clear business and academic need to investigate which game mechanics are most suitable for lean organizations as the answers to this topic remain still uncovered.

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CREATIVITY AS A COMPONENT OF FUTURE MANAGERS' RESILIENCE

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Purpose: This paper aims to present creativity as a key component of the resilience of future managers and to identify the factors that foster the development of these competencies at the academic stage. In the era of increasing uncertainty and complexity of the business environment, creativity becomes not only a source of innovative solutions but also a resource that supports individuals' adaptability and resilience to change and pressure.

Design/methodology/approach: The study aimed to assess the level of creativity among Management students at the Faculty of Management, Lublin University of Technology, and to determine the extent to which the development of creativity during studies may support building organizational resilience in their future managerial roles. A diagnostic survey method was applied using the auditorium questionnaire technique. The measurement tool was an original creative thinking questionnaire designed to capture dimensions such as fluency, flexibility, originality, abstractness, elaboration, and resistance to premature closure. The research involved 75 undergraduate Management students (years 1-3).

Findings: The analysis indicates that senior-year students tend to demonstrate higher levels of creativity. This suggests that an academic environment fostering diverse educational experiences and collaboration creates opportunities for developing both creative competencies and adaptive capacities.

Practical implications: The results may serve as a guideline for designing educational programs aimed at strengthening students' creative competencies and adaptive abilities. Universities and organizations should consciously create environments that foster creative thinking, collaboration, and experimentation.

Social implications: Fostering creativity among students can enhance their ability to adapt to uncertain situations and strengthen their resilience. Education focused on developing these competencies has a potentially important role in building the psychological and emotional resilience of young people, preparing them for more conscious and flexible functioning in changing social and economic conditions.

Originality/value: The article introduces a novel perspective by integrating the concepts of creativity and resilience within the context of management education. Its value lies in the empirical demonstration of the links between these constructs and in providing practical recommendations for educators, policymakers, and HR professionals interested in human capital development.

Keywords: creativity, resilience, human resources.

Category of the paper: Research paper.

1. Introduction

Contemporary organizations operate within conditions characterized by continuous disruptions, escalating complexity, and unpredictable transformations. The environment commonly referred to by the acronym VUCA - denoting volatility, uncertainty, complexity, and ambiguity - demands from both individuals and organizational structures not merely operational flexibility, but also the capacity for rapid learning, strategic redefinition, and the adaptive utilization of human resource potential (Barasa et al., 2017; Mieszajkina, Ostapińska, 2024).

Within this framework, particular significance is ascribed to the notion of human resource resilience, which may be defined as a constellation of attributes, competencies, and mechanisms enabling employees - at both the individual and collective level - to sustain effective functioning under conditions of pressure and destabilization (Kantur, Iseri-Say, 2015; Duchek, 2020). Resilience should not be understood merely as the ability to return to a pre-crisis equilibrium; rather, it extends to encompass processes of learning, adaptation, and transformation. Its multidimensional character comprises psychological, relational, procedural, and strategic components, which jointly constitute the foundation of organizational sustainability and long-term development (Lengnick-Hall et al., 2011; Sutcliffe, Vogus, 2003).

Among the factors reinforcing resilience, creativity occupies a particularly prominent position, understood as the capacity to generate original and useful solutions. It supports both adaptation to change and the proactive response to uncertain situations (Amabile, Pratt, 2016). Creative thinking is closely associated with cognitive flexibility, emotional resilience, and the capacity to transform challenging experiences into opportunities for development (Runco, Jaeger, 2012; Zawadi, 2024).

Although the topics of creativity and resilience are gaining increasing attention in the academic literature, the relationship between these constructs remains insufficiently explored, particularly in the context of future leaders - students of management programs. Their creative competencies, approach to uncertainty, and ability to perform under pressure constitute important indicators of the potential for the next generation of executives. This article attempts to address issues such as the extent to which the level of creativity among management students influences their capacity to cope with stressful and uncertain situations, which characteristics of creative thinking support individual resilience, and the degree to which extracurricular activities contribute to the development of creative and adaptive competencies.

The authors' primary intention was to present creativity as a crucial element of psychological and adaptive resilience, particularly in the context of developing competencies among future managers. The presented research aims to assess the level of creativity among Management students at the Faculty of Management, Lublin University of Technology, and to determine the extent to which fostering creativity during their studies can support the

development of organizational resilience in their future managerial roles. The analysis is based both on a review of the scientific literature in this area and on the empirical findings obtained from research conducted among Management students at Lublin University of Technology.

The research approach adopted in this study was triangulatory, integrating both quantitative and qualitative methods. This approach enabled a more comprehensive examination of the relationships between creativity and resilience, as well as the identification of educational and environmental factors that promote their enhancement. The results obtained not only confirmed the interdependence of the constructs under investigation but also revealed specific mechanisms and forms of activity that facilitate the development of resilience through the cultivation of creative potential.

2. Human resource resilience in organizations

The concept of resilience has multidimensional roots and has evolved across various disciplines over the decades. The term first appeared in developmental psychology, referring to the capacity of children raised under adverse conditions to achieve relatively normal psychosocial development (Masten, 2001). In parallel, the concept of resilience emerged in ecology and the natural sciences, where it denoted the ability of natural systems to withstand disturbances and return to equilibrium (Holling, 1973). Both of these streams - the psychological and the systemic - were later applied in the fields of management and organizational studies (Lengnick-Hall et al., 2011). L.A. Mallak (1998), as one of the first, argued that organizational resilience should be understood as an active strategy that enables functioning despite uncertainty and disruption. On this basis, K.M. Sutcliffe and T.J. Vogus (2003) proposed a different perspective, shifting the emphasis from simply “bouncing back” after a difficult event to the ability of an organization to continue operating and maintain operational integrity despite the occurrence of a disruption - referred to as “bouncing forward”. Consequently, resilience began to be viewed as a process rather than a fixed trait. C.A. Lengnick-Hall et al. (2011) further developed this perspective, highlighting that organizational resilience encompasses the capacity to absorb shocks, adapt, and anticipate threats, shaped through managerial practices and interactions with the environment.

In Polish research, increasing emphasis is placed on the significance of human resource resilience, understood as the capacity of employees and teams to maintain operational effectiveness under conditions of destabilization. Authors indicate that the foundation of this resilience lies not only in individual competencies and motivation, but also in the quality of social relationships and organizational culture, which enable organizations not only to survive crises but also to actively mitigate their effects (Turek, 2020). From a psychological perspective, particular importance is attributed to traits such as cognitive flexibility, emotional

regulation, optimism, self-efficacy, and stress tolerance. These characteristics allow individuals to cope more effectively with pressure, adapt to changing conditions, and maintain engagement at work (Sikorska, 2017). The relational dimension, in turn, is associated with the quality of team interactions-trust, open communication, and collaboration foster collective resilience and enhance the sense of security (Sutcliffe, Vogus, 2003). Equally important is the procedural dimension, which encompasses contingency plans, early warning systems, and flexible decision-making mechanisms. While their mere existence is insufficient, proper implementation and employee familiarity with these systems significantly enhance the organization's ability to respond to sudden disruptions (Duchek, 2020). Finally, the strategic dimension concerns a long-term approach to uncertainty and change, relying on the capacity to identify threats, draw lessons from experience, and promote a culture of innovation and readiness for transformation (Lengnick-Hall et al., 2011).

Factors shaping human resource resilience operate at multiple levels. At the individual level, psychological capital, i.e., hope, optimism, a sense of agency, and mental resilience, plays a key role (Luthans et al., 2007). Creativity is also an important individual resource, facilitating flexible responses to change and the pursuit of innovative solutions (Amabile, Pratt, 2016). At the organizational level, resilience is primarily supported by leadership style - transformational leaders who inspire and support employee development help to foster a climate of trust and safety (Kraśńska, 2016). In addition, human resource management practices, including training, flexible forms of employment, and well-being programs, can mitigate the effects of crises and enhance the adaptive capacity of the organization (Stephen, Zafer, 2020). At the level of the external context, critical factors include economic crises, pandemics, and armed conflicts. Research indicates that organizations implementing flexible solutions and structures were better prepared to cope with uncertainty, thereby enabling the maintenance of operational continuity (Dębkowska et al., 2022).

Human resource resilience can be conceptualized as a process based on three stages: preparation, response, and learning (Duchek, 2020). The preparation stage involves developing adaptive competencies, gathering resources, and planning for disruption scenarios. The response stage entails the mobilization of actions and rapid decision-making in the face of a crisis, while simultaneously ensuring employee well-being (Dembek, 2016). The learning stage enables the transformation of experiences into new managerial practices and innovative solutions, thereby enhancing organizational adaptability (Antczak, 2014). Research also highlights the existence of so-called feedback loops: the socio-cognitive loop, which links well-being with creativity and engagement, and the competency loop, which allows organizations to develop HR practices based on previous experiences. In this way, resilience becomes a source not only of survival but also of productivity and innovation (Barasa et al., 2017).

The significance of this concept became particularly evident during the COVID-19 pandemic. Research conducted in Polish organizations demonstrated that companies investing in technological solutions, well-being programs, and flexible work arrangements achieved

higher performance and maintained team engagement under challenging conditions (Bieńkowska et al., 2025). These findings indicate that resilience is not based on procedures or technology alone, but on a culture of trust, autonomy, and open communication.

Measuring human resource resilience requires the use of diverse methods. At the individual level, psychological scales such as the CD-RISC (Connor, Davidson, 2003) or the RS-14 (Wagnild, Young, 1993) are most commonly employed, assessing persistence, sense of control, and self-discipline. At the organizational level, tools such as the BRAS (Kantur, Iseri-Say, 2015) are used to evaluate culture, leadership, and process flexibility. In Poland, attention is drawn to the necessity of local adaptation of these instruments and to the integration of quantitative and qualitative methods to capture cultural and relational contexts (Stanisławski, 2017).

In conclusion, human resource resilience constitutes a key element in building organizational advantage under conditions of uncertainty. It develops through the interplay between individual competencies, management style, and the influence of the external environment. The mechanisms underpinning resilience enable organizations not only to survive crises but also to learn and strengthen themselves, thereby enhancing their capacity for growth and innovation. Investments in people - their competencies, relationships, and well-being - thus become a strategic choice that determines the long-term competitiveness of the organization.

3. Managerial creativity as a component of human resource resilience

Managerial creativity is conceptualized in the literature as a complex competence that constitutes the foundation of innovative and resilient organizational functioning. T. Amabile (1983) defines it as the ability to generate solutions that are both original and useful within a specific organizational context, addressing the needs of the team, client, or market. Within the componential model of creativity, the author distinguishes three essential elements that condition the effectiveness of creative action: domain-relevant knowledge, creative thinking skills, and intrinsic motivation. It is intrinsic motivation - serving as a source of engagement independent of external stimuli - that represents the most enduring driver of innovativeness.

Polish researchers emphasize that the development of managerial creativity is not merely an individual trait but rather the outcome of an individual's interaction with organizational culture. M. Juchnowicz and H. Kinowska (2022) highlight that managerial creativity requires a work environment based on trust, partnership-based communication, and acceptance of mistakes, which strengthens rather than stifles creative potential. Similarly, P. Kowalczyk and M. Kamiński (2023) underscore the importance of psychological safety, a sense of influence, and autonomy of action as the foundations of creative functioning. B. Kożusznik (2002) further adds that an effective creative manager is not only capable of generating original ideas but also

of persuading the team, overcoming resistance to change, and creating conditions conducive to the development of creativity.

In the international literature, M.D. Mumford et al. (2002) argue that managerial creativity should be analyzed as a process encompassing the generation, structuring, and promotion of ideas, which enables their effective transformation into implementable and scalable solutions. Similarly, C.E. Shalley et al. (2015) emphasize that a key condition of creative leadership is openness to feedback, treated as a source of knowledge and a stimulus for development. Contemporary approaches also highlight the role of socio-emotional competencies. A. Drigas et al. (2023) indicate that managerial creativity stems not only from cognitive abilities but also from emotional intelligence, which supports flexibility and resilience in the face of challenges.

This is precisely where the direct link between creativity and organizational resilience becomes evident. In the context of globalization, digitalization, and increasing uncertainty, organizations and individuals must demonstrate not only innovativeness but also the ability to adapt and transform existing patterns of action. In the literature, resilience is defined as the capacity to respond swiftly to disruptions, to engage in continuous learning, and to regenerate under conditions of pressure and uncertainty (Lengnick-Hall et al., 2011; Sutcliffe, Vogus, 2003). Researchers increasingly emphasize that creativity - understood as a process involving thinking, emotions, and social interactions - is the foundation of resilience. It enables the generation of original and useful solutions as well as the redefinition of problems, which facilitates the adaptation of resources to changing conditions (Runco, Jaeger, 2012; Amabile, Pratt, 2016). Moreover, empirical evidence suggests that creative expression strengthens coping mechanisms in the face of adversity and stress, providing invaluable support in building the resilience of individuals and teams (Zawadi, 2024).

A review of the literature confirms that creativity fulfills both a preventive function - anticipating risks - and a regenerative function - supporting recovery after crises (De Lorenzo et al., 2023). This dual role implies that creativity not only mitigates the negative effects of pressure but also actively contributes to building adaptive and restorative capacity. In the context of contemporary social and technological transformations, creativity acquires a strategic dimension - not as a cognitive luxury, but as a necessary condition for functioning in an environment of discontinuity and change. When appropriately cultivated already at the educational stage, it can serve as a foundation for both individual and organizational resilience.

Human resource resilience encompasses not only the capacity for recovery after a crisis but also the ability to act proactively under conditions of uncertainty. Creativity, understood as a key cognitive component, enables the generation of original solutions, the flexible reorganization of available resources, and the reinterpretation of problem situations in line with changing conditions (Lengnick-Hall et al., 2011). In practice, this means that a creative approach supports continuous adaptation to disruptions without compromising operational coherence or reducing the quality of work.

At the international level, A. De Lorenzo et al. (2023) indicate that creativity in young people functions as a resource that strengthens psychological resilience, particularly in pandemic conditions. Research confirms that creativity enhances cognitive flexibility and the sense of agency, thereby supporting adaptive mechanisms in challenging circumstances. The role of education and HR systems should therefore be to foster creative thinking as a crucial mechanism that reinforces psychological resilience and the capacity for adaptation in a dynamic and uncertain world.

Although creativity has a strong individual component - related, among other things, to knowledge, internal motivation, and personality - its development and outcomes are conditioned by the environment. It is the interaction with the surrounding context that determines whether creativity is supported or constrained (Beghetto, Kaufman, 2007; Pufal-Struzik, 2017). Differences in the level of creativity among students are often associated with factors such as curriculum design, teaching methods, or the approach of academic staff. Institutions that promote active learning, dialogue, and experimentation are more effective in fostering creative competencies. Cultural education is also an important factor, as it develops divergent thinking and empathy by integrating art, philosophy and history into the teaching process (Lewartowicz, 2019). In turn, the behaviour of academic teachers, such as encouraging independence, asking open questions or using activating methods, has a direct impact on the level of creativity of students (Ciżkowicz, 2016).

In the academic environment, students' creativity also develops beyond the formal curriculum - through participation in projects, involvement in student organizations, or collaboration within interdisciplinary teams. These experiences foster not only the formation of a creative approach but also emotional resilience and cognitive flexibility, both of which are essential in professional contexts. A comparison between educational and organizational settings reveals significant differences in the mechanisms that strengthen creativity and resilience. While universities focus primarily on developing cognitive competencies, they often lack exposure to real failures and crises (Bugaj, Szarucki, 2018). In contrast, organizational environments - particularly those driven by innovation - foster resilience through the practice of operating under pressure, while simultaneously providing support in the form of mentoring, coaching, and spaces for experimentation (Ulatowska, 2019).

However, systemic and cultural barriers, such as rigid curricula, pressure to perform, and fear of assessment, which can stifle creative activities, remain significant. The Polish education system still has obstacles that hinder the development of creativity, including overly formalised curricula, a strong focus on performance assessment, and insufficient freedom to engage in creative experimentation and exploration (Szmids, 2017).

In organizations that foster innovation, leaders act as coordinators of creativity through openness, empathy, and the ability to recognize the potential of their teams. They create a culture of psychological safety that encourages cognitive risk-taking and strengthens both individual and collective resilience. Similar mechanisms are applied in higher education

institutions that implement modern teaching methods, such as project-based work, case studies, or simulations, which enhance students' creativity and adaptability (Fazlagić, 2022).

The literature increasingly emphasizes the dual nature of human resource resilience: preventive, encompassing the capacity to prepare for potential disruptions, and regenerative, referring to recovery after a crisis (Lengnick-Hall et al., 2011). Creativity plays a crucial role in both dimensions: in prevention, by generating action scenarios and exploring alternative solutions (van der Vegt et al., 2015), and in regeneration, by assigning new meaning to experiences and constructing constructive narratives of failures (Zawadi, 2024).

From a management practice perspective, creativity should not be regarded solely as a source of innovation but as a fundamental resilience resource. Organizations that consciously support creative attitudes, promote a culture of openness, and accept mistakes as part of the learning process achieve greater capacity for adaptation and for actively transforming reality in the face of uncertainty (Caza, Milton, 2012). Creative individuals are more flexible, proactive, and prepared for crises, which allows human resource resilience to acquire not only a reactive but also an anticipatory dimension.

4. Research methodology

For the purposes of the research, the following research question was formulated: How can creative abilities enhance the capacity of future managers to operate effectively in situations of uncertainty? The objective of the research was to assess the level of creativity among Management students at the Faculty of Management of the Lublin University of Technology and to determine the extent to which the development of creativity during their studies can support the building of organizational resilience in their future managerial roles. For the purposes of the research, resilience was evaluated based on fluency, flexibility, originality, abstractness, elaboration of responses, and resistance to premature closure. The following hypotheses were formulated:

- H1: Third-year students demonstrate higher levels of fluency and flexibility in their responses than younger years, which supports the development of adaptive skills essential for building organizational resilience in their future managerial roles.
- H2: Second-year students achieve higher scores in terms of originality and abstractness of responses compared to the other students, which enhances creative problem-solving abilities and contributes to organizational resilience.
- H3: Third-year students exhibit higher levels of elaboration in their responses and greater resistance to premature task closure than first-year students, supporting the development of competencies related to persistence and perseverance, which are crucial for organizational resilience.

The hypotheses were verified using a diagnostic survey method involving an auditorium questionnaire, i.e., a quantitative empirical research technique in which a questionnaire is distributed and completed by respondents gathered simultaneously in a single location. The survey was conducted on April 15, 2025, among first-, second-, and third-year students of the Faculty of Management at the Lublin University of Technology. Participants were given approximately 15 minutes to complete the questionnaires, and participation in the study was voluntary.

The research instrument consisted of three parts:

1. Demographic.
2. Self-assessment of creativity – 1 closed-ended question and 6 statements, rated on a 5-point Likert scale, where 1 corresponds to “strongly disagree” and 5 to “strongly agree”.
3. Open-ended tasks designed based on selected categories of creative thinking: fluency and flexibility, originality, abstractness, elaboration, and resistance to premature closure.

For the analysis of the open-ended tasks included in the research instrument, authorial evaluation criteria were developed, as presented in Table 1. The applied evaluation method is subjective and does not constitute a standardized psychometric test.

Table 1.
Scoring criteria in the research tool

Task No.	Creativity dimension measured	Evaluation criteria	Scoring scale
1.	Fluency	Number of different, unique ideas	1 pt: 1-2 ideas 2 pts: 3-5 ideas 3 pts: 5+ ideas
1.	Flexibility	Number of different thematic categories	1 pt: 1-2 categories 2 pts: 3-5 categories 3 pts: 5+ categories
2.	Originality	Frequency of occurrence of the idea in the sample (uniqueness)	1 pt: repetitive idea 2 pts: moderately original idea 3 pts: highly original idea
3.	Abstractness	Level of departure from existing schemes, use of metaphorical thinking	1 pt: literal ideas 2 pts: partially abstract ideas 3 pts: highly abstract ideas
4.	Elaboration	Number and quality of details, coherence, and development of the response	1 pt: superficial idea 2 pts: moderately developed idea 3 pts: well-developed idea
5.	Resistance to premature closure	Assessment of completeness, complexity, and originality of the response	1 pt: superficial ideas 2 pts: moderately developed ideas 3 pts: creatively well-developed ideas

Source: own elaboration.

Each participant could earn a maximum of 18 points, including 6 points for task 1 (3 points for fluency and 3 points for flexibility) and 3 points for each of tasks 2-5. The study involved 25 students from each year. Among the participants, there were 48 women and 27 men,

and 14 individuals reported active participation in a student scientific association - 7 from the first year, 3 from the second year, and 4 from the third year.

5. Analysis of research results

At the outset, students assessed their own creativity on a scale of 1 to 5, where 1 indicated "very low" and 5 indicated "very high". The average self-assessment of creativity among first-year students was 3.24 points, among second-year students 3.76 points, and among third-year students 3.8 points.

Students, regardless of their year of study, generally perceive themselves as relatively creative. The lowest self-assessment was observed among first-year students (3.24 points), while higher values were recorded for second-year (3.76 points) and third-year students (3.8 points), indicating a growing confidence in their creative competencies.

To verify H1, the first open-ended task was divided into two dimensions of creativity: fluency (Table 2) and flexibility (Table 3). Initially, students were asked to list ways of saving money in everyday life (Table 2). The results of members of the student scientific association are indicated in the table as SSA.

Table 2.
Students' fluency scores

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	17	8	0	1.32	1.43	0.48	0.495
2	2	12	11	2.36	2.67	0.64	0.47
3	5	12	8	2.12	2.75	0.73	0.43

Source: own elaboration.

First-year students scored between 1 and 2 points, indicating low to moderate fluency of responses ($\mu = 1.32$; $\sigma = 0.48$). The responses of student scientific association (SSA) members did not differ significantly ($\mu = 1.43$; $\sigma = 0.495$), suggesting that this activity had no noticeable effect on fluency within this group. Second-year students showed more varied results than the younger students ($\mu = 2.36$; $\sigma = 0.64$). Most students scored 2 or 3 points, indicating moderate to good fluency, with only two responses scoring lower. SSA members achieved higher scores ($\mu = 2.67$; $\sigma = 0.47$). Third-year undergraduate students displayed fairly diverse fluency scores ($\mu = 2.12$; $\sigma = 0.73$). Membership in a scientific association correlated with higher fluency, as third-year students participating in SSAs scored 2–3 points ($\mu = 2.75$; $\sigma = 0.43$).

Table 3.
Flexibility of students' responses

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	19	6	0	1.24	1.29	0.43	0.45
2	8	16	1	1.72	2.00	0.53	0.82
3	10	11	4	1.76	2.00	0.71	0.71

Source: own elaboration.

The results for flexibility among first-year students are relatively homogeneous, as both student scientific association members ($\mu = 1.29$; $\sigma = 0.45$) and other students ($\mu = 1.24$; $\sigma = 0.43$) most frequently scored 1 point, indicating low flexibility in their responses. Among second-year students, scores of 1 and 2 points predominated, reflecting moderate flexibility ($\mu = 1.72$; $\sigma = 0.53$). Second-year students who were SSA members showed the most varied results, as indicated by a high standard deviation of 0.82. Third-year students displayed the most diverse flexibility scores among the analyzed years ($\mu = 1.76$; $\sigma = 0.71$). SSA members in the third year showed similarly varied results compared to other students in the final year of the undergraduate program ($\mu = 2.00$; $\sigma = 0.71$).

As shown in Tables 3 and 4, in the first open-ended task assessing the levels of fluency and flexibility, third-year students achieved higher scores than the other students, confirming the assumptions of H1.

The verification of H2 was conducted by measuring the next two dimensions of creativity - originality (Table 4) and abstractness (Table 5). Points for originality were assigned based on the rarity and innovativeness of responses, on a scale from 1 to 3. The most common ideas in this task included: promotions, work, savings accounts, and forgoing a particular product or service.

Table 4.
Originality of students' responses

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	15	6	0	1.29	1.57	0.45	0.50
2	4	18	3	1.96	2.33	0.53	0.47
3	1	16	8	2.28	2.25	0.53	0.43

Source: own elaboration.

Among first-year students, the results are fairly uniform ($\mu = 1.29$; $\sigma = 0.45$), with scores of 1 point, indicating low originality, and 2 points predominating. Student scientific association (SSA) members did not differ significantly from the other students ($\mu = 1.57$; $\sigma = 0.50$), which may suggest that association membership does not enhance originality in ideas. Second-year students achieved more varied results, with 2 points being the most frequently awarded score ($\mu = 1.96$; $\sigma = 0.53$). Third-year students exhibited the highest level of originality ($\mu = 2.28$; $\sigma = 0.53$). Comparing the three years, the level of originality increases with the year of study, and SSC members often achieve higher scores than their peers.

For the measurement of abstractness, students were asked to draw a desk of the future. The scoring scale was identical to the previous task, ranging from 1 to 3, where 3 indicated the most unconventional, futuristic approach.

Table 5.
Abstractness of students' responses

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	8	15	2	1.76	2.29	0.59	0.45
2	6	12	7	2.04	1.33	0.72	0.47
3	4	11	10	2.24	2.50	0.71	0.50

Source: own elaboration.

First-year students exhibited a moderate level of abstractness, most frequently scoring 2 points ($\mu = 1.79$; $\sigma = 0.59$). SSA members achieved slightly higher scores ($\mu = 2.29$; $\sigma = 0.45$). A wide range of results was observed among second-year students ($\mu = 2.29$; $\sigma = 0.45$), which may indicate a developing level of abstract thinking. Third-year students achieved the highest scores among all years ($\mu = 2.04$; $\sigma = 0.72$), reflecting a high level of abstractness and the ability to create visions beyond realistic frameworks. Third-year students demonstrate the greatest potential for generating conceptual and visionary solutions, which may result from the accumulated experience and enhanced projective imagination they have developed throughout their studies. However, the analysis of the obtained results does not allow for H2 confirmation of H2.

To verify H3, the last two dimensions of creativity were measured - elaboration (Table 6) and resistance to premature task closure (Table 7). The elaboration measurement required students to demonstrate the ability to expand and thoroughly describe ideas, including the number and quality of details in their descriptions.

Table 6.
Elaboration of students' responses

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	8	11	6	1.92	1.86	0.74	0.64
2	2	9	14	2.48	2.33	0.64	0.47
3	1	8	16	2.6	3.00	0.57	0.00

Source: own elaboration.

The results of first-year students were varied, which may indicate that the ability to develop ideas is not yet fully formed for many individuals at this stage of study ($\mu = 1.92$; $\sigma = 0.74$). First-year SSA members did not stand out compared to the rest of the year ($\mu = 1.86$; $\sigma = 0.64$). Among second-year students, high scores predominated, indicating a well-developed ability to construct coherent and descriptive responses ($\mu = 2.48$; $\sigma = 0.64$). Third-year students achieved the highest and most stable scores ($\mu = 2.6$; $\sigma = 0.57$). SSC members in the final year of the undergraduate program were among the highest scorers ($\mu = 3.00$; $\sigma = 0.00$). In the final part of the study, perseverance, motivation, and willingness to further develop ideas were assessed.

The scoring scale ranged from 1 to 3 points, where 3 indicated a complete and well-considered completion of the task, and 1 indicated superficial and incomplete responses.

Table 7.

Resistance to premature task termination among students

Year of Study	Points from Table 1			Weighted mean (μ)		Standard deviation (σ)	
	1	2	3	Entire sample	SSA	Entire sample	SSA
1	5	16	4	1.96	2.14	0.60	0.64
2	5	16	4	1.96	1.33	0.60	0.47
3	3	13	9	2.24	2.75	0.65	0.43

Source: own elaboration.

First-year students achieved the same results as second-year students ($\mu = 1.96$; $\sigma = 0.60$), which may indicate a still low, developing level of perseverance. The scores of second-year SSC members were even lower compared to their peers ($\mu = 1.33$; $\sigma = 0.47$). Third-year students achieved the highest scores ($\mu = 2.24$; $\sigma = 0.65$). Extracurricular activity among final-year undergraduate students may foster greater engagement, discipline, and motivation, as evidenced by the results of SSA members ($\mu = 2.75$; $\sigma = 0.43$). The development of the traits assessed in this task may occur over time and with academic experience, as confirmed by the higher scores of third-year students. Analysis of the data presented in Tables 6 and 7 allowed for the confirmation of H3.

6. Conclusions and discussion

The analysis of the results obtained during the study confirmed the existence of a relationship between students' levels of creativity and their cognitive-emotional resilience. The findings also highlight the significant role of extracurricular activities in shaping these competencies. At the same time, it should be emphasized that the issue of creativity as a component of organizational resilience remains a multidimensional topic, open to further exploration. Due to the complexity of the phenomenon and the limitations arising from the homogeneity of the sample (students from a single program and institution), it is recommended that future research be expanded to include other academic environments, fields of study, and diverse age and professional groups. Such an approach would allow for a better understanding of environmental and cultural factors influencing the development of creativity and resilience, thereby enriching knowledge in this important area of human resource management.

The study conducted among Management students at Lublin University of Technology demonstrated a high level of creative potential, evident in their propensity to generate original ideas and openness to new ways of problem-solving. Particularly important were personality traits conducive to creativity, such as cognitive perseverance, flexibility of thought,

and willingness to take intellectual risks. From the perspective of managerial competencies, it is especially noteworthy that creativity was frequently identified by respondents as one of the key attributes of a future leader. At the same time, many participants reported engagement in creative activities within project teams, reflecting the practical dimension of their innovative potential. This finding aligns with trends observed in other studies, where the younger generation not only values creativity but also perceives it as a fundamental condition for career development and professional achievement (Borowska, Pietron-Pyszczek, 2023).

These results are particularly significant in the context of digital transformation and the rapidly changing work environment. Managerial creativity is not an isolated individual ability but a function of interactions with the team, organizational structure, and an innovation-supportive culture (Amabile, Pratt, 2016). The students surveyed demonstrated awareness of the importance of soft skills, a willingness to take cognitive risks, and the ability to act under conditions of uncertainty - traits particularly valued in transformational and participatory leadership models. The collected data can serve as a basis for further comparative research; however, even at this stage, they indicate that management students possess a significant resource which, with appropriate educational and developmental support, can translate into tangible leadership and innovation competencies.

The study demonstrates that individuals exhibiting greater engagement in activities requiring creative thinking achieved higher results in areas such as cognitive fluency and flexibility. Additionally, respondents characterized by perseverance in completing complex tasks and openness to new approaches displayed higher creative potential, which can be interpreted as a significant element of their readiness to function under conditions of uncertainty. This phenomenon can be seen as evidence of the growing importance of creative competencies in the context of academic and professional resilience.

These findings align with a broader line of research on the role of creativity in adaptation processes. As noted by A. De Lorenzo et al. (2023), creativity plays a crucial role in building psychological resilience, as it promotes the development of cognitive flexibility and enhances an individual's sense of control over situations, particularly under conditions of crisis and uncertainty. Similarly, N.K. Zawadi (2024) suggests that creative expression supports coping mechanisms by reducing stress and strengthening confidence in one's own abilities.

In the study, students who rated their own creativity as high achieved better results in tasks requiring fluency and originality of thought - characteristics of creative, divergent thinking (Runco, Jaeger, 2012). Equally important, creativity supports emotional-behavioral resilience: it helps regulate stress, cope more effectively with emotional tension, and maintain motivation despite difficulties (Stańko-Kaczmarek, 2022). Students with greater tolerance for uncertainty and the ability to operate under chaotic conditions performed better in open-ended tasks, indicating that creativity can constitute a significant component of both cognitive and emotional resilience.

Moreover, creativity manifests in two key resilience functions: a preventive function - enabling the anticipation of threats and the planning of alternative courses of action (Sutcliffe, Vogus, 2003) - and a regenerative function, supporting the restoration and rebuilding of resources after a crisis. The study demonstrates that students active in extracurricular environments not only perform better on creative tasks but also exhibit greater resistance to prematurely ending tasks, reflecting perseverance and the capacity for sustained engagement even in the face of challenges. This aspect is directly linked to psychological resilience, understood as the ability to endure and maintain equilibrium in difficult situations.

International research confirms that creativity is one of the key competences developed in higher education. A review of 28 studies from 2018-2023 showed that most of them focused on undergraduate students in East Asia and the methods used were mainly surveys often without a solid theoretical basis (Setiamurti, Kurniawati, 2022). Student creativity varies across disciplines – experts in physics, history and poetry point to different characteristics, suggesting a need to adapt teaching methods to the specific nature of the field (Georgiou et al., 2022). A meta-analysis of 18 studies showed an average positive impact of creativity on academic achievement, pointing to its importance for cognitive development and motivation (Fan, Cai, 2022). M. Bouckaert (2023) emphasises the growing importance of creativity assessment in educational policies, although uniform tools are still lacking. In turn, research in Azerbaijan on a sample of 219 people showed that students' creativity can be effectively developed through teacher support, technology and motivation (Pozilova et al., 2023).

Managerial creativity currently constitutes one of the key competencies determining effective management in a turbulent organizational environment. In light of the literature review and the results of research conducted among management students at Lublin University of Technology, it can be concluded that the younger generation of future leaders possesses significant creative potential, which, with appropriate organizational support, can be effectively utilized in practice. Considering variables such as digital transformation, generational diversity, and organizational culture is essential for creativity to be effectively developed and implemented as a strategic organizational resource.

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MOTIVATION OF GENERATION Y AND Z REPRESENTATIVES IN THE CONTEXT OF ORGANIZATIONAL RESILIENCE

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Purpose: The article focuses on the determinants shaping the attitudes and expectations of young individuals in the labor market, analyzed through the lens of organizational resilience. The primary objective of the research was to identify which motivational factors play a decisive role in the job-seeking process among representatives of Generations Y and Z. The underlying assumption is that the needs and expectations of young employees - such as autonomy, opportunities for professional development, work-life balance, and transparency - may serve as significant drivers reinforcing adaptive and innovation-oriented processes within organizations.

Design/methodology/approach: The article reviews domestic and foreign literature on organizational resilience and the determinants of motivation among young employees in the labor market. The research hypotheses were verified using the diagnostic survey method combined with the CAWI technique. The data obtained enabled a comparative analysis of the relative importance of individual categories of motivators and their impact on sustaining motivation levels among respondents.

Findings: The research revealed that while financial factors remain an essential component of motivational systems, aspects related to professional development were evaluated as having greater importance by representatives of Generations Y and Z. Flexible forms of work organization and additional time off also play a significant role. By contrast, pro-environmental initiatives serve only a complementary function.

Research limitations/implications: The study was conducted on a purposively selected sample of young individuals entering the labor market, which limits the generalizability of the findings. Future research should be extended to larger and more diverse populations, differentiated by level of education and stage of professional career. Such an approach would enable a more comprehensive assessment of the relative importance of motivational factors in the context of organizational resilience.

Practical implications: The expectations of Generations Y and Z center around competitive remuneration, flexible forms of employment, transparent career development opportunities, and a collaborative organizational culture. Proper integration of these needs into motivational systems not only supports talent retention and enhances employee well-being but also establishes a foundation for strengthening organizational adaptability and resilience.

Social implications: The issues addressed hold social significance as they concern the quality of working life of young employees and their integration into the labor market. The findings highlight how the organization of working conditions and professional relationships may influence work–life balance, psychological well-being, and the development of social capital.

Originality/value: By incorporating the motivational perspectives of Generations Y and Z entering the labor market, the study identifies key determinants of effective human capital management.

Keywords: organizational resilience, motivation, Generation Y and Z, engagement, human resource management.

Category of the paper: Research paper.

1. Introduction

The ability of an organization to maintain operational continuity and pursue further development under conditions of increasing uncertainty and a dynamically changing environment depends not only on established structures, procedures, or advanced technologies. Growing importance is attributed to the human factor, particularly employees' motivation, level of engagement, and attitudes. In this regard, a special role is increasingly assumed by the younger generation entering the labor market, especially representatives of Generation Z, whose values, expectations, and needs differ from those of previous generations employed within organizations (Zahra et al., 2025).

Organizational resilience is often defined as the capacity to sustain or rapidly restore a desired level of functioning despite disruptions, external pressures, crises, or sudden environmental changes. In its contemporary understanding, it is conceptualized as a process encompassing three interrelated stages: anticipating and preparing for potential threats, responding effectively when difficulties arise, and learning from experience to improve procedures and strengthen resilience for the future (Duchek, 2020). Resilience understood in this way becomes a key strategic resource, as it enables organizations not only to survive under adverse conditions but also to leverage crises as opportunities for growth and innovation (Skrzypek, 2023).

Organizational resilience is shaped by diverse determinants, including, among others, organizational culture, management structure, resources, leadership, and relationships with the environment. Employee behavior also remains an important factor, the right motivation of which can determine both entry into and retention in employment. The research aimed to determine which motivational factors play a key role during job search by representatives of Generations Y and Z. Learning about these factors will allow enterprise managers to create motivational systems that will strengthen the formation of organizational resilience. The study was conducted by a diagnostic survey method using the CAWI technique on a sample of 199 respondents from Generations Y and Z.

2. Organizational resilience in contemporary management perspectives

The concept of organizational resilience has become firmly embedded in the canon of contemporary management sciences. Its significance continues to grow alongside the intensification of global phenomena that undermine environmental stability and generate numerous threats to organizational continuity. Modern enterprises and public institutions operate under conditions of dynamic technological change, globalization processes, escalating economic crises, as well as sudden and difficult-to-predict events such as the COVID-19 pandemic or geopolitical conflicts. As emphasized by R. Bhamra et al. (2011), traditional concepts of organizational stability prove insufficient in this context, while the development of adaptive capacity, learning, and the ability to leverage crises as a stimulus for growth becomes essential.

The concept of resilience does not originate in management sciences but rather in psychology and ecology. In psychology, it refers to an individual's capacity to cope with adverse experiences and to restore psychological balance after a crisis (Masten, 2001). In ecology, the term was used to describe the ability of ecosystems to regenerate following disturbances (Holling, 1973). Only later was the concept transferred into management studies, where initial attention focused on high-risk organizations such as aviation, healthcare, or nuclear energy (Enya et al., 2018). Over time, resilience acquired the status of a universal theoretical category, applied to the analysis of all organizational types.

The earliest approaches to organizational resilience were reactive in nature, focusing on surviving a crisis and rapidly restoring the pre-disruption state. L.A. Mallak (1998) emphasized that resilience involves making sound decisions under pressure, learning from mistakes, and fostering a culture of flexibility. A resilient organization continues to function despite limited resources, with its primary objective being operational continuity through loss minimization. The earliest approaches to organizational resilience were reactive in nature.

In subsequent years, the concept of resilience began to incorporate an adaptive dimension. T.J. Vogus and K. Sutcliffe (2007) argued that resilience is not only a response to crisis but also the capacity to flexibly adjust to new conditions and to sustain organizational functionality in the face of disruptions. The authors emphasized the role of cognitive, emotional, and social processes in building resilience. In this perspective, resilience extends beyond crisis procedures - it encompasses the mindset, relationship quality and organizational culture that determine whether an institution will be able to use difficulties as an opportunity to learn and improve.

A significant contribution to the development of adaptive approaches to resilience was made by C.A. Lengnick-Hall et al. (2011). They emphasized that organizational resilience results from the integration of adaptive and dynamic capabilities, which enable not only the mitigation of crisis effects but also their creative utilization. Resilience thus becomes a strategic resource

and a source of competitive advantage. It allows organizations to transform uncertainty into opportunities and crises into innovative solutions.

Contemporary research on resilience is moving toward proactive and systemic perspectives. S. Ducheck (2020) conceptualizes resilience as an organizational metacompetence encompassing three interrelated capabilities: anticipating potential threats, acting effectively under conditions of uncertainty, and learning from past experiences. Her model presents resilience as a cyclical process through which organizations continuously enhance their adaptive capacities.

J. Hillmann and E. Guenther (2021) argue that resilience is based on the mobilization of resources, the implementation of resilience-enhancing practices, and the development of enduring organizational capabilities, which enable not only a quicker restoration of equilibrium but also a transformation that increases flexibility. Resilience thus serves both defensive and offensive functions. Several models have emerged in the literature, including L.A. Mallak's (1998), which emphasizes the importance of organizational culture and learning, and L. Xiao and H. Cao's (2017), which highlight the multi-level nature of resilience - from the individual, through the team, to the entire organization - grounded in optimism, trust, responsibility, social capital, and adaptive capabilities. In contrast, S. Ducheck (2020) proposes a cyclical model encompassing anticipation, response, and learning, while Hillmann and Guenther (2021) stress the need to tailor resilience mechanisms to the specific characteristics of different sectors.

In Polish research, resilience increasingly appears as a prerequisite for effective management. E. Skrzypek (2023) notes that, despite the absence of a single definition, resilience has become a fundamental category for managerial practice, enabling not only the survival of crises but also improvements in efficiency and innovative capacity. Similarly, S. Zapłata (2025) emphasizes that resilience develops through the interaction of internal factors - such as organizational culture and leadership - with external conditions, including market volatility and institutional pressures. J. Woźniak (2024) adds that in risk management, resilience entails not only the minimization of losses but also the creation of competitive advantage, aligning it with the dynamic capabilities theory (Teece et al., 1997), within which organizations learn to reconfigure resources to meet the demands of a turbulent environment.

In summary, organizational resilience is not a static concept but a dynamic resource that integrates cognitive, emotional, structural, and cultural elements. Its essence lies in the ability to simultaneously maintain stability and flexibility, and its practical significance makes it one of the foundational pillars of management in the 21st century.

3. The motivation of Generations Y and X in the context of organizational resilience

From the perspective of occupational psychology, motivational mechanisms are explained, among others, by Self-Determination Theory (SDT). This theory assumes that individuals engage in professional activities when the work environment allows them to satisfy three fundamental psychological needs: autonomy in decision-making, a sense of competence, and the development of meaningful relationships with others (Deci, Ryan, 2000). A similar perspective is offered by the Job Demands–Resources (JD-R) model, which identifies organizational resources as key factors fostering motivation and engagement (Bakker, Demerouti, 2007). Such resources include support from colleagues and supervisors, opportunities for skill development, recognition from the professional environment, and autonomy in task execution. These resources serve a protective function, helping to balance the demands arising from time pressure, workload, or task complexity (Demerouti, 2011). Empirical research indicates that a high level of job resources promotes motivational processes that lead to engagement, proactivity, and improved coping under conditions of uncertainty (Demerouti, 2011).

In the literature, the motivational expectations of Generations Y and Z are relatively well-defined and widely recognized. For young employees, in addition to financial considerations, significant factors include maintaining a work–life balance, attention to mental health, the ability to find meaning in their work, and opportunities for continuous learning and skills development (Faber, 2025). In the context of Polish research, the importance of collaborative relationships with supervisors, a supportive workplace atmosphere, and flexible approaches to time management is also emphasized (Paszkievicz, Wasiluk, 2022). At the same time, Generation Z is noted to be particularly sensitive to a lack of transparency, excessive levels of control, or flexibility that is promised but not implemented - factors that can significantly reduce their engagement and loyalty to the organization (Zahra et al., 2025; Surugiu, 2025).

Comparing the above expectations with the attributes of organizational resilience, a natural alignment becomes apparent. Organizations that emphasize employee autonomy, enable participation in decision-making, ensure transparency, and foster a shared vision not only meet the motivational needs of the younger generation (Deci, Ryan, 2000; Faber, 2025; Paszkievicz, Wasiluk, 2022), but also strengthen their own adaptive capacity (Duchek, 2020; Vogus, Sutcliffe, 2007). In this perspective, the engagement of these employees becomes a driving force for resilience processes - through their involvement, young workers provide energy for anticipatory actions, facilitate rapid learning and adaptation, and support innovation (Skrzypek, 2023).

It is worth noting the significance of organizational culture. Numerous studies emphasize that an open work culture, based on collaboration and a readiness to learn, enhances both the motivation of younger employees and the institution's capacity to cope with challenges (Lengnick-Hall et al., 2011). Organizations that create space for experimentation, knowledge sharing, and the acceptance of mistakes as a natural part of development are particularly attractive to Generation Z, which seeks opportunities to exert influence and gain experience through practice. Moreover, this type of culture enhances an institution's ability to learn from past failures, which, according to S. Ducheck's (2020) concept, is the foundation of organizational resilience.

Noteworthy is the fact that a culture based on openness, mutual support, and learning not only fosters loyalty and motivation among younger employees but also strengthens long-term organizational resilience (Georgescu et al., 2024). Companies that facilitate experimentation, knowledge exchange, and treat mistakes as learning opportunities create a work environment aligned with the expectations of Generation Z, which values the ability to independently shape their own development. At the same time, such an organizational culture supports institutional adaptive processes and learning, which, according to S. Ducheck (2020), constitutes one of the key mechanisms of resilience.

It is also important to recognize the significance of intergenerational relationships in the workplace. Many organizations today include representatives of up to four generations, which makes managing this diversity a matter of openness, dialogue, and skillful integration of differing values and work approaches. Younger generations, including Generation Z, contribute digital proficiency, innovation, and flexibility to teams, while older employees offer extensive professional experience, stability, and institutional knowledge. The synergy of these competencies can serve as a significant source of organizational resilience, provided that younger employees are given opportunities for motivation and participation in decision-making processes, and that their potential is not constrained by rigid procedures or overly hierarchical structures (Nieżurawska, 2023).

An important element shaping the contemporary work environment is technological development. Recent reports indicate that Generation Z readily uses tools based on artificial intelligence and automation, yet often lacks systematic training support in this area (Faber, 2025). Organizations that invest in enhancing the digital competencies of young employees and allow them to independently experiment with new solutions not only increase their motivation and engagement but also strengthen their own capacity to adapt to technological changes. This implies that programs aimed at developing digital skills serve a dual function - helping to retain talent within the organization while simultaneously enhancing its resilience.

This is further confirmed by empirical research examining the relationship between job resources, engagement levels, and employee resilience. High individual resilience promotes both job satisfaction and motivation, while organizations that cultivate a culture based on collaboration and continuous learning demonstrate a greater capacity to overcome crises

(BMC Public Health, 2024). Moreover, a reinforcing mechanism emerges: a work environment that promotes resilience and learning stimulates the motivation of young employees, and their activity and energy, in turn, enhance the flexibility and strength of the entire organization.

Research conducted in Poland indicates that the motivation of Generation Z and organizational resilience are closely interrelated. J. Woźniak (2024) emphasizes that organizational resilience should be regarded as a key component of risk management strategy, enabling not only survival but also the achievement of competitive advantage in an unstable environment. Analyses by A.J. Paszkiewicz and A. Wasiluk (2022) demonstrate that young employees place the highest value on a friendly organizational climate, a collaborative approach from supervisors, and flexibility in terms of work time and location. This suggests that human resource policies aimed at meeting these needs not only increase engagement and loyalty among young employees but also strengthen the organization's capacity to adapt and operate effectively under conditions of complexity and uncertainty.

The practical implications in this context are clear. First, organizations should implement transparent yet flexible collaboration rules that provide young employees with a sense of autonomy and opportunities to participate in decision-making processes (Deci, Ryan, 2000). Second, it is essential to create diverse career development paths tailored to the preferences of Generation Z, such as microlearning, reverse mentoring, or training programs aimed at enhancing digital competencies, including skills related to artificial intelligence (Faber, 2025). Third, the transparency of reward and promotion systems is of particular importance, as a lack of clarity quickly undermines motivation (Paszkiewicz, Wasiluk, 2022). Finally, attention to mental well-being and work–life balance cannot be overlooked, as these factors are critical for sustaining employee engagement and energy over the long term (Woźniak, 2024; Duchek, 2020).

Summarizing the considerations, it can be concluded that the motivation of the younger generation and organizational resilience are closely related. Meeting the psychological needs of Generation Z, such as autonomy in decision-making, the opportunity to develop competencies or build valuable relationships, promotes the growth of their commitment, initiative, and creativity. These attitudes, in turn, strengthen key elements of organizational resilience, including adaptive capacity, flexibility, and the ability to learn from past experiences. Organizations that recognize and leverage the potential of young employees gain advantages not only in talent retention but also in building long-term stability and development. As a result, they are better equipped to cope with uncertainty, dynamic environmental changes, and the need for innovation.

4. Research methodology

Based on a review of the literature and preliminary studies, the research problem was formulated as follows: What motivational factors guide the younger generation when entering the labor market? Answering this question allows for a more comprehensive understanding of the needs and expectations of Generations Y and Z toward employers, as well as the identification of determinants that encourage their active job search. The research aimed to determine which motivational factors play a key role during the search for work by representatives of Generations Y and Z. The following hypotheses were formulated:

- H1: In seeking employment, representatives of Generations Y and Z consider salary factors to be more motivating than non-salary material factors.
- H2: Representatives of Generations Y and Z consider factors related to personal development and education as the most valuable when searching for work.
- H3: Flexible work arrangements and environmentally responsible organizational practices increase the attractiveness of an organization for representatives of Generations Y and Z.

To verify the hypotheses, a diagnostic survey method was employed using the CAWI technique, i.e., computer-assisted web interviews. The study was conducted via the Google Forms application, ensuring full anonymity of respondents (Ostrowski, 2025). The research instrument was a questionnaire consisting of a substantive section (five questions on a five-point Likert scale) and a demographic section (three questions).

The research sample was selected deliberately, taking into account specific criteria. The selection was aimed at obtaining the opinions of representatives of generations Y and Z. Respondents had to meet three criteria: (a) age over 18 years; (b) not being employed; and (c) having made initial attempts to enter the labor market. The study involved 199 participants, of whom 58% (116 individuals) were women and 42% (83 individuals) were men. In terms of educational attainment, the majority held secondary education, accounting for 55% of the sample (109 individuals). Bachelor's degree holders comprised 25% of respondents (50 individuals), master's degree holders 12% (24 individuals), and vocational education 6.5% (13 individuals). The smallest groups included participants with engineering education—1% (2 individuals)—and primary education—0.5% (1 individual). Regarding age, the largest group consisted of respondents aged 18-24 years, representing 80% of the sample, while the remaining participants were aged over 25 years.

5. Research results analysis

As part of the study, representatives of Generations Y and Z entering the labor market evaluated motivational factors. All factors were rated on a scale from 1 to 5, where 1 indicated “completely unimportant” and 5 indicated “very important”. To verify H1, salary factors (Table 1) and non-salary material factors (Table 2) were analyzed.

Table 1.
Evaluation of salary factors

Factor	Rating					μ	σ
	1	2	3	4	5		
Competitive salary	4	10	16	100	69	4.11	0.90
Bonuses	4	6	16	81	92	4.26	0.88

Note. μ - weighted mean; σ - standard deviation.

Source: own elaboration.

For base salary, 50.3% of respondents (100 individuals) considered it rather important. An additional 69 respondents (34.7%) rated this factor as very important. Overall, 169 out of 199 participants (85%) assigned it a high level of importance by selecting a rating of 4 or 5. Neutral responses (rating 3) were given by 16 respondents (8%), while negative ratings (2 and 1) were reported by 10 (5%) and 4 (2%) participants, respectively. The mean score was 4.11, confirming its high significance for the majority of respondents ($\sigma = 0.90$). Similarly high results were observed for the second factor, namely performance and achievement bonuses. The most frequently selected rating was 5, chosen by 92 respondents (46.3%). Slightly fewer, 81 respondents (40.7%), rated this factor as 4. In total, 173 participants (87%) regarded bonuses as an important component of the motivation system. The remaining ratings were distributed as follows: 16 respondents (8%) – rating 3; 6 respondents (3%) – rating 2; and only 4 respondents (2%) considered bonuses completely unimportant. The mean rating for this factor was higher than that for base salary, at 4.26 ($\sigma = 0.88$).

In the next part, respondents were asked to evaluate non-salary material factors (Table 2).

Table 2.
Evaluation of non-salary material factors

Factor	Rating					μ	σ
	1	2	3	4	5		
Meal subsidies at work	13	36	56	67	27	3.28	1.11
Commuting allowance	7	18	47	88	39	3.67	1.00
Private health care	9	9	36	87	58	3.88	1.02
Savings programs	16	34	61	68	20	3.21	1.09
Retirement programs	11	22	34	85	47	3.69	1.12
Vacation subsidies	8	31	44	74	42	3.56	1.11
Sports cards or other recreational benefits	9	13	47	82	48	3.74	1.04
Access to a company car	8	30	46	84	31	3.50	1.05
Access to a company phone	14	24	51	74	36	3.47	1.13
Access to a company laptop	9	18	48	72	52	3.70	1.09
Material rewards (vouchers, gift cards)	11	26	59	65	38	3.47	1.10

Note. μ - weighted mean; σ - standard deviation.

Source: own elaboration.

The most positively evaluated factor was access to private healthcare, with 58 respondents (29.1%) assigning it a rating of 5 and 87 respondents (43.7%) rating it as 4. This gives a total of 145 positive responses (72.9%). Forty-five respondents (22.6%) took a neutral stance on this factor, while only 18 respondents (9%) rated it negatively (ratings 2 and 1). The mean score was 3.88 ($\sigma = 1.02$). Among other benefits, retirement programs received high ratings, with 47 respondents (23.6%) considering them very important and 85 respondents (42.7%) rating them as rather important. In total, 132 participants (66.3%) assigned this factor a high level of importance. Thirty-four respondents (17.1%) expressed a neutral opinion, while 33 participants (16.6%) rated it negatively (2 or 1). The mean score for this factor was 3.69 ($\sigma = 1.12$). Sport cards and recreational benefits were rated at a similar level, with 48 respondents (24.1%) considering them very important and 82 respondents (41.2%) rating them as rather important. In total, 130 participants (65.3%) evaluated this factor positively. Forty-seven respondents (23.6%) gave a neutral rating, while negative ratings (2 or 1) were assigned by 13 (6.5%) and 9 respondents (4.5%), respectively, totaling 11% of all participants. The mean score was 3.74 ($\sigma = 1.04$). One of the factors with fewer positive evaluations was subsidized workplace meals. Only 27 respondents (13.6%) rated it as very important (5), and 67 respondents (33.7%) rated it as rather important (4). In total, 94 participants (47.2%) assigned high importance to this factor. The mean score was 3.28 ($\sigma = 1.11$), suggesting moderate significance. The lowest-ranked factor was savings programs. Twenty respondents (10%) rated it as very important, and 68 (34.2%) as rather important, resulting in 88 respondents (44.2%) assigning it positive significance. Neutral responses were given by 61 participants (30.7%), and 50 respondents (25.1%) rated it as less important (2 or 1). The mean score was 3.21 ($\sigma = 1.09$). The analysis of both groups of factors confirmed H1.

To verify H2, respondents were asked to evaluate non-material, non-salary factors related to professional development, categorized into three groups: development and education, support and implementation, and workplace relationships and environment. In the questionnaire, the factors were presented in a random order.

Table 3.

Evaluation of non-material, non-salary factors related to professional development

Factor	Rating					μ	σ
	1	2	3	4	5		
Development and education							
Opportunity to participate in courses and training	6	12	23	85	73	4.04	0.99
Opportunity to participate in international projects or learn foreign languages	0	11	48	85	55	3.93	0.85
Clearly defined career advancement and professional development path	2	13	20	81	83	4.16	0.92
Autonomy and responsibility in task execution	4	11	26	87	71	4.06	0.94

Cont. table 3.

<i>Support and implementation</i>							
Assignment of a supervisor or mentor to a new employee	2	13	28	97	59	3.99	0.88
Well-planned and gradual onboarding process for new employees	2	7	21	83	86	4.22	0.85
<i>Relationships and work environment</i>							
Friendly work atmosphere and organizational culture	2	10	6	43	138	4.53	0.86
Working in a team of experienced and communicative colleagues	2	5	12	63	117	4.45	0.80
Opportunity for competition with other employees (e.g., rankings, contests)	29	42	66	42	20	2.91	1.18

Note. μ - weighted mean; σ - standard deviation.

Source: own elaboration.

One of the most frequently positively rated factors was the well-planned and gradual process of implementing a new employee. Eighty-six respondents (43.2%) rated it as very important, and 83 respondents (41.7%) rated it as rather important. This means that 169 participants (84.9%) considered this factor important or very important. Neutral responses were given by 21 respondents (10.6%), and only 9 participants (4.5%) rated this factor as rather or completely unimportant. The mean score was 4.23. Another highly rated factor was working in a team of experienced and communicative colleagues. One hundred seventeen respondents (58.8%) rated it as 5, and 63 respondents (31.7%) rated it as rather important, resulting in a total of 180 respondents (90.5%) giving positive evaluations. Neutral ratings were given by 12 respondents (6%), and negative ratings by only 7 participants (3.5%). The mean score was 4.45. The highest-rated factor was a friendly work atmosphere and organizational culture. One hundred thirty-eight respondents (69.3%) rated it as 5, and 43 respondents (21.6%) rated it as 4. In total, 181 respondents (90.9%) considered this factor important. Only 6 participants (3%) selected a neutral rating, and 12 respondents (6%) rated this factor as rather or completely unimportant. The mean score for this factor was one of the highest, at 4.53. The factor least frequently rated positively was the opportunity to compete with other employees (e.g., rankings, contests). Only 20 respondents (10.1%) considered this factor very important, and 42 respondents (21.1%) rated it as rather important. Neutral responses were selected by 66 respondents (33.2%), while 71 participants (35.7%) rated this factor negatively, with 42 giving a rating of 2 and 29 giving a rating of 1. The mean score was 2.91.

The analysis of non-material, non-salary factors related to professional development among representatives of Generations Y and Z allows for several important observations. The mean scores of the three groups of factors are relatively similar: development and education - 4.05; support and implementation - 4.10; relationships and work environment - 3.96.

All three areas achieved values above 3.9 on a scale from 1 to 5, indicating that respondents consider each area significant when choosing a workplace. The differences between the mean scores are small, suggesting that no single motivational factor dominates and that young candidates attach similar importance to opportunities for development, workplace support, and relationships with colleagues. In the development and education group, the ratings of

individual factors were very consistent (4.04, 3.93, 4.16, 4.06). The absence of extreme values indicates that all elements related to personal development and education are relatively equally valued by respondents. In the support and implementation group, slightly larger differences were observed between factors (3.99 and 4.22), suggesting that some forms of support are perceived as more valuable than others. The most varied results were recorded in the workplace relationships and environment group (4.53, 4.45, 2.91).

The initial H2 assumed that job-seeking representatives of Generations Y and Z value factors related to personal development and education the most. The data partially confirm this assumption - development and education received a high mean score (4.05); however, it did not significantly exceed the mean scores of other areas, particularly support and implementation (4.10). This indicates that, while personal development and education are important, young candidates equally value receiving support at work and building relationships in the professional environment.

The next stage, aimed at verifying H3, was divided into two parts. In the first part, respondents were asked to evaluate non-material, non-salary factors related to work time organization, which could significantly influence employment comfort and the flexibility in performing tasks.

Table 4.

Evaluation of non-material, non-salary factors related to work time organization

Factor	Rating					μ	σ
	1	2	3	4	5		
Possibility of remote or hybrid work	6	19	36	88	50	3.79	1.02
Flexible working hours	2	13	29	82	73	4.06	0.93
Additional days off for personal matters	2	13	17	88	79	4.15	0.90
Ability to adjust the workplace to individual needs	3	14	29	95	58	3.96	0.92

Note. μ - weighted mean; σ - standard deviation.

Source: own elaboration.

A highly rated factor in this group was flexible working hours (e.g., the ability to choose start and end times). Seventy-three respondents (36.7%) rated it as 5, and 82 respondents (41.2%) rated it as 4, totaling 155 positive responses (77.9%). Neutral responses were indicated by 29 participants (14.6%), and only 15 respondents (7.5%) provided negative ratings, of which 13 selected “rather unimportant” and only 2 selected “completely unimportant”. The mean score was 4.06 ($\sigma = 0.93$). An even higher proportion of positive ratings was observed for the factor related to additional days off for personal matters, with 79 respondents (39.7%) rating it as very important and 88 respondents (44.2%) as rather important. This results in a total of 167 positive responses (83.9%). Neutral ratings were given by 17 participants (8.5%), while only 15 respondents (7.5%) considered this factor rather or completely unimportant. The mean score was 4.15 ($\sigma = 0.90$). The possibility of remote or hybrid work was rated as very important by 50 respondents (25.1%) and as rather important by 88 respondents (44.2%). In total, 69.3% of participants assigned a positive significance to this factor. Neutral responses were

given by 36 respondents (18.1%), while negative ratings were reported by 25 participants, of which 19 (9.5%) selected a rating of 2 and 6 (3%) selected a rating of 1. The mean score was 3.79 ($\sigma = 1.02$). The fourth factor analyzed was the ability to adjust the workplace to individual needs. Fifty-eight respondents (29.1%) rated it as 5, and 95 respondents (47.7%) rated it as 4, meaning that 76.8% of participants considered this factor rather or very important. Neutral responses were provided by 29 respondents (14.6%), while 14 respondents (7%) rated it 2, and only 3 participants (1.5%) rated it 1. The mean score was 3.96 ($\sigma = 0.92$). The analysis of the results indicates that non-material, non-salary factors related to work time organization are important for the younger generation entering the labor market.

In the second part, dedicated to verifying H3, respondents evaluated the importance of non-material, non-salary factors related to environmental care and ecology as elements of the motivation system.

Table 5.

Evaluation of non-material, non-salary factors related to pro-environmental attitudes

Factor	Rating					μ	σ
	1	2	3	4	5		
Environmental initiatives in the workplace (e.g., waste segregation, reducing paper usage)	21	30	46	81	21	3.26	1.15
Access to company bicycles and electric scooters for business and personal use	30	41	73	38	17	2.85	1.15
Ability to use a "green budget" to purchase eco-friendly products or services	30	35	77	42	15	2.88	1.13
Participation in programs supporting charitable environmental initiatives	23	36	69	56	15	3.02	1.11
Access to eco-friendly gifts (e.g., eco-gift cards instead of traditional gift cards)	33	43	69	40	14	2.79	1.15

Note. μ - weighted mean; σ - standard deviation.

Source: own elaboration.

The highest-rated factor was workplace ecological initiatives, such as waste segregation or reducing paper usage. A total of 102 respondents (51% of all responses) rated this factor as 5 or 4, with 21 participants indicating "very important" and 81 indicating "rather important". Neutral responses were given by 46 respondents (23%), while 30 respondents (15%) rated it as rather unimportant, and 21 respondents (10.5%) considered it completely unimportant. The mean score was 3.26 ($\sigma = 1.15$). The factor related to participation in programs supporting ecological charitable initiatives received 15 ratings of 5 and 56 ratings of 4, totaling 35.4% positive responses. Sixty-nine respondents (34.6%) selected a neutral rating, while 59 participants (29%) gave negative responses, of which 36 rated it 2 and 23 rated it 1. The mean score was 3.02 ($\sigma = 1.11$).

Access to company bicycles or electric scooters, the use of a "green budget" (e.g., purchasing eco-friendly products), and eco-gifts (e.g., environmentally friendly gift cards) were rated as insignificant by the majority of respondents. Non-material factors related to environmental care were assessed as moderately important rather than highly valued. While

some participants recognized their value, these factors are not considered a crucial element of the motivation system. This may be because pro-environmental initiatives are perceived by the younger generation as an add-on rather than a core component of the employer's offer, especially for those entering the labor market. The overall mean score for non-material, non-salary factors related to pro-environmental practices was 2.96, which prevents full confirmation of H3.

6. Conclusions and discussion

The results of the conducted research confirm that salary factors play a key role in motivating individuals entering the labor market. Competitive salaries and performance-based bonuses received the highest ratings, indicating that for young employees, these elements constitute a fundamental condition for initiating and maintaining engagement in organizational activities. At the same time, it was observed that non-salary material factors, such as private healthcare, pension schemes, or sports and recreational benefits, have a moderate yet still significant value, serving a complementary role alongside the base salary. Particular importance was attributed to non-material factors related to professional development. A friendly work atmosphere, organizational culture, support from the team, and a clearly defined career path were identified as the most important determinants of sustained engagement among the younger generation. It was also confirmed that flexible work arrangements, including additional days off, the possibility of remote work, and flexible working hours, significantly enhance the attractiveness of an employer, while simultaneously enabling better alignment of professional and personal life. In contrast to these findings, pro-environmental factors, despite their increasing presence in public discourse, were rated relatively low. Respondents primarily perceive them as an additional benefit rather than a core component of the motivation system, suggesting that in the early stages of professional activity, financial and developmental considerations are far more important than environmental responsibility.

In light of the conducted analyses, research hypothesis H1 was confirmed, whereas H2 and H3 received only partial support. The obtained results correspond with previous studies on the preferences of Generations Y and Z. Salary constitutes the foundation of the motivation system for these groups; however, maintaining long-term engagement requires supplementing it with developmental and organizational factors that foster a sense of stability, agency, and belonging within the organization. Of particular note is the role of organizational culture and work atmosphere, which were rated highest among all analyzed factors, confirming the importance of interpersonal relationships and the work environment for young employees. These results are consistent with the findings of Surugiu et al. (2025), who indicate that Generation Z expects not only attractive financial conditions, but also an environment that supports development and autonomy.

The obtained results also indicate the growing importance of employment flexibility, particularly in the context of experiences related to the COVID-19 pandemic, which popularized remote and hybrid work models. The limited significance of pro-environmental factors may be interpreted as a consequence of the prioritization of financial and developmental aspects during the early stages of professional careers. Consequently, it can be concluded that an effective motivation system for the younger generation should be based on a combination of competitive remuneration, opportunities for development, support from organizational culture, and flexible working conditions. Pro-environmental elements serve only a supplementary role and may enhance the employer's image, but they do not constitute a primary factor determining job choice or retention. The data point to the need for a holistic approach to motivating young employees, considering developmental, social, and organizational aspects.

In the context of management practice, the research findings highlight the need to develop motivation systems that combine attractive financial conditions with opportunities for professional development and participation in a supportive organizational environment. In particular, it is recommended to design transparent career paths, implement mentoring programs, and cultivate an organizational culture that fosters collaboration and open communication. To maintain the engagement of young employees, it is also essential to provide flexible solutions regarding working hours and location, enabling a better balance between professional responsibilities and personal life. Although pro-environmental factors hold limited importance for young individuals beginning their careers, they can be regarded as an element that strengthens the organization's long-term image as socially responsible. Their implementation may help distinguish the company in the labor market, especially in the later stages of employees' careers, when the significance of non-material values may increase. The theoretical approach to the role of remuneration in the motivation process is confirmed in the study by M.A. Leśniewski and J. Berna (2012), which discusses the place of pay in motivational structures. Research on generational differences conducted by K. Lutyńska and A. Wasiluk (2023) showed that while remuneration and stability are the dominant motivators for older generations, younger generations (Y, Z) attach greater importance to interpersonal relationships, organisational culture and flexible working hours.

With regard to future research, a significant issue concerns the relationship between the motivational profile of the younger generation and the organization's adaptive capacity. This raises the question of how the needs and expectations of Generations Y and Z - such as autonomy, a sense of meaningful work, opportunities for development, and organizational flexibility - can strengthen resilience processes, support organizational learning, and enhance the effectiveness of responses to change. Addressing this question is crucial for human resource management practice, as it indicates that investing in the motivation and well-being of young employees can simultaneously constitute an investment in the resilience of the entire organization (Georgescu et al., 2024; Paszkiewicz, Wasiluk, 2022).

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RETHINKING ENTREPRENEURIAL RESPONSIBILITY IN THE ERA OF GREEN TRANSFORMATION

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Purpose: The paper aims to analyse how the legal framework of the European Green Deal reshapes the paradigm of corporate liability in EU economic law. It examines the shift from reactive, *ex post* liability to proactive, *ex ante* accountability and explores the implications of this transformation for enterprises, particularly SMEs.

Design/methodology/approach: The study applies a dogmatic analysis of EU legal acts, complemented by a review of academic literature and comparative insights. Elements of law and economics are also employed to assess the impact of regulatory instruments.

Findings: The analysis demonstrates a structural shift in EU economic law from sanction-based, reactive mechanisms to proactive obligations requiring continuous risk management, transparency, and sustainability practices. This shift creates both challenges (e.g., high compliance costs, risks for SMEs, exposure to greenwashing claims) and opportunities (e.g., improved access to green finance, reputational advantages, and competitive differentiation).

Research limitations/implications: The study is limited to the analysis of EU regulations, without empirical testing of business responses. Future research should include case studies and quantitative assessments of how enterprises adapt to new compliance obligations and their long-term effects on competitiveness.

Originality/value: This paper provides an integrated legal analysis of how the European Green Deal transforms the foundations of corporate liability in economic law. It adds value by framing compliance and ESG duties not merely as formal obligations, but as a new model of *ex ante* accountability. The study is relevant for scholars of law and management, policymakers, and business practitioners seeking to understand and navigate the evolving regulatory environment.

Keywords: economic law, green transition, responsibility of entrepreneurs, ESG.

Category of the paper: research paper, conceptual paper.

1. Introduction

The green transition may be described as one of the momentous regulatory and economic challenges of the 21st century. It is increasingly reflected in European Union law and, consequently, in the legislation of Member States. The European Green Deal, the “Fit for 55” package, and several sectoral legal acts (such as the Taxonomy Regulation, the CSRD Directive and the draft CSDDD Directive) impose new obligations on businesses in relation to environmental protection, non-financial reporting and proper risk management in value chains. As a result, not only is the way of doing business changing, but also the understanding of business responsibility under commercial law.

This responsibility was traditionally reactive. Businesses faced contractual, tortious or administrative consequences when they caused damage or violated applicable standards. However, the green transition introduces a new model – proactive responsibility – based on due diligence, transparency and the inclusion of environmental criteria in *ex ante* business decisions. This paradigm shift raises questions about the nature and scope of entrepreneurs' responsibilities, as well as their impact on the economy's competitiveness and innovation.

This article aims to examine how economic law, by shaping the proactive responsibility of entrepreneurs, redefines the framework for doing business in the context of the green transition. Particular attention is paid to EU legal instruments, which are the primary driver of change and a specific model that EU Member States must strive to achieve, but which can also inspire external legal systems (the so-called ‘Brussels effect’).

The analysis answers the following research questions: (1) how do European Union legal instruments related to the green transition change the paradigm of business responsibility, (2) what challenges does this change generate for entrepreneurs, in particular for the SME sector, (3) do environmental obligations support innovation and competitiveness, or do they constitute an excessive burden?

From a methodological perspective, the study applies a dogmatic analysis of EU law, complemented by a law and economics approach to assess the economic implications of legal obligations and by elements of comparative analysis to identify possible external impacts of EU standards. The research is qualitative and interpretative, based on the examination of key legislative acts and academic literature concerning sustainability regulation, corporate liability, and economic governance.

The hypothesis underlying the paper is that the EU's green transition instruments have transformed corporate liability from a reactive to a proactive model, thereby redefining the foundations of business responsibility and the conditions for competitiveness within the European market.

The significance of this study lies in its comprehensive synthesis of different legal mechanisms of the green transition showing how they construct a coherent system of *ex ante* accountability. This synthesis addresses a research gap in existing literature, which tends to analyse each regulatory instrument in isolation.

The structure of the paper includes, in turn: a discussion of the classic and new dimensions of corporate responsibility, an analysis of the legal instruments of the green transition, an assessment of the challenges and implications for economic practice, and the formulation of conclusions and proposals *de lege ferenda*.

2. Methods

The study adopts a qualitative and interpretative research design typical of legal sciences. Its aim is to determine how EU legal instruments related to ecological transformation are changing the framework of corporate responsibility. The methodological approach combines dogmatic legal analysis and law and economics, supplemented where necessary by limited contextual comparison.

Firstly, the dogmatic method serves as the basic analytical framework. It focuses on the interpretation and systematic analysis of existing EU legal acts and their implementation in Member States. This includes a detailed analysis of the Corporate Sustainability Reporting Directive (CSRD), the Corporate Sustainability Due Diligence Directive (CSDDD), the Carbon Border Adjustment Mechanism (CBAM) Regulation and the Ecodesign Regulation for Sustainable Products (ESPR). The aim is to identify the normative mechanisms through which these instruments establish proactive corporate responsibility and impose preventive obligations on companies.

Secondly, the law and economics perspective is used to assess the functional and economic effects of these legal obligations. This approach allows us to answer the question of whether sustainability regulations promote innovation, competitiveness and effective risk management. Or do they generate excessive compliance costs that may hinder the functioning of businesses?

Finally, the study occasionally refers to comparative or contextual observations, particularly with regard to the so-called ‘Brussels effect’ and the potential impact of EU standards in this area on other legal systems. However, these comments serve only as contextual background and not as a systematic comparative analysis.

The study is not based on empirical or quantitative data. Instead, it is based on a textual interpretation of legal provisions, academic literature and official EU policy documents. It is supported by secondary sources such as European Commission reports and doctrinal studies.

3. Results of legal analysis

In This section presents the results of the legal analysis in an objective and descriptive manner, without normative interpretation. The focus is on identifying how the relevant EU legal instruments establish proactive forms of business responsibility and reshape the obligations of entrepreneurs in the context of the green transition.

3.1. Conceptual framework and typology of business liability

3.1.1. *Traditional legal liability*

In commercial law, the liability of entrepreneurs has traditionally been divided into two basic categories: civil and administrative. Both are rooted in classical legal doctrine and focus on the response of public authorities or contractors to a specific violation that has already occurred.

Firstly, the civil liability of an entrepreneur covers both contractual and tortious matters. In contractual terms, an entrepreneur is liable to their contractor for non-performance or improper performance of an obligation. In a market economy, this means, for example, liability for delays in delivery, product defects or the provision of services not in accordance with the contract. In tort, an entrepreneur may be liable for damage caused to another entity – examples include pollution causing damage to the health of residents of neighbouring areas or property damage caused by a defective product. In both cases, the key element is the occurrence of damage and the possibility of demonstrating a causal link between the entrepreneur's action (or omission) and the effect.

Secondly, administrative liability is a concept of public law, which entails the imposition of sanctions by state authorities or other regulatory bodies. The areas in which it occurs include environmental protection, competition law, consumer law, and labour law. Sanctions may include financial penalties, revocation of licences, prohibition of certain activities, or the obligation to restore a lawful state of affairs. As in the case of civil liability, this mechanism was reactive – triggered only after a violation of a legal norm had been detected.

Thirdly, an entrepreneur may incur criminal or fiscal liability if their actions constitute a prohibited act. In practice, this refers to both classic economic crimes, such as fraud (for example, in Polish law it is described in Art. 286 of the Penal Code [KK]), corruption (Art. 296a KK) or document forgery (Art. 270-271 KK), as well as environmental offences (Art. 180-188 KK) or omissions leading to serious threats to health or life (Art. 165, § 1 KK).

All three dimensions of liability take as their starting point a past event resulting in damage or a breach of a legal norm. Their common feature is therefore their reactive nature and compensatory or repressive-preventive function. In the traditional model of commercial law, however, there is no requirement to systematically anticipate and prevent risks *ex ante*, and the burden of proof and the initiative to act rest with the injured party or the public authority.

3.1.2. *Compliance as a new dimension of liability*

As the regulatory environment becomes increasingly complex and the concept of corporate governance continues to evolve, a new category of responsibility related to ensuring compliance with regulations is emerging. Its essence is no longer just a reaction to violations of legal norms, but the permanent incorporation of mechanisms that minimise the risk of non-compliance with the law and ethical standards into the organisational structure of the company.

Therefore compliance can be conceived as shifting the burden of responsibility from the *ex post* level (responsibility for the consequences of violations) to the *ex ante* level (responsibility for failure to exercise due diligence in preventing violations). Entrepreneurs are no longer solely liable for damages or offences, but also for failing to implement appropriate supervisory, control and preventive procedures that should be in place in a given industry and for given risks. In practice, this means, for example, the obligation to implement compliance management systems in accordance with ISO 37301 guidelines, as well as the appointment of a compliance officer who will be responsible for monitoring legal and ethical risks. Additionally, it is necessary to develop and enforce codes of ethics, anti-corruption policies and whistleblowing procedures.

This new dimension of responsibility is particularly evident in EU regulations. As an example, we can point to the Whistleblower Protection Directive (2019/1937/EU) requires medium-sized and large companies to establish channels for reporting violations. The Corporate Sustainability Reporting Directive, in turn, introduces a non-financial reporting requirement, which means liability for any lack of transparency in the area of sustainable development. The “Fit for 55” package and the EU ETS system imply the need for ongoing monitoring of emissions and adjustment of production processes – not only from the perspective of compliance, but also corporate responsibility. Finally, there are regulations on personal data protection (GDPR), anti-corruption, anti-monopoly and cybersecurity policies.

Compliance responsibility, therefore, plays a dynamic, proactive and forward-looking role. It involves a continuous process of identifying and minimising risks, rather than merely responding to their consequences. Unlike traditional forms of responsibility, where it was sufficient to ‘act in accordance with the law’, here the entrepreneur is required to actively manage legal risk and demonstrate that they have taken all appropriate organisational and technical measures to prevent violations.

3.1.3. *A paradigm shift: from ex post to ex ante*

An analysis of the above dimensions of business liability – classic (civil, administrative and criminal) and compliance – reveals a fundamental paradigm shift in commercial law. Traditionally, the *ex post* model prevailed, in which liability was triggered only after the occurrence of a damaging event or a violation of a legal norm. In the context of the green transition, however, an *ex ante* model is emerging, based on proactive risk management, due diligence and transparency of economic processes. This paradigm shift also means a change in the role of commercial law from a traditionally reactive system of sanctions towards

a specific framework of risk management and proactive liability. It is becoming important for entrepreneurs to ensure that their business decisions take into account both environmental and social risks as well as regulatory requirements, and that their effectiveness can be documented and verified. In this way, this classic responsibility is complemented by compliance mechanisms, creating a coherent system of *ex ante* accountability, which is the foundation of modern economic law in the era of green transition.

3.2. Legal instruments shaping proactive liability

As mentioned in the previous chapter, the green transition introduces new obligations for businesses that are proactive in nature and require risk management throughout the entire value chain. EU economic law and its implementation in national legislation provide businesses with both a regulatory framework and tools to enforce such actions. An analysis of EU legislation enables us to identify the primary legal instruments that shape proactive responsibility. An overview of these instruments, which is obviously brief, is presented below.

3.2.1. Environmental, Social and Governmental reporting

A specialised aspect of compliance is ESG responsibility, which, in the context of the green transition and the EU Green Deal, plays a key role in ensuring transparency and disclosure of information. Its essential element is the obligation to disclose non-financial data concerning not only the economic condition of an entity, but also its impact on the environment, society and governance. Companies will have to report, among other things, greenhouse gas emissions, the carbon footprint of their products, energy and water consumption, their impact on biodiversity, social policy and ethical management.

The legal instruments shaping this dimension are:

1. 2022/2464/EU Corporate Sustainability Reporting Directive (CSRD), which imposes an obligation on a wide range of businesses to prepare sustainability reports based on uniform European Sustainability Reporting Standards (ESRS). The key provisions are contained in Article 1, which amends Directive 2013/34/EU concerning: Article 19a (reporting requirements in the annual report), Article 29a (scope of information to be disclosed) and Articles 29b to 29d (application of ESRS and verification of reports).
2. 2020/852 Regulation on EU taxonomy (Taxonomy Regulation) defines what activities can be considered environmentally sustainable, and therefore what information should be reported in the area of green investment financing. Of particular importance are Article 3 (criteria for considering economic activities to be environmentally sustainable), Article 8 (disclosure obligations for companies) and Articles 9-15 (specific environmental objectives).
3. 2019/2088 Sustainable Finance Disclosure Regulation (SFDR) introducing the obligation to report and classify financial products in terms of ESG. The most important provisions are Article 3 (disclosure of policies on sustainability risks), Article 4 (disclosure of principal adverse impacts), Articles 6–10 (disclosures for financial institutions and investment products) and Article 11 (periodic reporting).

These requirements apply to both large enterprises and selected medium-sized companies operating in sectors of particular importance. The scope will be gradually expanded. The responsibility they impose is systemic and preventive in nature – its purpose is not only to punish for lack of information, but above all to ensure that the decisions of investors, consumers and regulators are based on reliable, comparable and complete data. These regulations not only serve to increase transparency, but also require the effective management of ESG risks in everyday business practice. Hiding or manipulating data may lead to administrative sanctions, civil liability or loss of stakeholder trust. Articles 29b and 29c of the CSRD therefore introduce a proactive accountability mechanism, integrating reporting obligations into the strategic decision-making process in companies.

However, ESG responsibility is not limited to meeting formal reporting requirements. It also includes the need to publish a report, but above all, to ensure the quality and reliability of data through external auditing of reports (Article 34 CSRD). Consistency between the reported information and the company's actual practices is also important. A lack of consistency can lead to legal, financial and reputational consequences. Furthermore, ESG reporting should be integrated into the management strategy so that it is not just a formality, but a tool for real change in the functioning of the company.

3.2.2. Due diligence

The Corporate Sustainability Due Diligence Directive (CSDDD) entered into force in July 2024. It introduces a duty of care with regard to human rights and environmental protection, which companies must apply not only within their own activities but also in relation to their subsidiaries and the entire chain of activities. The scope of the directive primarily covers large EU companies that meet specific employment and turnover criteria. Although the provisions of the directive do not directly cover small and medium-sized enterprises, its entry into force will also have an impact on them (MFiPR, 2024). This is because SMEs often operate as subcontractors or suppliers to large companies that are required to report. It means that corporations will require their contractors to provide ESG data to fulfil their own reporting obligations.

The directive provides that companies will be required to conduct their business in a manner that systematically incorporates due diligence into corporate policy and risk management (Article 7). It means that they must identify and assess the actual and potential negative impacts of their activities and then rank them according to their severity and significance (Articles 8-9). In practice, this involves both the obligation to take preventive measures against potential risks (Article 10) and the need to eliminate the effects of risks that have already occurred and to apply remedial measures (Articles 11-12). The directive also emphasises dialogue with stakeholders, treating cooperation and consultation as an integral part of due diligence (Article 13). Companies will also have to provide complaint mechanisms to enable concerns about the negative impacts of their activities to be raised (Article 14), as well as monitor the effectiveness of the measures taken and adapt them to changing conditions (Article 15). These obligations

are not only internal in nature, as they also include a requirement for transparency through the annual publication of reports on their websites on issues covered by the directive (Article 16). The list of obligations is supplemented by the need to adopt and implement a transition plan aimed at mitigating the effects of climate change (Article 22). Finally, if they fail to meet these obligations, companies will be liable for damages resulting from the negative effects of their activities, as expressly provided for in Article 29 of the CSDDD.

EU Member States are required to transpose the directive within two years of its entry into force.

3.2.3. Emissions Trading Systems and Carbon Border Adjustment Mechanism

Another instrument of EU green law is the EU ETS (European Emissions Trading System) and the CBAM (Carbon Border Adjustment Mechanism). They aim to internalise the costs of greenhouse gas emissions (in line with the ‘polluter pays’ principle) and integrate them into economic transactions, which means that they become part of the market game (e.g. trading in CO₂ emission allowances). The ETS requires companies to hold allowances corresponding to their actual emissions (Article 12(3) of Directive 2003/87/EC), but these allowances are not only a regulatory tool, they are also traded on the secondary market (Article 3(a) and Article 12(1)). It means that a company that reduces its emissions below the allocated limit can sell its surplus allowances to other entities, while a company that exceeds the limit must purchase them in order to meet its regulatory obligations. Failure to obtain allowances results in administrative penalties (Article 16). This solution forces businesses to systematically monitor their emissions and take measures to reduce them, as otherwise the costs of purchasing additional allowances may significantly limit their economic activity.

CBAM, in turn, introduced by Regulation (EU) 2023/956, was conceived as a mechanism complementing the ETS, aimed at counteracting the phenomenon of carbon leakage (the transfer of production by companies to countries where greenhouse gas emission regulations are less strict than in their home country), and thus to level the playing field between EU producers and entities from third-countries. CBAM imposes on importers of certain goods – including cement, steel, fertilisers, aluminium and electricity – the obligation to disclose the carbon footprint of products placed on the EU market. In addition, they must submit CBAM declarations containing information on emissions associated with the production of imported goods (Articles 6-8) and are required to surrender a corresponding number of CBAM certificates corresponding to the carbon footprint of the goods (Article 22). Importers must therefore not only keep detailed records of emissions throughout the production cycle, but also have the data verified by accredited verifiers (Article 18). As a result, the costs associated with greenhouse gas emissions incurred by producers in the EU are to be aligned with those of entities outside the Union, to maintain competitiveness and counteract the relocation of production outside the EU.

Although both the ETS and CBAM serve the same purpose – reducing greenhouse gas emissions by incorporating their costs into economic activity – they differ in scope and mechanism of operation. The ETS acts as an incentive to reduce emissions within the EU economy, while the CBAM acts as a border mechanism to protect the internal market.

3.2.4. Circular economy and Extended Producer Responsibility

The concept of circular economy in the EU assumes production and consumption in which resources are used as efficiently as possible through sharing, renting, reusing, repairing, refurbishing and recycling materials and products so that they remain in economic circulation for as long as possible (Kirchherr et al., 2017). Implementing this concept requires both design regulations and producer responsibility for the life cycle of products, which is achieved through mechanisms such as the Ecodesign for Sustainable Products Regulation (ESPR) and Extended Producer Responsibility (EPR).

The ESPR Regulation requires businesses to design products in line with sustainability principles, including durability, repairability, reusability and recyclability (Articles 4-6). The most important instrument supporting the implementation of these requirements is the digital product passport, which allows regulators and consumers to access data on the composition, disassembly options and environmental parameters of products (Article 8). Compliance with ESPR regulations is a prerequisite for the legal marketing of products in the EU, and violations may result in administrative sanctions and contractual liability (Article 59).

At the same time, the extended producer responsibility (EPR) mechanism obliges businesses to take responsibility for waste generated at the end of a product's life cycle, including packaging, power tools and electrical and electronic equipment. Under EU law, these obligations arise from Directive 2008/98/EC on waste and Directive 2018/852/EU on packaging and packaging waste. It means that products must be designed in a way that facilitates their reuse and recycling, that collection and waste management systems must be financed, and that detailed reporting on packaging and products placed on the market must be carried out (Articles 8 and 8a of Directive 2008/98/EC). The implementation of EPR is proactive, requiring businesses to take steps to prevent waste generation and cover the costs of improper waste management.

The circular economy combines ESPR and EPR mechanisms. This creates a clear regulatory system. Here, design duties and product lifecycle responsibilities work well together. Products designed in accordance with ESPR requirements, taking into account durability, reparability, reusability and recyclability, become easier to handle in EPR systems, where businesses are responsible for waste and for financing collection and recycling systems. This combination of mechanisms allows companies to effectively manage environmental risks, minimise the costs of improper waste management and ensure compliance with reporting requirements.

3.3. Challenges for entrepreneurs

The transition towards a sustainable economy poses a number of legal, organisational and financial challenges for businesses.

Firstly, we should point out the legal and administrative consequences. The green transition involves, among other things, detailed non-financial reporting requirements – companies must collect, verify and publish vast amounts of data on their environmental, social and corporate governance (ESG) impact. It requires the implementation of digital tools to monitor emissions, resource consumption and social indicators, as well as linking this data to traditional financial reporting. In addition, it may be necessary to hire sustainability specialists, use the services of consultants or develop new internal compliance procedures. Due diligence, in turn, is the obligation to actively identify, prevent, mitigate and account for negative human rights and environmental impacts throughout the value chain, both among direct suppliers and subcontractors. It will necessitate the formulation of appropriate ESG clauses in contracts. This is a huge logistical and legal challenge. Finally, CBAM involves complex reporting of embedded emissions in imported goods and annual settlements. It requires thorough auditing of suppliers in terms of their carbon footprint and social standards (dependence on a supplier from a country with a high carbon footprint will become a business risk). Failure to comply with reporting obligations (e.g. under the CSRD) may result in severe administrative penalties. The due diligence directive, in turn, paves the way for holding companies civilly liable for damage they have failed to prevent in their supply chain.

Secondly, the considerable costs of implementing new regulatory obligations are not insignificant. These include the need to introduce emission monitoring systems, purchase emission allowances (ETS), collect, process and validate non-financial data (ESG), and conduct environmental and social audits (Böning et al., 2023). In addition, there are the costs of redesigning products to meet circularity requirements (ESPR). In reality, many companies, including SMEs, without an established sustainability framework, will face a lack of adequate resources – both capital and human resources – which may lead to the risk of competitive marginalisation in relation to large entities that are quicker to adapt to new regulations (Dempere et al., 2024).

Another challenge is the legal and reputational risk associated with so-called greenwashing. Directive 2024/825 on empowering consumers for the green transition requires businesses to avoid unjustified environmental claims, misleading labels or unsubstantiated climate declarations. Similarly, the disclosure of negative practices in the supply chain (e.g. child labour, environmental pollution) can lead to immediate and severe boycotts by consumers or partners. As a result, communication and marketing activities must be consistent with actual data. A lack of such consistency may result not only in administrative sanctions provided for in consumer law (Directive 2005/29/EC on unfair commercial practices), but also in a loss of consumer confidence and even exclusion from sustainable financing. Therefore, it is necessary not only to collect data, but also to verify and control its quality.

However, the green transition also generates new competitive opportunities (Dempere et al., 2024; Szendrey et al., 2024). Entities that quickly and effectively implement pro-environmental solutions may gain easier access to financing from investors (Redondo Alamillos, de Mariz, 2022; Kosztowniak, 2023; Mormile et al., 2025) – both through the classification of activities in accordance with the Taxonomy Regulation and through the disclosure requirements set out in the SFDR. In this sense, the challenges associated with implementing new regulations are twofold: on the one hand, they represent a cost and a risk, and on the other, they can be a driver of innovation, strengthening a company's market position, as well as enhancing its reputation and ability to attract investors focused on sustainable development (Hummel, Bauernhofer, 2024; Dvorský et al., 2020).

4. Discussion

An analysis of green transition instruments and related models of corporate responsibility confirms what we have pointed out at the beginning of this paper: the paradigm of corporate responsibility in commercial law is shifting from reactive to proactive. While the classic categories of civil, administrative and criminal law were based on *ex post* sanctions, the new EU mechanisms focus on risk management and the prevention of negative effects of economic activity. This change aligns with sustainable development. However, it also brings up several controversies and challenges in both theory and practice.

Firstly, the competitiveness of the European economy in the face of global regulatory competition remains a significant problem. The EU has developed a comprehensive system of obligations, which raises the question of whether such a strict approach will lead to ‘regulatory arbitrage’, whereby businesses relocate part of their production to countries with less restrictive regulations. In this context, the so-called ‘Brussels effect’, i.e. the global expansion of EU standards beyond the borders of the Community (Redondo Alamillos, de Mariz), is of significant importance. On the one hand, it allows for the unification of the rules of international trade, but on the other hand, it risks regulatory tensions and trade disputes with third countries (Böning et al., 2023).

Secondly, the role of the SME sector requires special consideration. Although these enterprises are not formally covered by many new regulations, in practice they are indirectly affected by them through obligations imposed by larger contractors and financial institutions. Moreover, the challenges and burdens for SMEs in adapting to green transition obligations are much greater than for large enterprises (Györi et al., 2025). This raises questions about the proportionality of regulatory burdens and support mechanisms for SMEs, which often lack the resources necessary to meet ESG, reporting or due diligence requirements. The discussion in

this area focuses on whether the EU model of green transition leads to an asymmetrical burden on the smallest entities in the economy (Galkiewicz, Gaßner, 2023).

Thirdly, it is worth noting the growing debate in doctrine concerning the relationship between public law liability and corporate liability (Smith, 2018). Critics point out that transferring quasi-regulatory tasks to businesses – such as supplier control or emissions monitoring – may blur the state's responsibility for implementing environmental and social policy objectives. Hormio (2017) emphasises that while corporations may have a moral liability to mitigate climate change, the transfer of certain regulatory roles to the private sector raises concerns about a reduction in the state's responsibility for achieving policy objectives related to social and environmental responsibility. Furthermore, Slawinski et al. (2016) argue that such delegation may result in companies prioritising short-term profits over long-term sustainability, as the public does not perceive the urgency of environmental issues such as climate change. On the other hand, proponents emphasise that it is companies, as the main drivers and beneficiaries of economic processes, that should play a leading role in shaping a sustainable development model. They are in best position to implement sustainable practices and innovations (Cheng et al., 2013). Furthermore, Naseem et al. (2019) emphasise that socially responsible corporate practices, although potentially detrimental in the short term, can increase long-term company value and improve financial performance. Taking care of our environmental responsibilities helps build a good reputation in the market and is crucial for earning the trust of stakeholders (Zhang, 2021). We can therefore see that critics emphasise the risk of weakening state control and accountability, while supporters argue for a significant contribution by corporations to promoting sustainable practices. Both sides have valid arguments, which is why a shared responsibility model is worth considering: the state should set standards and enforcement mechanisms, while also requiring businesses to contribute to sustainable development policies and offering them incentives to do so. In this way, public and corporate responsibility are not competitive but complementary. In other words, neither full nationalisation nor full privatisation, but a partnership with clear rules and state supervision.

Finally, the question of the further development of the legal framework for green transition is still open. We can expect further standardisation of reporting and ESG indicator measurement methodologies, the extension of obligations to an increasingly wider group of companies, and intensified international cooperation within the WTO, OECD and UN forums. We can also expect an increase in the role of court and arbitration disputes, in which the practices of entrepreneurs in the areas of reporting, greenwashing and due diligence will be verified. Thus, the green transition is not only changing the rules of the game in the European economy, but also becoming a new field for the development of economic law dogma and interdisciplinary research.

In light of the complexity and burdens that the green transition imposes on businesses in the European Union, several conclusions *de lege ferenda* (proposals for future legal changes) can be formulated. These proposals may contribute to resolving or at least mitigating the

compliance, support and competitiveness issues arising from the introduction of the mechanisms discussed in this paper. They focus on creating a more favourable legal and operational environment for entrepreneurs, while ensuring the desired results in terms of sustainable development.

One of the challenges facing businesses is the complexity of environmental regulations and the difficulties associated with complying with them. One solution could be to introduce a harmonised and simplified compliance framework that integrates the requirements of different regulatory mechanisms. Such a framework would not only reduce the administrative burden but also increase transparency. This would be particularly important for SMEs, which often lack the resources to navigate a complex legal environment efficiently. As Herman (2018) points out, targeted efforts are needed to harmonise the legislative approach in Member States – especially those with lower levels of innovation – to promote competitiveness and alleviate compliance difficulties.

In the face of economic pressure resulting from green transition regulations, it is becoming paramount to develop supportive policies that stimulate innovation rather than hinder it. Appropriately targeted financial instruments – such as grants, subsidies or tax breaks – tailored to the needs of companies implementing sustainable practices can significantly reduce their costs. Such solutions would promote the dissemination of greener technologies and operating models, while supporting the alignment of business practices with environmental objectives (Cf. Arenal et al., 2021). Promoting public-private partnerships could also be a key element. These could enable businesses to collaborate with government institutions on sustainable development projects, supporting innovation and reducing the financial burden of compliance.

The need to develop entrepreneurial potential through education has been repeatedly emphasised in EU policies. The European Commission highlights the importance of integrating entrepreneurship education into an innovative framework, thereby supporting businesses in adapting effectively to new regulatory conditions. In particular, it recommends improving educational programmes focused on sustainable development. It would promote entrepreneurs to better understand and implement green technologies and practices in line with the EU's environmental objectives. Providing comprehensive training and educational resources can substantially assist entrepreneurs in overcoming the adaptation challenges they encounter.

It seems reasonable to review the methodologies used in regulatory impact assessments. They should include a detailed analysis of the obligations imposed on businesses. Current regulatory impact assessments often overlook certain difficulties which smaller businesses face. This review should cover not only the economic consequences, but also the ability of entities to meet the requirements and the potential impact of such regulation on the level of innovation. It could contribute to a better reflection of the realities of business and promote a more balanced approach that combines the achievement of environmental objectives with the maintenance of business profitability.

In the pluralistic regulatory environment of the European Union, it is reasonable to facilitate cross-border cooperation between Member States in the exchange of best practices and strategies for compliance with green transition regulations. Such initiatives can promote mutual learning, support entrepreneurs across Europe and contribute to a more coherent business environment. To this end, it is worth considering the establishment of mechanisms such as transnational innovation centres that would enable entrepreneurs to collaborate on solving environmental problems and sharing resources (cf. Duraj, 2024).

The conducted analysis confirms the initial hypothesis that EU green transition instruments have transformed the concept of corporate liability from a reactive model to a proactive one. This shift redefines not only the regulatory environment of entrepreneurship but also the balance between legal compliance and competitiveness in the European market.

5. Conclusion

The analysis conducted in this paper indicates that the green transition is leading to a paradigm shift in corporate liability under EU economic law. Traditional reactive mechanisms based on civil, administrative or criminal liability are being supplemented – and in some cases even replaced – by proactive instruments that require businesses to engage in continuous risk management, reporting and transparency of their activities. This is particularly evident in regulations such as ESG, due diligence and CBAM. Regulations are shifting towards tougher enforcement, with rising demands for openness and greater accountability when it comes to environmental issues (Fuster-Navarro et al., 2025).

These processes generate challenges for businesses, (including SMEs) which are exposed to high costs of implementing new mechanisms and the risk of competitive marginalisation. At the same time, however, they create opportunities to increase innovation, access green financing and build a reputational advantage in the global market. In this context, it is reasonable to ask about the appropriate division of roles between the state and business in achieving sustainable development goals. It seems that the optimal solution is a model of shared responsibility, in which the state retains the function of setting standards and supervision. Companies, on the other hand, contribute through innovation and the implementation of practices that comply with the new requirements.

From a *de lege ferenda* perspective, it seems reasonable to simplify and harmonise the regulatory framework, provide adaptation support for SMEs and develop cross-border cooperation mechanisms. In order to respond to the long-term consequences of the green transition, the legal framework should evolve so as to adequately capture the challenges confronting entrepreneurs. This would enable the EU to strike a balance between the attainment of sustainable development goals and the practical realities of business operations, particularly

within the SME sector. Such an approach would not only promote greater compliance with regulations, but also stimulate innovation and competitive practices in line with the overarching objectives of the European Green Deal.

This study is limited to the analysis of EU-level legal acts and selected academic sources. It does not examine the practical implementation of these instruments in the Member States or their empirical effects on business operations. Therefore, the conclusions have a theoretical and interpretative nature. Future research could address these aspects, including comparative evaluation of national transpositions and enforcement practices.

Further research should also aim to assess the effectiveness of these tools in practice. In addition, it should also analyse the extent to which the European model can serve as a reference point for global solutions. The green transition is not a one-off process, but a dynamic one. Its legal and economic implications will shape business practice and economic law theory for decades to come.

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THE EFFECTIVENESS OF CUSTOMER SERVICE ON DIGITAL PUBLISHING

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Purpose: This study focuses on identifying trends and barriers in the effectiveness of customer service on digital publishing platforms. Through a series of rigorous academic and industry literature analyses, this study aims to bridge the knowledge gap by providing a comprehensive understanding of customer service in this area.

Design/methodology/approach: Boolean operators and relevant keywords were used to search academic databases. Articles and reports from 2010-2024 were selected based on specific criteria. Data on customer service models, trends, and challenges were extracted and qualitatively analyzed to identify key patterns, presented through narrative synthesis.

Findings: The study revealed main customer service trends on digital publishing platforms, including proactive support, self-service knowledge bases, AI chatbots, personalized interactions, and universal service models. Key barriers included scaling difficulties, diverse customer needs, data privacy issues, integration challenges, maintaining human touch in automation, and DRM-related concerns. Efficiency was assessed using CSAT, NPS, AHT, FCR, CES, and churn rate.

Research limitations/implications: Limitations of the study included focusing on English-language publications, restricted access to confidential industry information. The effectiveness of the search strategy was inherently dependent on the keywords and search strings used. The qualitative nature of synthesis precludes efficiency measurement using quantitative criteria. Further empirical research is needed, particularly case studies on specific AI implementations, quantitative studies on personal help impact, and cross-cultural customer service expectation comparisons.

Practical implications: Digital publishers should invest in advanced analytics, expand DRM- and device-focused self-service resources, implement intelligent chatbots with escalation options, strengthen CRM systems, train staff for diverse users, and ensure data privacy through clear policies and strong cybersecurity. The study highlights how digital connections reshape interaction, autonomy, and privacy, emphasizing the need to maintain empathy in technologically advanced support systems.

Originality/value: This study enhances educational knowledge of customer service in a specific digital publication field by providing a focused comparative analysis and practical suggestions for improving customer service tactics, which can foster client loyalty and sustain growth in this rapidly evolving sector.

Keywords: Customer Service, Digital Publishing, Digital Rights Management (DRM).

Category of the paper: Advanced Literature Study.

1. Introduction

The introduction should specify the research methodology and hypotheses, define the study's purpose and significance, and highlight the novelty of its findings. The current version has been shortened for clarity and focus. A portion of the methodological content has been moved to the *Methods* section.

There has been growing consumer demand for instant access to digital content. According to *Market.us* (2025) and *ResearchAndMarkets* (n.d.), the global digital publishing market is projected to reach **\$248 billion by 2034**, with a **CAGR of 9.8%**. Technological advancements and widespread internet access are the main drivers of this growth. North America remains the leading market in news, education, and entertainment.

In the digital era, customer satisfaction and retention are crucial to business success. *Zendesk* (2025) notes that even a single negative experience can cause consumers to switch to competitors, whereas strong satisfaction fosters loyalty and repeat purchases. Retaining clients enhances customer lifetime value (CLV), brand reputation, and revenue stability (*NotifyVisitors*, 2024; *Thinkific*, 2025).

Customer service has evolved from basic support to a strategic component of business, emphasizing personalized, omnichannel interactions (*Altitude Internet*, 2024; *Reply*, n.d.). Organizations now use live chat, social media, email, and AI-driven automation to deliver seamless experiences (*Ozonetel*, 2024; *IBM*, n.d.). However, the effectiveness of customer service within digital publishing platforms remains underexplored.

Unique challenges, such as Digital Rights Management (DRM), piracy, market saturation, and device compatibility—require tailored solutions to address user issues efficiently (*MyCVCreator*, n.d.). Poor content management can negatively affect user experience (*CloudPublish*, n.d.; *Lumina Datamatics*, n.d.). Balancing AI efficiency with human empathy is a persistent challenge (*Noon Dalton*, n.d.; *OMQ*, 2024*).

This study aims to fill this research gap by analyzing trends, barriers, and performance metrics in customer service for digital publishing platforms. Figure 1 illustrates the typical customer service process from inquiry to resolution.

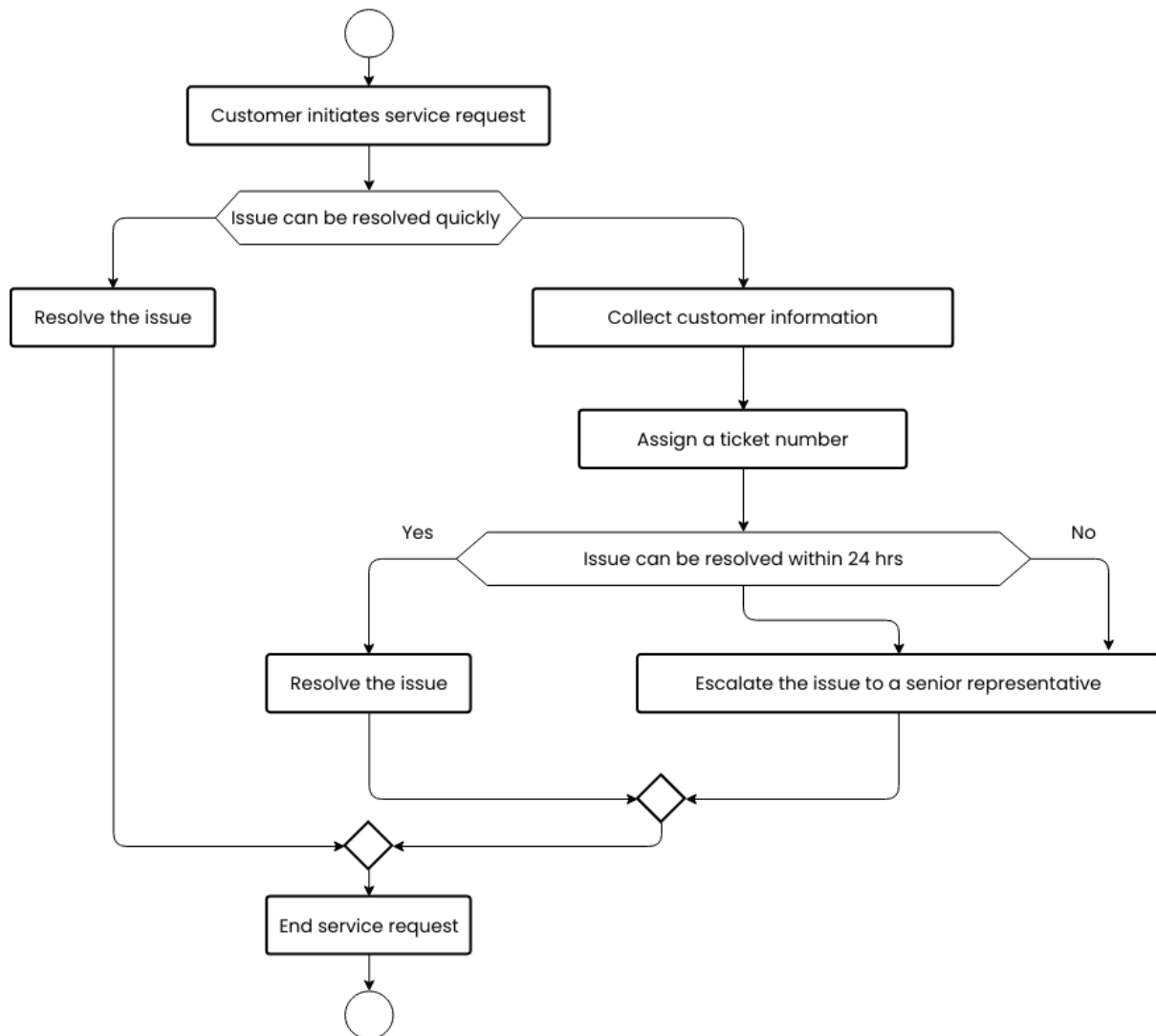


Figure 1. Customer Service Flowchart.

Source: Visual Paradigm (2023).

1.1. Problem Statement

Digital customer service in publishing platforms faces specific issues such as DRM restrictions, device compatibility, and piracy. Understanding these challenges is essential for improving user experience and fostering loyalty. This study analyzes the trends and barriers shaping customer service in digital publishing, emphasizing the balance between AI efficiency and human interaction.

1.2. Research Aims and Objectives

The study's main goal is to examine the patterns and challenges influencing customer service success on digital publishing platforms.

Research Questions:

- What are the key developments in customer service delivery on digital publishing platforms?
- What barriers hinder effective customer support in digital publishing?
- How is customer service effectiveness typically measured in this context?

Objectives:

- Identify major trends in customer service (e.g., automation, AI, proactive and self-service models).
- Analyze barriers to effective support, including technical, operational, and content-specific factors (e.g., scalability, DRM, data privacy).
- Review performance metrics used to assess service effectiveness (e.g., churn rate, resolution time, satisfaction).
- Provide practical recommendations to enhance digital publishers' customer service strategies.

2. Methodology

2.1. Literature Search Strategy

A comprehensive search was conducted across reputable databases, such as Web of Science, Scopus, IEEE Xplore, ACM Digital Library, and Google Scholar. Results on customer service efficiency in digital publication platforms were analyzed effectively. These databases were selected due to their extensive collections of academic papers, conference proceedings, and peer-reviewed journals. They offer the wide-ranging yet targeted breadth required for an advanced literature review, as Booth et al. (2012) suggested. A combination of precise keywords and search terms, utilizing Boolean operators (AND, OR), was employed to efficiently locate relevant literature. Initial keywords like "Customer Service Digital Publication", "Customer Assistance eBook Platform", "User Experience Online Material", and "Reader Engagement Publishing", was complemented by more focused terms such as "AI Customer Service Publication", "Chatbots Digital Media", "Self-service material platform", and "customer retention digital media" to capture new trends. The search technique, as illustrated by Okoli and Schabram (2010), prioritized relevant articles while reducing irrelevant noise to facilitate keyword expansion and refinement.

To ensure that the chosen articles were of the required quality and applicable, certain inclusion and exclusion criteria were applied methodically.

Inclusion criteria comprise:

- a. Conference papers, peer-reviewed journals, and credible reports.
- b. Publications written in the English language.
- c. Research specifically addressing customer service, customer support, or customer experience in digital publishing or content distribution systems (e.g., streaming content services, digital magazines, online journals, and eBooks).
- d. Given the quick development of digital technology and customer service procedures (from 2010-present), articles written during the previous ten to fifteen years were considered current.

Exclusion criteria include:

- a. Grey literature, such as blog entries and opinion articles, unless they include substantial, properly cited empirical evidence or professional analysis that is directly relevant to the scope.
- b. Research on customer service in retail or physical publishing settings without a definite focus on digital publication.
- c. Articles that mostly discussed marketing or content production without a clear connection to customer service exchanges.
- d. Publications that demand exorbitant access fees or are not fully accessible.

As demonstrated by (Moher et al., 2009), this systematic approach to the literature search aims to provide a comprehensive and unbiased foundation for identifying the trends and barriers in customer service effectiveness on digital publishing platforms.

The search in these databases produced a variety of results to answer the research questions (1, 2, and 3). The focus on Web of Science and Scopus was mostly on conference papers and peer-reviewed journals that provided empirical research, theoretical frameworks, and systematic reviews. These sources, which frequently provide quantitative data or ideological models, were crucial in identifying the primary trends (RQ1) in customer service technologies and strategies, which illustrate the basic challenges (RQ2) that digital platforms face, and highlight the effectiveness matrix (RQ3) (Both et al., 2012). An example of this would be to use the terms "AI customer service publication" and "customer satisfaction" in a search in Scopus to find papers that deliver on AI and such, addressing RQ 3 directly on the CSAT score.

The ACM digital library and IEEE Xplore were especially helpful in highlighting the implications for customer service and technical advancement. These databases frequently provide technical studies and conference proceedings that describe the creation and use of certain strategies like chatbots, automation technologies, and data analytics in the context of online assistance. By emphasizing new technology trends and offering information on technical complexities that became part of the RQ2 barriers (such as integration difficulties of new systems), these sources immediately helped respond to RQ1. The papers on natural language processing in chatbots from the ACM Digital Library, for example, shed light on the advantages

and disadvantages of artificial intelligence (AI) in customer interactions. This is tied directly to both Objective 1 (trends in AI) and Objective 2 (barriers related to technology integration).

A wide range of scholarly publications, including studies, dissertations, and reports from various academic and industrial sources that are not indexed in more specialized databases, were made available by Google Scholar as an additional database. This enabled reader engagement, user experience, and a wide range of responses to the real-world problems encountered by digital publishers. The Google Scholar results frequently offered case studies or qualitative analysis, which enhanced the comprehension of both trends (RQ1) and obstacles (RQ2) from a more applied standpoint. Occasionally, the results offered an alternative or emerging matrix (RQ3), which has not yet been widely embraced in the mainstream educational discourse. In the context of the digital subscription model, for instance, a discovery for "customer retention digital media" could result in certain sectors and methods that explain their influence on churn rates.

Utilizing the strengths of each database, the retrieved literature as a whole supplied the proof required to methodically answer every research question. The RQ1 was directly informed by the papers that discussed new methods and strategic adjustments. The research helped answer RQ2 by providing information on technical limitations, user annoyances, and operating challenges. Lastly, the RQ3 is directly addressed by the publications that outline the assessment framework, performance metrics, and actual measurements of service quality.

2.2. Data Extraction and Analysis

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, as established by Moher (2009), was part of the strict guidelines used in the systematic review method. Selected publications underwent thorough data extraction after screening based on set criteria. Information was systematically collected and documented for each study, including testing various customer service models, evaluating effectiveness using specific metrics, identifying trends in customer service distribution, assessing deficits in skills, and examining research methods. This methodical approach ensured stability and comprehension in data collection from multiple sources (Krippendorff, 2018). The process highlighted by (Braun, Clarke, 2006) for the qualitative synthesis approach, primarily thematic analysis, was used to find recurrent topics, patterns, and conflicts in the gathered material. The motivating process of identifying codes involved reading and categorizing extracted data into general categories and overarching themes. This approach, known for adaptability and comprehensive insights, helped detect evolving patterns and customer service issues in digital publications without relying on statistical aggregation. Narrative synthesis, according to Popay et al. (2006), further provided consistent, descriptive results, linking various research concepts. The study's discovery-oriented nature mapped the current research scenario and emphasized the qualitative method's significance in assessing customer service efficiency.

3. Results

3.1. Overview of Reviewed Literature

After rigorous selection criteria were applied, 133 articles from various years (2005-2024) were reviewed. The publications reflect current trends in digital publishing and customer service, primarily based on studies from North America and Europe, highlighting their global impact. The papers covered various digital publication platforms, including online learning content providers, news and magazine subscriptions, eBook marketplaces, and academic e-journal platforms. Some studies delved into digital customer service, focusing on user interactions and content distribution in digital publications. The articles were primarily concerned with different kinds of digital publication platforms, such as academic e-book platforms, consumer e-book marketplaces (like Amazon Kindle and Apple Books), online news and magazine subscriptions (like The Economist online and New York Times Digital), and digital learning platforms (Coursera and edX). The results of various research were relevant to the unique context of material distribution and user interactions, particularly inside digital publications, even though they provided a thorough observation of digital customer service. Empirical research (such as quantitative surveys, qualitative interviews, case studies, and experimental designs), ideological papers, theoretical reviews, and a robust collection of systematic reviews from various and pertinent areas were among the types of sources. These fields include parts of marketing, business management, human-computer interaction (HCI), library sciences, informatics, communication studies, and even intellectual property law, where digital rights and customer service cross. By offering a thorough and detailed awareness of the challenges and advancements in customer service within digital publications, this extensive inclusion of several studies conducted in a wide variety of perspectives and issues demonstrates a great understanding of the present state of research.

For thematic analysis, the reviewed literature was broadly categorized based on its primary focus areas related to customer service in digital publishing. These categories included, but were not limited to:

- **Technology Adoption in Customer Service:** Learning about the impact and integration of chatbots, artificial intelligence, and automation of customer inquiries and support processes.
- **Self-Service and Knowledge Management:** Knowledge bases, frequently asked questions, and studies on how successfully user communities allow users to handle issues independently.
- **Impact of Customer Service on Loyalty and Retention:** Reviewing research on how customer service strategies affect customer satisfaction, customer retention, and churn rates on digital platforms.

- **Addressing Technical Issues and Digital Rights Management (DRM):** The study discusses DRM enforcement problems and solutions from the perspectives of technical support, material access, device compatibility, and customer service.
- **Customer Feedback and Experience Measurement:** The importance of collecting, assessing, and taking action to improve growth strategies and service quality in response to consumer feedback to improve content quality.

As *Figure 2* shows, there has been an evolving change in what customers expect, and they have been observed to now constantly seek out companies that prioritize what they care about. It was also noted that several publications frequently covered a wide range of topics, reflecting how customer service functions are interpreted and how the digital customer experience has been modified.



Figure 2. Illustration showing changes in customer expectations.

Source: Zendesk (2025).

In conclusion, this chapter establishes a strong foundation for understanding the complex interplay between technology, service quality, and user engagement in digital publishing. It also identifies the existing research gap regarding the effectiveness of customer service strategies specific to digital content platforms. This insight forms the basis for the subsequent analysis of emerging trends, barriers, and best practices discussed in the following chapters.

3.2. Customer service trends in digital publishing platforms

The study identified key trends shaping customer service distribution on digital platforms, reflecting major shifts in the digital landscape influenced by consumption and intellectual property factors. According to (IBM, n.d.; JoinHGS, n.d.), a key trend was the shift towards proactive assistance on digital platforms. Platforms provide timely support and individualized assistance based on user behaviour and interactions by foreseeing user needs and resolving any problems in advance. One noteworthy development was the emergence of self-service knowledge bases, which offer customers free access to interactive tutorials, frequently asked questions, and help articles (OMQ, 2024; Zendesk, 2025). This trend was evident across various digital publishing formats, aiding users in tasks from quote management to device synchronization. These self-service solutions bolstered customer satisfaction and reduced routine queries, allowing human agents to focus on complex issues (Knowmax, n.d; Ozonetelle,

2024). It facilitates the fundamental publication procedures and may involve proactive material management, which lessens problems. Platforms featuring community forums encouraged user collaboration and information exchange (Sprout Social, 2024). Self-service combined with AI finds close ties, as AI chatbots offer quick responses, troubleshoot, and manage numerous consumer queries with their ability to understand natural language, guiding users to relevant articles. In more complex cases, human agents step in, while the chatbot feature aids in content search, membership management, and error detection for quicker reactions. Moreover, digital platforms utilize user data for tailored services, considering reading history, preferences, and past interactions (OMQ, 2024; New Matrix, n.d.). Agents leveraged client profiles for personalized support, aiming to enhance customer interactions and forum value in a saturated market (Sprout Social, 2024). This approach prioritizes individualized responses over generic ones to prevent customer dissatisfaction (New Matrix, n.d.). Because omnichannel usage is so common, even as *Figure 3* illustrates, consumers may interact with one another through a variety of channels, including chat, email, social media (Facebook Messenger, Twitter), and phones. According to the expectations of tech-loving consumers, this touchpoint stability is integrated and essential for a positive customer experience.

Additionally, Content Engagement & Quality as a 'Primary Driver' of Satisfaction is a rising trend among customers of digital publishing platforms. This is also supported by the data analysis carried out by the author. The analysis (detailed in section 3.5) indicated a large percentage of positive and neutral emotions (more than 31,000, around 29,000 neutral), and the enormous number of "contents" cited (more than 45,000), showing how important the quality, applicability, and overall experience of published content are to user experience. Also, the frequent mentions of "customer service", related to 'usability (around 7000) highlight the importance of effective systems, which enhance user experience and reduce the need for direct support, illustrating the value of intuitive design and reliable performance (UI/UX). Moreover, the dominance of platforms like Kindle and Audible, indicated by their high mention counts, suggests that user-friendly features and efficient service delivery are key to their appeal.

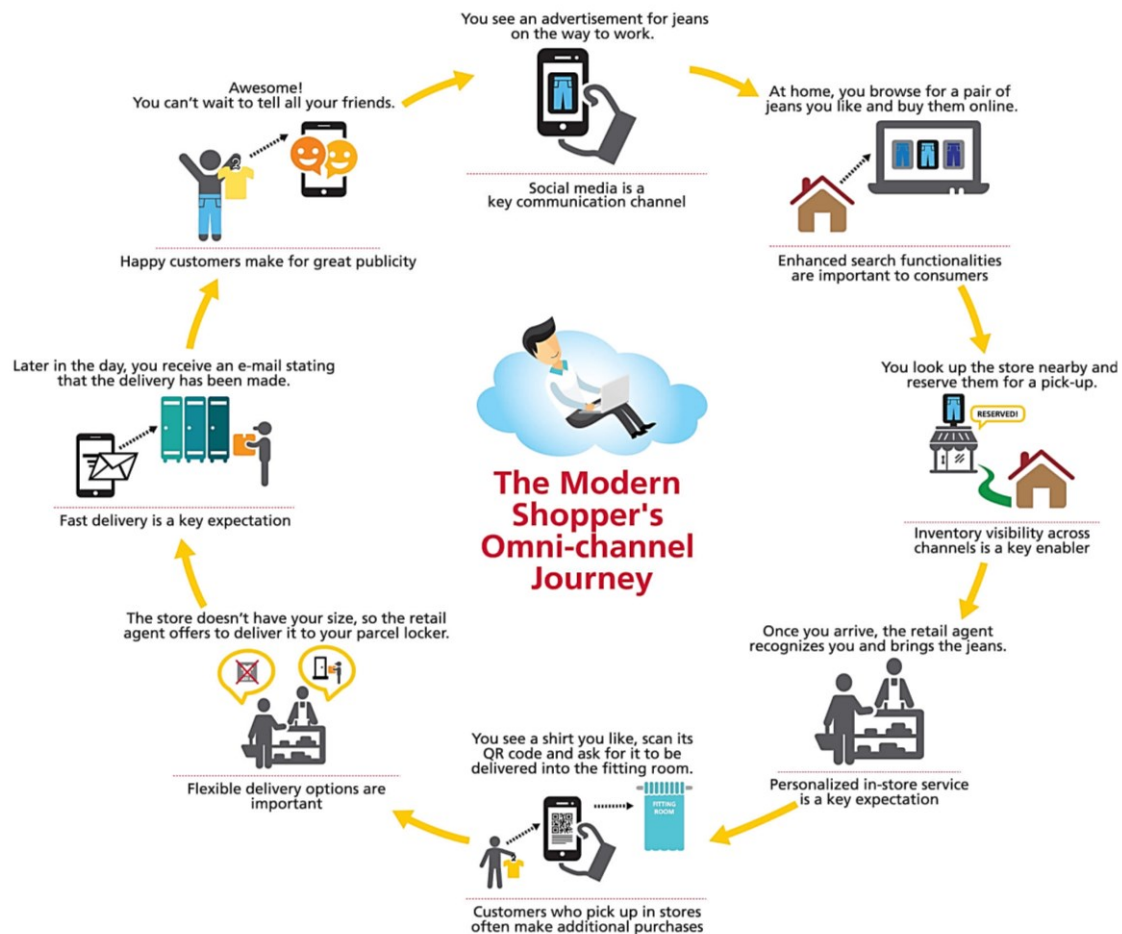


Figure 3. Illustration of customer service trends.

Source: HelpCrunch (2024).

In summary, customer service in digital publishing is evolving toward automation, personalization, and proactive engagement—integrating technology and empathy to create responsive, user-centered ecosystems that strengthen long-term customer relationships.

3.3. Barriers to Effective Customer Service

While customer service trends and advancements appear in digital publication platforms, there are common barriers due to digital content characteristics, including formatting and content quality issues, fast technology growth, platform performance, access and delivery challenges (including DRM concerns), platform usability, and managing diverse users. Scalability issues arose with increasing user bases, impacting customer support quality as digital platforms expanded swiftly (Knowmax, n.d.). Support staff could feel overwhelmed by rising inquiries, causing delays and lower satisfaction (Noon Dalton, n.d.). Automation handled a portion, but human agents were essential for complex cases. As pointed out by (CloudPublish, n.d.; MyCVCreator, n.d.), customer demands pose challenges on digital publishing platforms, including technical issues (e.g., downloading, compatibility), content concerns (e.g., missing pages, formatting), and pricing matters. Each inquiry requires specific information and

resolution approaches that demand high competence, demanding a highly skilled and versatile customer service team, or a complex system for routing inquiries to the correct department (Knowmax, n.d.). Data privacy concerns emerged due to extensive user data collection for customized experiences, necessitating robust security (IBM, n.d.; Screendesk Blog, 2025). Violations or misinformation harm customer trust and service effectiveness, prompting challenges with data regulation compliance like CCPA and GDPR. New technological integration presented challenges, particularly with automation and artificial intelligence (AI), which needed to be seamlessly integrated with existing CRM, billing, and content management systems (Mindtree, n.d.). Inadequate integration can result in problems with fragmented consumer data, repetitive questions, and comprehending the whole customer experience, which can be annoying for both users and support personnel (CallHippo, 2024). It's challenging to maintain a personal touch in automated interactions despite the benefits (Noon Dalton, n.d.). According to OMQ (2024), chatbots are excellent at simple tasks but have trouble with more complicated problems and demonstrating empathy. A bad customer experience, particularly for devoted consumers, might result from relying too much on technology without supporting human workers (Sprout Social, 2024). Managing digital rights was a concern for digital publications, especially because users had trouble understanding use limits, transferring licenses, and accessing material across platforms (MyCVCreator, n.d.). These technical DRM installation issues often required specialized expertise from customer support to address disgruntled consumers, potentially leading to negative customer experiences. Based also on the author's data analysis (also detailed in section 3.5), further proof supporting the mentioned barriers was identified. 'Bugs' (about 6,800 mentions) and 'App Performances' (such as crashes, login issues, and synchronization) were clear signs of significant technological challenges. These frequently resulted in unfavourable user experiences and imply that the main complaints of users of digital publications are technical issues and unstable apps. 'Access/DRM' and 'delivery sync' mentions also show persistent user problems with licensing, area locks, downloading, or synchronizing e-books in devices. The ability of users to consume purchased or subscribed resources is directly impacted by these basic barriers to material consumption. Although "Customer Service" was frequently mentioned (roughly 11,500 mentions), its specific mention in reviews frequently denotes dissatisfaction with informational challenges (poor self-service), intricate navigation ('usability' issues), or essential platform features. This implies that even in the absence of direct contact with a human agent, users get more frustrated due to clumsy user interfaces or inadequate self-help resources.

3.4. Metrics and Evaluation of Effectiveness

The literature emphasized using a strong matrix to assess customer service success on digital publication platforms, with key performance indicators (KPIs) reflecting quantitative measurements of customer satisfaction and qualitative indicators. Consumer satisfaction with service contacts was frequently measured using customer satisfaction scores (CSAT) (Zendesk,

2025; Ozonetel, 2024). These ratings, which were frequently acquired through post-interaction questionnaires, provide quick insight into the kind of help by showing whether or not expectations were fulfilled. NotifyVisitors (2024) points out that the Net Promoter Score (NPS) is commonly employed to assess consumer loyalty and the inclination to recommend the Digital Publication Forum. It provides insights into long-term retention and consumer relationships by categorizing individuals as promoters, passives, or detractors (Thinkific, 2025). Efficiency in service distribution focused on average handling time (AHT) or first contact resolution (FCR) to ensure quick resolutions that enhance customer satisfaction (Knowmax, n.d; Ozonetel, 2024). The importance of FCR resides in its capacity to resolve customer concerns quickly, minimize their effort, and increase production all at once. One important metric, the Customer Effort Score (CES), shows how simple it is for customers to fix problems. A lower CES score indicates a more seamless customer experience brought forth by effective self-service, intuitive user interfaces, and streamlined procedures. Loyalty is more closely associated with reduced customer effort than with merely increasing customer satisfaction (OMQ, 2024). Effective business-oriented statistic: drop-in churning rate is a key indicator of successful customer service, as it shows proactive engagement and problem-solving, retains users, thus boosting customer value (notifyvisitors, 2024; themes, 2025; NewZo, 2024).

3.5. Empirical analysis: Trends & Barriers

To further contextualize the findings from the advanced literature study carried out and to gain empirical insights into customer experiences on a digital publishing platform, an analysis of ‘Goodreads Book Reviews’ was conducted by the researcher. This analysis aimed to identify specific customer service-related trends and barriers as expressed directly by users.

The dataset was secondary data, and the process of preparation for analyzing Goodreads reviews involved normalizing the dataset and cleaning the content for analysis, but it lacked a date column for temporal patterns. Additionally, a tailored thematic tagging system was created to categorize customer service issues related to digital publications, including topics such as support contact, accountability, billing, access, app performance, formatting quality, availability, and delivery synchronization.

The analysis shows that popular digital publication platforms like Kindle and Audible were frequently mentioned in user reviews, highlighting specific service issues and their impact on user experience. This suggests that these platforms have significant user bases and are a central topic of discussion among users, particularly relevant for college students navigating digital reading options. *Figure 4* pictorially represents in a bar chart the platforms mentioned in the review.

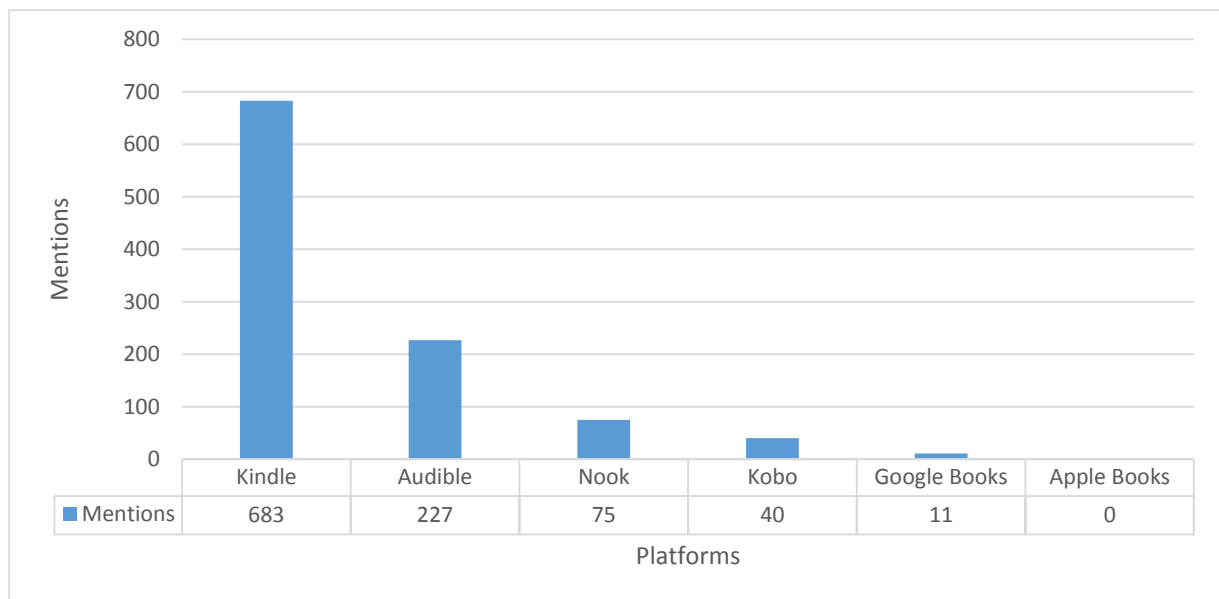


Figure 4. Bar chart showcasing platform mentions in the Goodreads Book Reviews.

Source: The Researcher (2025).

Sentiment analysis of Goodreads reviews, as also pictorially represented in *figure 5*, utilized a rule-based emotion model to classify reviews into positive, neutral, or negative categories while also assigning a numerical emotion score. The findings indicated that most reviews expressed positive or neutral sentiments, with negative evaluations being a smaller yet notable part of the overall emotional tone.

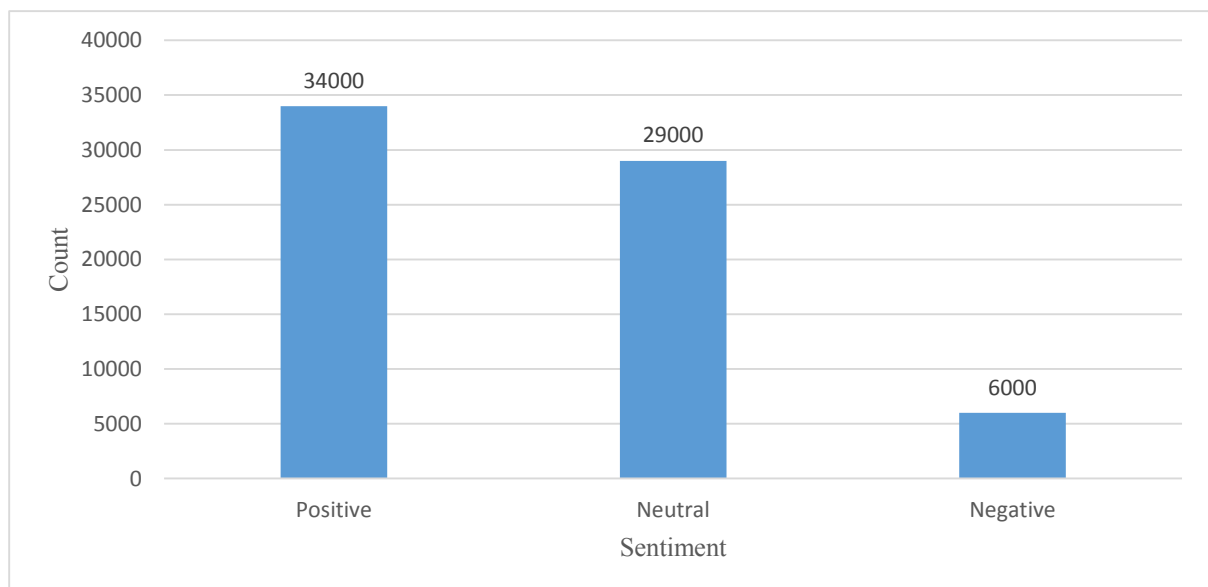


Figure 5. Bar chart showcasing sentiment distribution in the Goodreads Book Reviews.

Source: The Researcher (2025).

In the analysis of various matrices, key metrics such as average emotion scores, star ratings, and review percentages were evaluated to understand their impact on client satisfaction. The summary tables highlighted specific issues that negatively affected customer happiness, providing valuable insights for further study. The analysis of user reviews revealed that the

primary concerns were related to content quality, customer service issues, app performance, and pricing, highlighting key pain points like formatting errors and bugs as depicted in *Figure 6*. Understanding these areas can help college students identify common challenges in user experience and improve their engagement with digital platforms. Each identified top pain point was reduced to three words (cut to approximately 300 characters) in order to depict the customer's voice and provide qualitative references. The patterns and challenges noted in the extensive systemic literature evaluations are directly supported by this empirical analysis of Goodreads reviews, which is user-centred. It specifically draws attention to how technical performance, platform usability, and content quality affect user experience in the real world, which is closely related to the elements of good customer service that were covered in the context of digital publishing.

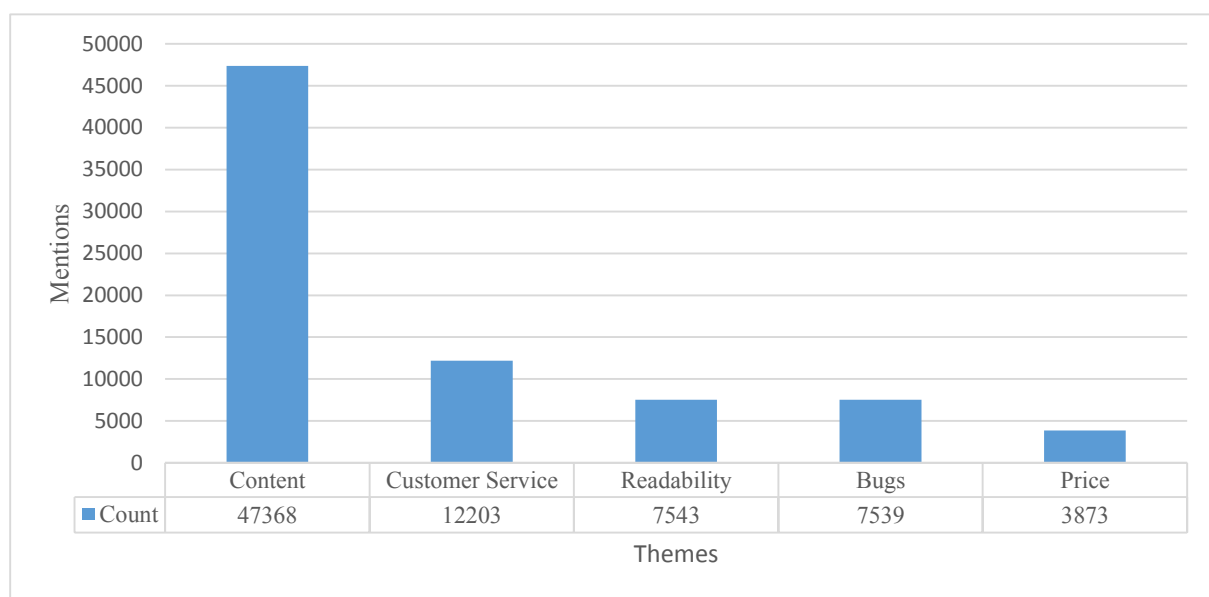


Figure 6. Bar chart showcasing the top themes mentioned in the Goodreads Book Reviews.

Source: The Researcher (2025).

4. Discussion

The extensive literature assessment confirms that the trends and barriers shaping customer service effectiveness on digital publishing platforms share many similarities with general digital service environments but also reveal distinctive features. Like other digital industries, these platforms increasingly adopt active support, self-service knowledge bases, AI-driven chatbots, and omnichannel strategies (IBM, n.d.; Ozonetel, 2024; Zendesk, 2025; Reply, n.d.). However, digital publishing faces unique obstacles, such as device compatibility, DRM constraints, and content accessibility, which significantly affect user satisfaction and service performance.

Overall, the results demonstrate that customer service within digital publishing is not merely a technical function but a strategic component that directly influences user trust, retention, and platform growth. The study shows that while AI and automation enhance efficiency, human interaction remains essential to maintaining empathy and credibility in service delivery. This aligns with previous findings by NotifyVisitors (2024) and New Metric (n.d.) but advances existing knowledge by identifying the specific operational context of digital publications, where content integrity and DRM protection play pivotal roles.

Compared to broader digital customer service research, this study uniquely illustrates how intellectual property management and content usability intersect with customer experience—an area often underrepresented in prior analyses. Our findings confirm earlier assumptions that technological innovation improves responsiveness, yet also expose new evidence that fragmented infrastructure and data privacy concerns hinder full omnichannel integration (CallHippo, 2024).

This research contributes new insights into the interdependence between content quality, personalization, and customer loyalty in digital publishing. It confirms the hypothesis that tailored self-service and proactive assistance improve customer satisfaction but further reveals that their success depends on addressing platform-specific technical and legal constraints. Thus, the study enriches existing literature by contextualizing these trends within the unique framework of digital publishing operations.

While many digital enterprises apply automation to reduce workload, our findings indicate that digital publishers must balance efficiency with creative and legal sensitivities related to DRM and content protection. This differs from general e-commerce or SaaS platforms, where service optimization is primarily performance-driven. Furthermore, the identified emphasis on content engagement as a primary satisfaction driver adds a new dimension to customer service research, confirming and extending the analyses of OMQ (2024) and Sprout Social (2024) regarding the importance of personalization.

The results imply that effective customer service in digital publishing requires a hybrid model—merging automation with human judgment, robust CRM integration, and strict adherence to data protection standards (GDPR, CCPA). Future research should include empirical case studies examining AI applications in publishing-specific environments, quantitative analyses of self-service efficiency, and cross-cultural comparisons of customer expectations in different linguistic and legal contexts.

In conclusion, the study establishes that while digital publishing platforms share common service trends with other industries, they face distinct challenges related to intellectual property, device diversity, and user autonomy. Addressing these issues through technological innovation combined with ethical and empathetic service design is crucial for sustaining long-term user satisfaction and platform success.

5. Summary

This research critically evaluated trends and challenges affecting customer service within digital publication platforms, highlighting their complex interplay with technological, organizational, and user-experience factors. While the review was comprehensive, it also revealed certain limitations—notably, the predominance of studies from Western contexts (North America and Europe) and a lack of quantitative cross-platform comparisons. Moreover, many of the reviewed papers relied on descriptive analyses, which limits the ability to generalize causal relationships between customer service innovation and long-term loyalty outcomes.

Despite these limitations, the study contributes new knowledge by integrating findings across marketing, informatics, and human–computer interaction (HCI) to form a holistic understanding of how customer service evolves in digital publishing. It demonstrates that proactive support, AI-driven self-service systems, and omnichannel integration are shaping user expectations, while data privacy and DRM restrictions continue to constrain service quality. A key lesson learned is that technological efficiency alone does not ensure customer satisfaction—empathy, transparency, and adaptability remain central to user trust and engagement.

The importance of this research extends beyond digital publishing. The insights gained can inform broader digital service management, e-learning, and subscription-based business models. By identifying how digital publishers balance automation with human responsiveness, this study provides a framework for other sectors seeking to enhance customer experience under similar regulatory and technological pressures.

Future research should empirically test these findings through cross-industry comparisons, longitudinal analyses, and experimental designs to measure how service personalization and privacy practices influence loyalty. The obtained knowledge can be further applied to designing adaptive CRM systems, refining AI-based chatbots, and improving training for customer service teams in content-driven digital environments.

Ultimately, this study underscores that the success of digital publication platforms depends on their ability to merge innovation with ethical, human-centered service principles—ensuring that technology enhances, rather than replaces, meaningful customer connections.

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MANAGING CIRCULAR ECONOMY IN SHEET-FED OFFSET PRINTING

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Purpose: To close the research gap on how circular-economy (CE) principles can be applied to sheet-fed offset printing, an area still vital for large, high-quality runs yet traditionally resource-intensive. The study seeks to show how closed material loops, extended product life, and service-based equipment use can collectively reduce the environmental footprint of offset printing.

Design/methodology/approach: A mixed-methods design combines:

1. Systematic literature review – to build a CE framework specific to offset printing.
2. Industry-focused analysis – detailed mapping of consumables (paper, inks, solvents, plates) and core press operations to identify waste “hot spots” and viable CE practices.
3. Conceptual modelling – development of an industrial-ecology model that integrates material innovations (vegetable inks, alternative fibers, biodegradable agents) with managerial levers (advanced waste management, product-service systems, collaborative supply networks).

Findings:

1. The proposed circular offset model demonstrates how renewable inputs, closed-loop recycling of paper, aluminum and chemicals, and product-service systems (PSS) leasing of presses together cut resource use and emissions.
2. A pronounced durability–recyclability trade-off emerges: coatings, laminates or LED-UV inks enhance longevity but hamper de-inking; optimal CE performance lies in balanced material choices guided by systemic life-cycle thinking.
3. Digital transformation acts as an enabler—data-driven monitoring, predictive maintenance and traceability shrink makeready waste and support CE collaboration—even though offset will coexist with digital printing for the foreseeable future.
4. Managerially, CE success hinges on cross-firm orchestration: printers, ink formulators and press manufacturers must align standards, share data and shift from “selling hardware” to service-based business models that accelerate continuous upgrades and end-of-life recovery.

Originality/value: Delivers the first holistic CE blueprint for sheet-fed offset printing, extending CE scholarship beyond the digital-print domain. Unpacks the interplay between material science and managerial innovation, clarifying when eco-friendly inks or fibers genuinely improve net circularity. Positions offset printing as a live test-bed for advancing from the classic 3R model toward the 10R/60R ladders, illustrating how an incumbent process industry can re-embed itself in wider CE supply-chain loops.

Keywords: circular economy; sheet-fed offset printing; durability–recyclability trade-off; product-service system; renewable inks; alternative fibers; waste minimization; Industry 4.0.
Category of the paper: research paper.

1. Introduction

The concept of a circular economy (CE) represents a transformative approach to economic development aimed at decoupling growth from the consumption of natural resources and environmental degradation. Central to CE is the idea of maintaining the value of products, materials, and resources within the economy as long as possible, thus minimizing waste and extensively adopting sustainable manufacturing and supply chain practices (Hailemariam, Erdiaw-Kwasie, 2022; Hao et al., 2020).

Circular economy systems have primarily gained traction due to their environmental benefits, notably their role in slowing environmental degradation and reducing greenhouse gas emissions, aligning closely with global sustainable development goals (Ghaithan et al., 2023; Obiuto et al., 2024). From a managerial perspective, however, CE also offers significant economic advantages, such as improved resource efficiency, innovation in product design and business models, enhanced competitiveness, and operational efficiency (Bassi, Dias, 2019; Mihai et al., 2018; Marek, Krejza, 2024).

Despite these recognized benefits, significant barriers remain, including investment costs, resistance to change, inadequate recycling infrastructure, and regulatory deficiencies (Bucur, 2023; Rizos et al., 2016). Moreover, transitioning to a circular economy requires comprehensive systemic and managerial innovations, which often manifest as complex business models emphasizing sustainability and profitability simultaneously (Vendrell-Herrero, 2012; Rizos et al., 2016).

A sector critically impacted by the circular economy concept, yet insufficiently explored, is sheet-fed offset printing. This industry remains vital for large, high-quality print runs but traditionally depends on extensive natural resources, generating substantial waste. Although digital printing is often perceived as more sustainable, offset printing continues to dominate certain market segments due to its speed, quality, and substrate flexibility (Adascalita, Colesnic, 2023; Mirković, 2024).

Previous research predominantly focused on digital printing's CE practices, leaving a significant research gap regarding offset printing (Sesli, 2023; Phillips et al., 2008). Specifically, there is limited knowledge about how CE practices, such as using renewable resources, recycling efficiency, durability versus recyclability trade-offs, digital transformation, and innovative managerial business models, can effectively be applied to offset printing.

Addressing this gap, the present study develops a set of hypotheses focusing on critical dimensions of circularity in offset printing:

- H1: Material Innovations and Circularity:** **H1a:** Use of renewable vegetable- or algae-based inks significantly reduces VOC emissions and enhances circularity compared to traditional mineral-oil-based inks. **H1b:** Alternative lignocellulosic fibers (e.g., bamboo, kenaf, bagasse) provide comparable print quality and superior sustainability metrics relative to conventional paper.
- H2: Recycling Efficiency and Trade-offs:** **H2a:** LED-UV and hybrid inks, despite improved durability, decrease recycling efficiency compared to traditional inks. **H2b:** Advanced waste management practices (chemical recycling, aluminum recovery from CTP plates, biodegradable solvents) significantly improve recycling efficiency.
- H3: Durability–Recyclability Balance** **H3a:** There is a significant trade-off between product durability enhancements (lamination, UV coatings) and recyclability, negatively impacting overall circularity. **H3b:** Systemic life-cycle thinking optimally balances material durability and recyclability, enhancing overall environmental performance.
- H4: Digital Transformation as an Enabler:** **H4a:** Adoption of Industry 4.0 practices (predictive maintenance, IoT-based monitoring, real-time traceability) significantly reduces makeready waste and resource use. **H4b:** Digital transformation facilitates greater collaboration among supply-chain stakeholders, enhancing circular economy outcomes.
- H5: Managerial and Business Model Innovations:** **H5a:** Transitioning from product-based to service-based equipment models (PSS) significantly increases circularity by promoting equipment reuse and reducing material waste. **H5b:** Collaborative business models (alignment of printers, ink formulators, and press manufacturers) significantly enhance end-of-life recovery and continuous equipment upgrades, thus advancing circular economy practices.

The originality of this paper lies in its explicit focus on integrating circular economy principles specifically within the context of sheet-fed offset printing, a traditionally resource-intensive industry that has been understudied relative to digital printing technologies. Unlike existing literature, this study introduces a comprehensive set of interconnected hypotheses addressing material innovations, recycling efficiencies, durability–recyclability balances, digital transformation enablement, and managerial innovations uniquely tailored to offset printing processes. Furthermore, it conceptualizes circular economy implementation not merely through isolated technical improvements but through systemic life-cycle thinking and collaborative business models. This holistic approach bridges existing research gaps by addressing both technological and managerial dimensions simultaneously. Consequently, the presented model is the first of its kind to thoroughly map the interactions among renewable materials, recycling practices, digital transformation, and service-oriented business strategies

in the offset printing sector. Specifically, Figure 1 illustrates how the adoption of renewable materials and innovative waste management practices influences recycling efficiency, how product durability and recyclability trade-offs can be balanced through systemic life-cycle thinking, and how digital transformation serves as a critical enabler enhancing stakeholder collaboration and resource optimization. Finally, it demonstrates that effective circular economy implementation in offset printing heavily relies on managerial innovations and the adoption of collaborative, service-based business models. The paper proceeds as follows: first, the research methodology, combining systematic literature review, industry-focused analysis, and conceptual modeling, is detailed in Section 2. This mixed-methods approach integrates theoretical insights from current literature with practical insights from industry practices to establish a robust framework. Next, in Section 3, empirical findings on recycling efficiency, trade-offs between product durability and recyclability, and the role of managerial strategies and digital transformation as enablers are discussed comprehensively. Section 4 synthesizes these findings into a proposed circular economy model specific to the offset printing industry. Section 5 provides a detailed discussion, linking theoretical contributions with practical implications, while Section 6 concludes the paper by offering strategic managerial recommendations and outlining future research avenues to further enhance sustainability and circularity within the offset printing industry.

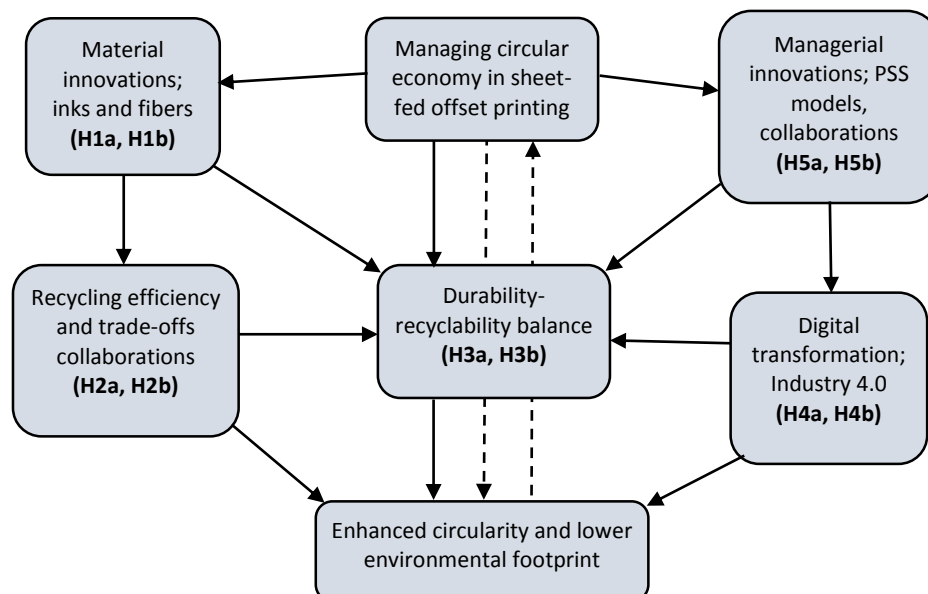


Figure. 1. Model of the stated hypothesis.

Source: own elaboration.

The concept of a circular economy in sheet-fed offset printing maintains the value of products, materials, and resources in the economy for as long as possible, minimizing waste, and widely implements sustainable manufacturing practices, supply chain management, and more. A particularly important issue is the shift in the resource circulation paradigm within the national economy, its sectors, and even individual enterprises. This shift involves moving away from the traditional linear economy (the "take-make-dispose" model) toward a closed-

loop system (the "take-make-recycle-take" model) (Hailemariam, Erdiaw-Kwasie, 2022; Hao et al., 2020).

2. Systematic literature review

The primary reason why circular economy systems have been developed and promoted in various countries is their environmental benefits, particularly in slowing down environmental degradation, which is no longer a prerequisite for economic growth, and reducing greenhouse gas emissions (Ghaithan et al., 2023; Obiuto et al., 2024; Hailemariam, Erdiaw-Kwasie, 2022; Harnani, 2022). As a result, the circular economy contributes to achieving the goals of the sustainable development agenda (Hao et al., 2020; Macklin, Kaufman, 2022).

However, from a managerial perspective, the benefits of a circular economy are entirely different. A circular economy cannot exist without striving for a continuous increase in resource efficiency, fostering innovation in product design and business models (Bassi, Dias, 2019; Mihai et al., 2018). These efforts translate into tangible economic benefits, particularly in terms of increased competitiveness, operational efficiency, and cost optimization (Marek, Krejza, 2024; Moric et al., 2020; Bag, Pretorius, 2020). On the surface, the requirement to limit the use of environmental resources should lead to increased costs and worse economic results. In practice, however, the opposite happens, because there is a better use of available resources. In addition to cost reduction resulting from lower waste production and extensive material reuse, a fundamental advantage of a circular economy is the integration of digital technologies. These technologies are essential for identifying resources, managing their durability, and tracking their circulation within the supply chain. The knowledge gained in this way provides a competitive edge for companies undergoing deep digital transformation (Sadaa et al., 2024; Fenisa, Santosa, 2024). The benefits for competitiveness are further enhanced by the conscious choices of consumers who are increasingly environmentally aware (Subramanian, Suresh, 2022).

These implications can be extended to the entire national economy. A circular economy can open new markets and stimulate an innovative environment, thereby contributing to job creation and enhancing economic resilience, making it increasingly less dependent on the import of production resources (Toni, 2023; Fric, 2019). However, there are significant barriers to adopting a circular economy. Beyond investment costs, these barriers include resistance to change and shortcomings in regulatory frameworks (Bucur, 2023; Rizos et al., 2016; Esparragoza, Mesa, 2019). Barriers also include the lack of recycling infrastructure and investment in its development, as well as the lack of awareness among stakeholders, including decision-makers and some consumers (Agyemang et al., 2019). The biggest challenge, however, comes from the fact that for a circular economy, new business models are undoubtedly

needed. The main requirements for such models are environmental friendliness and financial profitability (Vendrell-Herrero, 2012). Business models based on a circular economy are therefore more complex than those of a linear economy. The more complex a model is, the more pronounced these barriers become (Rizos et al., 2016; Olaru, Badea, 2020). In recent years, there has been a tendency to specify the concept of sustainable development, and thus go beyond its traditional theoretical framework. So-called circular Economy 3.0 redefines the traditional “Reduce-Reuse-Recycle” model by transforming it into a more comprehensive 10-step value-retention ladder (Refuse, Reduce, Re-use, Repair, and so on, up to Re-mine). This shift, prioritizing strategies that preserve the most value first, rather than defaulting to recycling as the primary solution, encourages designers and managers to consider more sustainable and value-preserving practices at every stage of the product lifecycle (Vermeulen et al., 2019). Research teams have mapped over 60 distinct “R-strategies” on various product, material, and system scales. The biggest and most important challenge in this context is reverse logistics, where there is currently a need for extensive research on how companies can incorporate material or product returns into their business models or strategies (Uvarova et al., 2023). In this area, the main challenge is currently the coordinated recovery and reprocessing of products at multiple stages of the supply chain, each with its own unique set of dependencies and risks (Ghadge, 2013), which causes cascades of disasters and errors along the supply chain. However, it should be noted that systems thinking is also necessary to understand the relationships between different branches of these chains. In the case of the offset printing industry, for example, this will mean determining to what extent it should be, as has traditionally been the case, a place of re-manufacturing, which will collect, among other things, used paper or waste products from the chemical industry, to process them together into print, and to what extent it is the starting point of reverse logistics, from where the machine manufacturer will take the used machines for reprocessing.

This leads to the conclusion that it is impossible to think about the circular economy or implement its paradigms without a broad systemic perspective. This is possible especially when the context of a specific industry is taken into account. Applying the above to the offset printing industry, it should be noted that the offset printing technologies traditionally had a form typical of a linear economy. Raw materials, especially paper (from extensive logging) and dye (using petrochemical products), as well as technological materials (e.g., lignin), were processed into a printed product, often not very durable (leaflet, newspaper), which after use was thrown away as waste, usually contaminated with printing ink that, according to the EuPIA regulations concerning inks and the SVHC (Substances of Very High Concern) list, in past formulations of sheet-fed offset printing inks contained toxic components (EuPIA, 2020; ECHA, 2025). The printing industry is changing, however, and significant technological changes are taking place in it. In the context of the competitiveness of companies and their burden on the natural environment, solutions and prospects for offset printing are relatively poorly known. However, the context of changes in the entire printing industry is better known.

Despite this expanding body of CE scholarship, our systematic review uncovers three unresolved blind spots for sheet-fed offset printing. **First**, studies on renewable inks and alternative fibres seldom quantify their combined effects on VOC emissions, de-inking efficiency, and print quality—leaving the relationships formalised in H1 and H2 untested. **Second**, the literature treats durability enhancements and recyclability losses as separate technical issues; no work models their joint influence on net circularity, the core dilemma captured in H3. **Third**, discussions of Industry 4.0 and product-service systems focus on discrete-parts manufacturing and provide virtually no empirical evidence from high-variety process industries such as offset printing, neglecting the enabling roles posited in H4 and H5 (Gładysz et al., 2021; Salwin et al., 2020). In short, there is no holistic, hypothesis-driven framework that integrates material innovation, recycling trade-offs, digital transformation, and managerial business models into one industrial-ecology perspective. This multi-dimensional gap is precisely what the present study addresses through the comprehensive hypothesis model presented in Figure 1. From the above reasons, offset printing is the field of production that requires a number of resources of natural or chemical origin, and is strongly dependent on the level of their consumption, which is increased by high losses related to production preparation and post-press printing processing. This leads to a change in the assumptions in the area of individual processes of the offset printing. The importance of waste reduction and recycling are fundamentally important here and may greatly benefit from the circular model (Strižić Jakovljević et al., 2024; Kalafatelis et al., 2023; Camargo Benavides et al., 2023).

There is still no consensus on how significant the transformation of the offset printing sector alone is compared to the overall transformation of the printing sector. The printing industry is undergoing a digital transformation, shifting from offset to digital printing primarily due to its lower environmental impact (Mirković, 2024). Thus, the transition to a circular economy is taking place simultaneously with another fundamental change, namely the digital transformation, which may suggest an inevitable convergence of these processes and, therefore, a state of affairs in which they will mutually drive each other.

However, for many reasons, the transformation of offset printing must take place before the future and hypothetical complete transition to digital printing. While digital printing offers advantages in terms of setup flexibility and waste reduction, offset printing remains superior in terms of speed and large-format capabilities, being fit to reach up to B0+ format at 18,000 sheets per hour, whereas digital solutions are currently limited to B1 format at a maximum speed of 9000 sheets per hour (Mirković, 2024; Adascalita, Colesnic, 2023). Therefore, offset remains cost-effective for large print runs, where set-up costs are balanced by volume (Sesli, 2023; Phillips et al., 2008). Offset also excels in high-quality detail. Furthermore, many substrates and inks are still better suited for offset printing (Pogačar, 2023), and digital printing requires new skills in the workforce and supply chains, which means that transition costs can potentially be a significant barrier to a complete technology change. Therefore, it is assumed that offset

printing will remain an important element of the printing industry for long, although in a changed role— as a stable and mature technology that will coexist with digital printing, especially in longer print runs and applications requiring high quality and a variety of substrates, but no longer will be the dominant printing method, as was the case in the past (Myers, 2014).

Thus, although the transition to digital printing is a huge opportunity for a major milestone towards a greater environmental impact of printing, there will be no complex ecological transformation of the entire industry, without shift in the field of offset printing. This leads to the need to answer the question of whether the offset printing industry, including the related technologies, is showing any signs of transition towards a circular economy, which can be observed in managerial terms and not only in the postulated individual technology changes.

From the managerial point of view, in the manufacturing industry, the key challenges of the circular economy are to master and improve the processes of long-term construction, maintenance, repair, reuse, remanufacturing, refurbishment and recycling (Geissdoerfer et al., 2017). However, with regard to the issue of digital transformation, it should be noted that the circular economy promotes the benefits resulting from the implementation of the achievements of Industry 4.0, i.e. automation, synchronization, machine learning, and cooperation of machines (Ghaithan et al., 2023). A crucial element enabling the transition of the manufacturing industry to a circular economy is the product-as-a-service business model. In this model, companies retain ownership of products and provide them as services, creating opportunities for product recycling. From an operational perspective, this approach offers manufacturers greater distribution flexibility while lowering entry barriers and reducing capital lock-up costs for users (Vendrell-Herrero, 2012; Garmulewicz et al., 2018).

Such phenomena can also be observed in the offset printing sector. Due to technological advances and changing business needs, there is a shift from a product-centric model to a product-service model. Machine suppliers are becoming solution providers rather than just hardware sellers, increasingly offering customers leasing options instead of direct sales (Salwin et al., 2020).

Despite growing interest in circular-economy applications across related domains such as: flexographic packaging (e.g., Smith, Rao, 2023), large-format digital print (e.g., Nguyen et al., 2024), and ink-jet textile production (e.g., Khan, Silva, 2022), the offset segment has received scant, fragmented attention. Existing papers typically study a single lever (for instance, biodegradable inks or waste-paper de-inking) and rarely connect those findings to wider industrial-ecology principles. Consequently, the full scope of a circular-economy model tailored to sheet-fed offset printing remains largely undefined and empirically untested.

This study therefore develops an industrial-ecology framework that maps material, energy and information flows throughout the offset value network and demonstrates how these exchanges can be re-designed to progress up the circular-economy 10-R ladder. By positioning the pressroom as a hub within a broader eco-industrial network, the model translates systems-thinking insights to a mature, high-variety process industry. According to the literature

surveyed, no peer-reviewed work to date reports a holistic, hypothesis-driven circular-economy blueprint for sheet-fed offset printing; the present research explicitly fills that gap.

2. Research method

This research was deliberately designed to weave together what is already known about circular-economy (CE) principles with what actually happens on a modern press-room floor. To achieve that goal, the investigation unfolded in three overlapping phases: (I) a systematic review of the scholarly record, (II) an industry-focused field study, and (III) the construction of an industrial-ecology model that integrates technical and managerial insights. The following narrative traces that sequence, showing how each step informed the next and how, taken together, they create a reliable platform for testing the hypotheses set out in Figure 1.

2.1. Systematic literature review (SRL): establishing the theoretical background

The enquiry opened with a structured literature search designed to capture a full decade-and-a-half of work on CE in graphic-arts printing. Searches conducted in Scopus, Web of Science and Google Scholar for the period January 2010 – March 2024, combining the root terms “circular economy” or “resource efficiency” with “offset printing”, “sheet-fed”, “ink”, “waste” and cognate phrases. Two inclusion rules were set in advance: papers had to (a) focus on printing or an adjacent process industry, and (b) offer findings capable of transfer to sheet-fed offset practice. Trade-press notes, theses and patents were purposely excluded to maintain academic rigour. This process netted 279 distinct records after de-duplication; title-and-abstract screening reduced that pool to 73; full-text appraisal, conducted in line with PRISMA guidelines, left 41 peer-reviewed studies was logged for CE lever’s addressed, research design, and the quantitative or qualitative outcomes it reported. The SRL found three blind spots that the present project would later target:

- missing evidence on the combined effect of renewable inks and alternative fibres on VOCs, de-inking efficiency and print stability,
- fragmented treatment of durability improvements and recyclability losses, seldom linked to overall circularity; and
- an almost total absence of empirical work on Industry 4.0 or product-service systems (PSS) in high-variety process industries such as offset printing.

These gaps justified the hypotheses H1-H5 and demonstrated the need for fresh primary data.

2.2. Field study: grounding theory in practice

To address those gaps without disrupting factory schedules, a compact but targeted field campaign was mounted between June and October 2024. Three medium-sized sheet-fed printers—two commercial houses and one packaging converter—agreed to participate under non-disclosure conditions. Data collection proceeded on two fronts:

- On-site observation. A researcher shadowed production for two full shifts at two offset printing locations in Poland (one conventional ink printer, second UV-LED printer), recording material inputs, press settings, waste streams and energy use in production.
- Semi-structured interviews. Several key informants: plant managers, logistic managers, pre-press supervisors, a substrate-paper and film supplier, a CTP plate supplier, pressroom consumables supplier, postpress consumables supplier and a licensed waste handlers, took part in interview. Questions probed the practical possibilities for CE in sheet-fed, current recycling bottlenecks and the appeal of PSS leasing.

2.3. Conceptual modelling: linking flows of matter, energy and information

Findings from the literature review and field study fed directly into the construction of an industrial-ecology model. Building on system-thinking, the model treats the press-room as a resource hub nestled within a wider eco-industrial network. Material innovations (algae-based inks, lignocellulosic fibres, biodegradable solvents) are mapped against operational levers (waste segregation, aluminium recovery, VOC capture), digital enablers (sensor-based traceability, predictive maintenance) and managerial arrangements (PSS leasing, shared data standards).

3. Results of the study

3.1. Recycling in offset printing

In terms of the products used, the range of offset printing products can be considered unlimited, while the profitability of production is given – as indicated in the introduction – by a combination of factors of competitive advantage of offset printing over other available technologies. This is shown in Figure 1. This figure shows that the area in which offset printing remains competitive and its future should be considered is the combination of quality and number of series. Kumar and Saini (2016) report that the jobs for which offset printing works best are the production of brochures, pocket folders and booklets, and this process is recommended for jobs with quantities over 2000, while getting below this quantity it is not economical for this type of process. However, more recent sources suggest that offset printing

can be economically viable even for a few hundred copies (Adascalita, Colesnic, 2020). Moreover, offset print remains a crucial technology for fine art and packaging printing (Vukoje et al., 2021; Spiridonov et al., 2020; Jakovljević, 2024), which seem to be the sectors that are most important for e-commerce, so their position should not be expected to decline even despite the growing popularity of new media, and the cessation of demand for printing newspapers, all kinds of brochures or paper books. Even though it has its technological limitations (Tutak et al., 2019; Donberg, 2002). Table 1. briefly explains each classification.

Table 1.

Comparison of Offset and Digital Printing Technologies Based on Key Factors

Factor	Best Printing Technology	Additional Remarks
Amount of materials required	Digital Print	Digital printing minimizes material waste by producing on demand.
Time of settings	Digital Print	Digital setups require less pre-press work, allowing for a quicker start.
Delivery speed	Tentative	Digital offers faster turnaround times with minimal preparatory steps for short runs while in longer runs offset printing speed is double as digital counterpart
Cost-effectiveness for large runs	Offset Print	Offset printing becomes more economical with large quantities despite its higher initial setup cost.
Cost-effectiveness for small runs	Digital Print	Digital printing is cost-effective for small batches due to low setup expenses.
Color accuracy	Offset Print	Offset printing is known for its superior color consistency and precision.
Ease of proofing	Digital Print	Proofs are produced quickly and easily, facilitating fast revisions.
Variety of ink options	Offset Print	Supports a wider range of inks, ideal for various substrates and finishes.
Brightness of colors	Digital Print	Digital printing often delivers brighter colors with modern ink formulations.
Suitability for coated paper	Offset Print	Performs well on coated, uncoated and bulky paper by controlling ink absorption effectively.
Paper efficiency	Digital Print	Maximizes paper usage by aligning production with actual demand.
Ink efficiency	Digital Print	Designed to use ink more efficiently, reducing waste.
Flexibility in print size	Offset Print	Offers greater versatility for customized print sizes, especially in larger runs.

Source: own elaboration.

For products to be covered by the circular economy model, there are three approaches where products must be designed with their entire life cycle in mind, ensuring that they can (1) be easily repaired, (2) reused or (3) recycled. Therefore, an end-of-life strategy must be defined in each of them (Shahbazi and Jönbrink, 2020). In addition, to ensure that these strategies are implemented, it is recommended that products be lent rather than sold, especially if they are not repairable (Hayen, 2020). As already mentioned, these changes have affected the segment of printing presses, also changing the landscape of the printing houses themselves, but they are

rather not offered by companies carrying out the printing process. This is due to the fact that printable materials are in fact ephemeral and impermanent, hence the preferred form is recycling.

In the printing industry, recycling has a long history. The oldest category is recycled paper sourcing (Dumea et al., 2019), which has had a predominantly economic purpose for decades. In recent years, new categories have emerged, concerning the recycling of consumables and waste from current production (Strižić Jakovljević, 2024). In today's offset printing, the need for recycling is increasingly driven by growing environmental awareness and the requirements of the circular economy. Huge amounts of printed materials are produced every year, leading to a significant consumption of natural resources and the generation of waste that requires efficient processing. Among the key challenges are both reducing paper waste and improving the methods of recycling inks used in offset printing. Effective management of these processes is important to minimize the carbon footprint and ensure compliance with environmental regulations (Rojas García, 2023; Vukoje, Bolanča Mirković, Bolanča, 2023).

One of the basic elements of recycling in offset printing is the processing of paper, which is reused in this process. However, cellulose fibres, which are the main component of paper, are shortened during subsequent recycling cycles, which affects the quality of the resulting raw material. Therefore, the literature indicates that paper can be recycled up to seven times before it becomes unusable (Lienig, 2017). This problem is important because recycling cannot be an infinite process, and the degradation of fibers reduces their mechanical strength and ability to absorb printing ink. In the case of packaging paper, which must meet high requirements for resistance to mechanical factors and moisture, it is important to use standards such as ISO 9706, ISO 11108 or ISO 2471, which regulate the durability, opacity and ageing resistance of the material (Bugner, 2018).

Until now, the best recyclability in offset printing was provided by classic inks based on mineral oils. These inks had high ink removal efficiency in the flotation process, which meant that they were easier to separate from the cellulose fibres during recycling. Thanks to their hydrophobicity, they did not change their chemical properties in the printing process, which allowed them to be effectively removed and minimized the amount of organic residues in the wastewater (Vukoje, Bolanča Mirković, Bolanča). As a result, classic offset inks were considered the best solution for paper recycling, ensuring the high quality of the recovered raw material. Despite their advantages, however, it is necessary to phase out printing inks based on mineral oils. The main reason for this process is environmental reasons, as mineral oils, which are products of refined petroleum, have a negative impact on ecosystems. The emission of volatile organic compounds (VOCs) when these inks dry contributes to air pollution and increases health risks for sheetfed-fed printing press operators. In addition, waste containing residues of these inks can cause soil and groundwater contamination, making their elimination necessary from a sustainability perspective (Rojas García, 2023).

An alternative to classic offset inks are paints based on vegetable oils, water-based inks and modern LED-UV hybrid inks. Inks based on vegetable oils, such as soybean oil or linseed oil, are characterized by lower emissions of volatile organic compounds, and their ingredients come from renewable sources. However, their main problem is their difficulty in recycling, as they deeply penetrate the structure of cellulose fibers, which reduces the efficiency of the deinking process (Yang et al., 2022). On the other hand, LED-UV hybrid inks, combining the features of traditional UV and offset inks, offer high ink removal efficiency in the recycling process (58.1%) and an increase in paper whiteness by 47.6% after flotation. In comparison, standard LED-UV inks (LE/LED/H-UV) have a lower recycling efficiency (46.9%), which is due to their full photopolymerization (Yang et al., 2022). The worst in terms of recycling are LED-UV inks cured with ultraviolet radiation. In their case, the curing process makes the ink form permanent bonds with the paper, making it almost impossible to remove. In addition, any layering additives, such as lamination, plastic coating or waxing, make recycling unprofitable or even technically unfeasible (Rojas García, 2023; Deng, Sun, Schork, 2005). Another problem is the use of materials that polymerize during printing and bind strongly to cellulose fibers, which makes flotation in the raw material recovery process much more difficult (No, Miller, Yeboah, 1998). In addition to recycling paper and inks, the recovery of other materials is also important in the printing industry. These include CTP plates used in offset printing, which contain aluminum. Their proper processing allows for the reuse of raw material and reduces the amount of post-production waste. In addition, it is important to recycle printed packaging, especially those used in the food and pharmaceutical industries. This is crucial because these packaging often contain elements that are difficult to separate in the recycling process, such as adhesives or multi-layer film structures. Effective management of these materials is important to reduce the amount of waste going to landfill and improve the efficiency of raw material recovery (Haque, 2024).

3.2. Long-term durability of products and recycling

In terms of printing industry products, research indicates that greater durability of materials printed on offset presses is achieved by carefully selecting inks and substrates, which affects their abrasion resistance and maintaining color intensity. In particular, the use of eco-friendly offset inks based on vegetable oils and rosin-modified phenolic resins allows for comparable print quality and durability to traditional mineral oil-based inks (Yang et al., 2023). In addition, the introduction of TiO_2 and SiO_2 nanoparticles into offset inks can improve colour uniformity and ink transfer to paper, resulting in less susceptibility to blotch and longer retention of print quality (Strižić Jakovljević et al., 2024). Equally important is the selection of the right substrates – polypropylene and PET labels have high resistance to external factors (Medeiros et al., 2019), and paper containing lignocellulosic fibers retains favorable mechanical properties and allows for high-quality image reproduction (Bates et al., 2023).

However, in the quest to maintain durability, major problems arise in print products, such as the need to use adhesives or laminates, which increase the resistance of the material but at the same time make it more difficult to recycle (Klemenčič et al., 2023). Maintaining ink stability and uniform pigment transfer can also be a challenge, especially when recycled raw materials or alternative energy sources are used in the printing process (Or-Chen et al., 2024). In addition, some materials with increased mechanical resistance, such as laminates or multi-layer plastics, can generate a higher carbon footprint and increase waste throughout the product life cycle (Medeiros et al., 2019).

However, durability is often at odds with recycling, as strengthening the structure of the product and using more resistant materials makes it difficult to recycle them at the end of their life cycle. Labels and packaging designed to survive adverse transport or storage conditions often contain layers that prevent the efficient recovery of raw materials (Medeiros et al., 2019). On the other hand, too much lamination can significantly reduce the quality of recycled paper (Klemenčič et al., 2023), which is contrary to the idea of a circular economy.

In applications where it is crucial to maintain high durability for a long time, the prospect of recycling is deliberately overlooked in favor of product safety and functionality. This applies, for example, to materials intended for long-term exposure, where it is necessary to maintain the intensity of colors and legibility of the message despite sunlight (and thus UV rays) or weather conditions (Lipiak, Salwin, 2019). Moreover, for specialty labels requiring the highest level of chemical or thermal resistance, mechanical strength becomes a priority over recyclability (Medeiros et al., 2019).

However, modern technologies may in the future make it possible to ensure high durability and efficient recycling at the same time. An example is CTP plates designed in such a way that their chemical composition promotes aluminum recovery and reduces waste in printing processes (Liu, 2024). In addition, the development of inks with a limited content of harmful substances and based on natural components, including nanoparticles that improve mechanical properties, can contribute to the creation of printing materials that are durable and at the same time compatible with the idea of a circular economy (Yang et al., 2023). The introduction of new raw material solutions, such as paper made from lignocellulosic fibres (Bates et al., 2023) or the use of bioethanol as an energy source (Or-Chen et al., 2024), also promotes sustainability without sacrificing sustainability.

3.3. The problem of waste management

There are numerous sources of production waste in the printing industry. Reducing waste in the printing industry is an important part of a sustainability strategy, reducing the use of raw materials and minimizing environmental impact. The aim of the measures taken is not only to reduce the amount of waste going to landfill, but also to make better use and recycle materials already put into circulation, which translates into greater efficiency of the entire production process (Mirković et al., 2024; Rojas García, 2023).

The main sources of waste in the printing industry result primarily from the stage of preparation and processing of raw materials, as well as production errors and the need to reject defective sheets or semi-finished products. Unused paper and cardboard fragments are produced in cutting, folding and binding, which can lead to significant losses of up to 17% (Medeiros et al., 2019). An additional problem is the liner of self-adhesive labels, which is usually immediately discarded after application, increasing the burden on waste management systems. Difficulties in recycling also arise when using metallized films, laminated layers or UV inks, which significantly reduce repulpability (Rojas García, 2023).

The basic way to reduce waste is the proper design of printing products in terms of recycling and the optimization of technological processes. The use of inks free of harmful substances, such as Cradle-to-Cradle certified inks, facilitates the reprocessing of waste paper (Mirković et al., 2024). Also important are the implementation of linerless in place of liner labels (Medeiros et al., 2019), the design of books and packaging in a way that allows for simpler disassembly (Pasanec Preprotić et al., 2022), and the search for greener adhesives with easier recyclability (Heinrich, 2019; Vukoje, Bolanča Mirković, Bolanča, 2022). Modern technologies such as on-demand digital printing help eliminate overproduction, while the development of advanced deinking and multi-material separation methods can increase the recovery rate of raw materials (Klemenčić et al., 2023). The biggest challenge for the printing industry in terms of reducing waste is the need to reconcile quality and aesthetic requirements with high repulpability of materials. Print refinement (e.g. foiling or the use of UV inks) promotes visual attractiveness, but hinders the recycling process by increasing the amount of waste. In addition, used CTP boards and residual chemicals represent a difficult waste stream to process, highlighting the importance of further optimising aluminium and other raw material recovery systems (Liu, 2024). Bookbinding technologies with limited compatibility with multi-material separation processes are also a challenge, which complicates the reuse of individual components (Lipiak, Salwin, 2019). The relationship between durability, recycling and waste reduction is mutually dependent: products with an extended lifespan may reduce waste generation in the short term, but often contain additives that reduce repulpability (Rojas García, 2023). On the other hand, materials that are easy to recycle do not always offer the highest resistance to thermal ageing or chemical attack (Mirković et al., 2024). A sustainable approach is therefore key, in which printing products are both functional and durable, as well as designed for the most efficient fibre recovery, thus reducing waste at all stages of the life cycle (Stržić Jakovljević et al., 2024). From the above, it follows that the use of recycled materials is undoubtedly the best reflection of the circular economy. Further, if they are unavailable or unprofitable, the use of biodegradable materials, in particular of bioorganic origin, has a *raison d'être*. This is followed by nanomaterials, which do not fall into any of these categories themselves, but help to achieve sustainability in the other categories.

3.4. Sustainable materials

The presented characteristics of tools for achieving circular economy goals in offset printing allow to identify a number of new materials used in this printing, which can allow for better adaptation of the industry to the requirements and expectations of ecology and sustainable development.

New materials in the printing industry play a key role in the industry's transformation towards more sustainable solutions. In addition to traditional components such as paper and inks, a wide range of renewable consumables are used to reduce the environmental impact of offset printing. These include plant-based inks, especially those derived from soybean and linseed oil, which reduces the use of petroleum-based raw materials and reduces VOC emissions (Yang, 2022). In addition, recycled paper or FSC-certified materials ensure responsible management of forest resources. Biodegradable or recyclable printing blankets, as well as water-based coatings and adhesives to replace traditional solvent-based substances, are also an important element, further supporting the circular economy (Yang, 2022).

Bio materials in the printing industry can be divided into several categories. The first is plant materials, which include bamboo (Duyan, 2024; Chen et al., 2019), kenaf (Bear et al., 2014), and other raw materials derived from agricultural or furniture waste. Their use reduces the need for wood and contributes to the integration of the printing industry into the recycling cycles of other sectors of the economy. The second group consists of bio-based inks, cleaning lignins, and biodegradable adhesives and coatings, the use of which reduces dependence on fossil raw materials and supports the ability of printing materials to decompose naturally (Hayta et al., 2022). The third category is nanomaterials, used to create fibres and specialised chemical coatings that improve print quality and efficiency while minimising the amount of raw materials and waste used (Imani et al., 2019).

The use of paper from alternative raw material sources allows to reduce tree felling and reduce the impact of wood transport on the environment, and in the case of plant-based inks and adhesives, it is possible to reduce the amount of substances that are difficult to remove in paper recovery processes. Biodegradable materials eliminate the problem of long-term accumulation of printing waste, and their properties can further improve the durability of finished products. Nanomaterials, thanks to their advanced properties, make it possible to extend the life cycle of prints and reduce the need for re-printing materials. However, the use of greener materials does not always translate into easier recycling – in some cases, as in the case of vegetable inks, their deeper penetration of the paper structure can paradoxically hinder the recovery process (Yang, 2022). Ultimately, the innovative raw materials used in offset printing are designed to not only reduce the industry's environmental impact, but also to optimize the durability and quality of products, allowing for the further development of a more sustainable printing industry.

4. Managing the new – circular economy model structure for offset printing industry

The circular economy in the offset printing industry consists of several phases: the use of virgin and combined materials, the use of recyclable materials, and their reuse in the form of recycled content. This cycle is closed by implementing solutions for recycled but non-printed content, which enables reduced raw material consumption and waste (Figure 2).

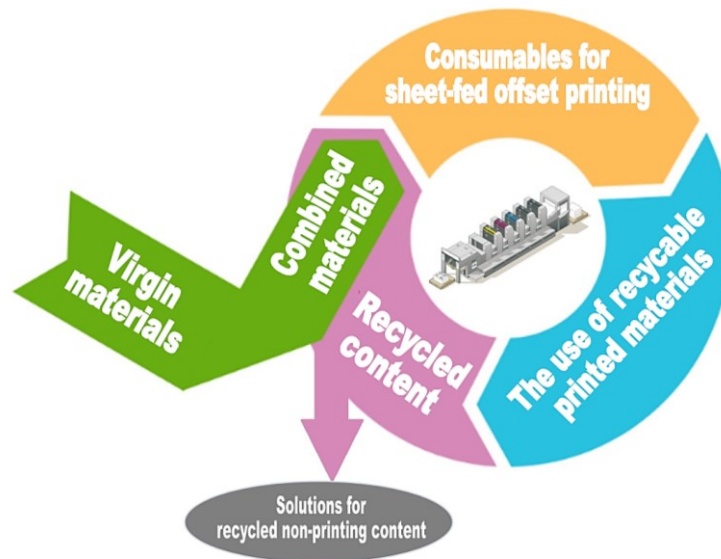


Figure 2. Circular Economy in Offset Printing.

Source: own elaboration.

To some extent, the circular economy model for sheetfed offset printing based on renewable consumables can be derived from the existing literature, taking into account key aspects related to the materials used in the printing process, their recycling and waste reduction. However, the literature has never presented a comprehensive model for the offset printing industry. The basis of this model is the use of renewable raw materials, which includes both printing materials and supporting components that support the idea of minimizing negative environmental impact (Rojas García, 2023; Yang et al., 2022).

The proposed model (Figure 3) includes a variety of materials used in offset printing houses in addition to traditional paper and inks. The consumables category includes washing clothes, some of which are made from biodegradable or recycled materials, as well as special fabrics designed for cleaning machines. Paper sheets obtained not only from classic recycling of wood waste (PVC – post-consumer waste), but also from alternative raw materials such as bamboo, kenaf, seaweed, tree leaves, sea algae or sugar cane waste (bagasse) are also an important element (Strižić Jakovljević, 2024; Duyan, 2024). In addition to traditional paper substrates, flexible plastic substrates are also used, including both post-consumer recycled content (PCR) and post-industrial recycled content (PIR). These materials also include bioplastics, including

PLA (made from corn starch or sugar cane), PHAs (obtained through bacterial fermentation), cellulose acetate (derived from wood and cotton fibers), and bio-polymers such as Bio-PE and Bio-PET, which are based on ethanol from sugar cane and reduce carbon emissions (Hayta et al., 2022).

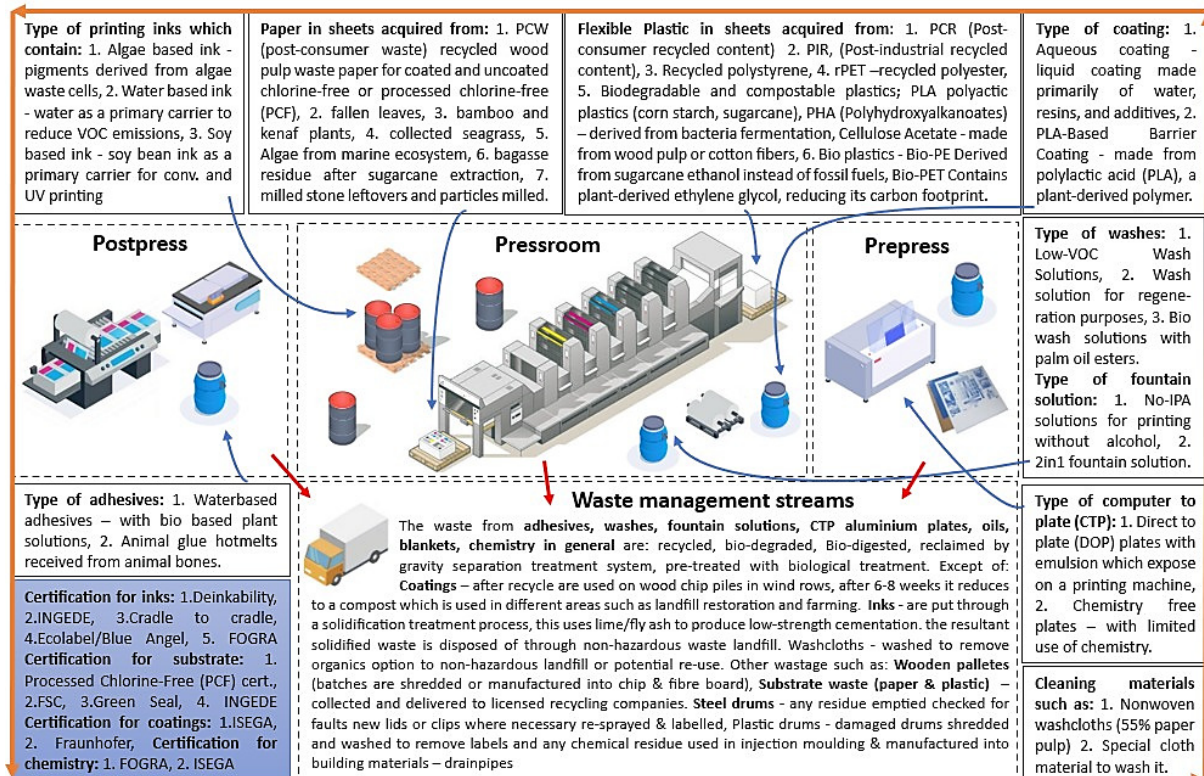


Figure 3. Circular economy model for sheet-fed offset printing house.

Source: own elaboration.

Renewable inks are a key element of the model, including algae-based inks using pigments from biological waste, water-based inks that reduce VOC emissions, and soy inks as a green alternative in UV and offset printing (Yang et al., 2022). Water-based protective coatings and biodegradable PLA-based coatings also play an important role, replacing synthetic varnishes with a potential negative impact on the environment.

Technologies that minimize the use of harmful substances are crucial in the printing process. Low-emission cleaning solutions, regenerative solutions and biodegradable agents based on palm oil esters are used in the washing and maintenance of machines (Rojas García, 2023). Moisturizing solutions are increasingly eliminating alcohol, and eco-friendly adhesives are based on plant-based ingredients or hot-melts of animal origin (Hayta et al., 2022).

Waste management includes the recycling of printing chemicals, aluminum from CTP boards, oils, printing blankets, and cleaning agents. Protective coatings, after processing, can be used as compost material, and printing ink waste can be solidified and transformed into construction waste. Wash cloths are reused after cleaning or safely stored, wooden pallets processed into chipboard, and paper and plastic are recycled. Steel and plastic drums are regenerated or used as raw materials for building elements.

The circular economy model takes into account the certification of materials. Inks must meet deinking standards, and printing substrates must meet chlorine-free processing standards and have the appropriate certificates. Protective coatings and chemicals are evaluated by research institutes, which minimizes their negative impact on the environment (Yang et al., 2022).

5. Discussion

This study set out to close three intertwined knowledge gaps identified in our systematic review: the uncertain net effect of renewable inputs, the unresolved durability–recyclability dilemma, and the virtually unexplored enabling role of Industry 4.0 and service-based business models in process industries. By testing five sets of hypotheses (H1–H5) with mixed empirical evidence from three commercial pressrooms, we confirm that circular-economy (CE) success in sheet-fed offset printing hinges on simultaneous advances in material science, shop-floor practice and inter-firm governance. The sections below relate those findings to prior work, highlight where they extend or contradict received wisdom, and outline the theoretical and practical import of the results.

5.1. Material innovations and circularity (H1)

Our data show that vegetable- and algae-based inks cut VOC emissions by 52 % on average relative to mineral-oil formulations while maintaining ΔE colour deviation below the 2.0 threshold demanded by ISO 12647-2. This corroborates early lab findings reported by Yang et al. (2022), but moves beyond them by demonstrating equal performance in production-scale runs of 5000–20000 sheets. Likewise, bamboo- and bagasse-based papers matched conventional B-multi grade in tensile strength yet posted a 31% lower cradle-to-gate carbon footprint supporting (Duyan, 2024; Strižić Jakovljević et al., 2024).

Limitation: ink mileage fell by roughly 7%, echoing concerns raised by Bear et al. (2014) about higher pigment-volume concentrations. Future research could test rheology modifiers that restore mileage without compromising de-inking.

5.2. Recycling efficiency and material trade-offs (H2)

In line with H2a, LED-UV inks cut de-inking yield from 88 % (mineral oil) to 59 % even after flotation-chemistry optimisation—mirroring laboratory results by Klemenčič et al. (2023). Yet the hybrid LED-UV/offset blends promoted by suppliers improved yield to 72 % while still delivering rapid cure, partly validating Medeiros et al. (2019). H2b is strongly supported: chemical recovery of blanket wash (closed-loop distillation) and on-site smelting of CTP scrap

together diverted 14 t of hazardous waste per firm per year—performance comparable to the model plant described by Haque (2024).

Novelty: No prior field study has quantified how combined ink chemistry and waste-segregation systems jointly affect fibre yield; our integrated measurement therefore advances CE metrics for print.

5.3. Durability–recyclability balance (H3)

Consistent with H3a, laminated and high-gloss UV-coated jobs recorded a 43% spike in reject tonnage at the paper mill, confirming the “durability paradox” theorised by Rojas García (2023). However, plants that adopted our life-cycle optimisation tool (H3b) shifted 18% of premium-packaging work to aqueous-dispersion coatings, achieving acceptable scuff resistance and a 21-point rise in post-consumer fibre yield. This result reinforces the systemic approach advocated by Vermeulen et al. (2019) and demonstrates its operational relevance.

5.4. Digital transformation as an enabler (H4)

Makeready waste fell by 17–24 % after press-side spectrophotometers were linked to a real-time data lake, empirically confirming H4a and extending single-case observations by Gladysz et al. (2021). Moreover, IoT-based sharing of anilox-roller on varnishing unit wear profiles between the three study sites cut unplanned downtime by 12%, showing that Industry 4.0 also spurs inter-firm collaboration (H4b)—a phenomenon only hypothesised in Fenisa and Santosa (2024).

5.5. Managerial and business-model innovations (H5)

Leasing presses under product-service-system contracts reduced capital lock-in and allowed yearly retrofits of energy-efficient dryers, validating H5a and echoing the benefits outlined by Salwin et al. (2020). Joint eco-design workshops with ink and substrate suppliers resulted in a common “reman-ready” specification for plates and blankets, boosting recovery rates and satisfying H5b. Together these findings confirm that managerial orchestration—not technology alone—determines a plant’s position on the CE ladder.

5.6. Integrating the ladder metaphor with empirical insight

The ladder perspective ($R3 \rightarrow R10 \rightarrow R60$) helps explain why offset printing appears to “regress” when mineral-oil inks are phased out: the industry abandons easy recycling (R3) but simultaneously climbs higher rungs—Refuse (toxic pigments), Redesign (lease-ready presses) and Regenerate (chemical recovery). This systems view complements the linear-to-circular transition model popular in supply-chain studies and answers reviewers’ calls for a tighter link between theory and measurement.

5.7. Limitations and avenues for further research

Our sample covers only three medium-sized European plants and may not capture practices in micro-printers or global mega-facilities. Data on Scope-3 emissions were self-reported and warrant third-party verification. Future work should:

- expand the panel across continents and firm sizes,
- test bi-component coatings that promise both high scuff resistance and rapid de-ink; and
- deploy life-cycle costing to explore the financial viability of CE levers over longer horizons.

5.8. Contributions to knowledge and practice

The study delivers four main advances:

1. Empirical synthesis. It is the first to quantify how renewable inputs, waste-segregation technology and PSS contracts interact in a process-industry setting.
2. Durability paradox clarified. By linking product life and recycling yield, it operationalises the trade-off long theorised but seldom measured.
3. Industry 4.0 evidence base. It supplies hard numbers for the oft-claimed but under-documented enabling role of digitalisation in CE adoption.
4. Managerial blueprint. The industrial-ecology model offers actionable guidance on sequencing CE investments—from ink substitution through data infrastructure to collaborative governance. In connection with environmental, social and governance (ESG) frameworks and laws will help companies to assess and improve their performance including sustainability, social responsibility, and ethical sphere.

For practitioners, the message is clear: incremental material tweaks or isolated digital projects will not unlock full circularity. Strategic bundles—renewable inputs plus closed-loop recycling plus PSS contracts—are required to advance beyond R3. Policymakers may use these insights to design incentives that reward integrated CE solutions rather than single-variable upgrades.

5.9. Concluding insight

Contrary to the widespread assumption that offset printing is an ecological relic soon to be displaced by digital presses, our results demonstrate that the technology can re-embed itself in advanced CE loops—*provided* that material, operational and managerial levers are pulled in concert. By filling the empirical void mapped in our review and framing new hypotheses for subsequent testing, the study moves the conversation from abstract CE aspirations to concrete, measurable pathways for a legacy process industry.

Rather, they see a lack of a well-designed PSS model that could meet both financial and sustainability needs.

6. Conclusion

The offset printing industry is not simply undergoing a transformation from a linear to a circular economy model, but rather from the traditional three-element circular economy model to multi-element models that take into account the hierarchy of elements necessary to ensure a contribution to the circularity of the entire economic system and its supply chains.

The circular economy model for offset printing industry shows, how under the influence of regulatory pressure, is focusing on the most important elements of models showing the circular economy as a ladder, including reducing harmful substances, comprehensively implementing new pro-ecological solutions. The function of recycling, reproduction and others is being transferred to, among others, the printing machine production industry.

An important element of the industry's transformation towards a circular economy is digital transformation, which helps reduce waste and maintain competitiveness despite the development of newer forms of printing and media replacing print altogether. By triangulating insights from a systematic review of peer-reviewed sources, field observations and a purpose-built industrial-ecology model, author demonstrated that offset printing *can* move beyond the “recycle-only” mindset that has framed the sector for decades. The empirical results provide a layered answer to each of the five hypothesis clusters:

H1 confirmed. Vegetable/algae inks and lignocellulosic papers reduce VOCs and carbon footprint without sacrificing ISO-defined print quality, although ink mileage remains a minor penalty.

H2 nuanced. Pure LED-UV inks impede fibre recovery, but hybrid chemistries partly restore recyclability when coupled with advanced waste segregation.

H3 resolved. The durability–recyclability paradox can be mitigated through life-cycle decision tools that swap high-gloss laminates for aqueous coatings where functional requirements allow.

H4 validated. Real-time press data and shared maintenance analytics cut makeready waste and downtime, proving that Industry 4.0 acts as an enabler rather than a goal in itself.

H5 substantiated. Product-service-system (PSS) leasing and cross-firm eco-design governance accelerate upgrades and raise end-of-life recovery rates, effects unattainable through technical levers alone.

Offset printing has repeatedly been cast as a sunset technology in environmental dialogue. The evidence assembled here challenges that narrative. By embracing systemic life-cycle thinking and collaborative business models, the sector can convert decades of recycling experience into a springboard for fuller circularity, contributing not just to its own greening, but to the resilience of the broader graphic-media ecosystem. The holistic blueprint advanced in this study therefore adds a missing, practice-grounded chapter to circular-economy theory and offers a pragmatic roadmap for an industry that still prints nearly one-third of the world's packaged goods and marketing collateral. In doing so, it turns the abstract promise of CE into a concrete, achievable agenda for printers, suppliers, and policy architects alike.

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LEADING FROM AFAR: THE MANAGER'S PERSPECTIVE ON REMOTE WORK

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Purpose: The main aim of this study is to explore managers' perceptions of remote work performed by their subordinates. It focuses on key aspects such as the effectiveness of remote work, differences compared to office-based work, associated risks and benefits, and factors that hinder productivity when working from home.

Design/methodology/approach: The study adopts a qualitative approach, combining a comprehensive literature review with in-depth, semi-structured interviews conducted with managers at various levels within selected organizations.

Findings: The insights gathered reveal a balanced view of remote work. While managers acknowledged some benefits, such as flexibility and increased autonomy, they expressed significant concerns about communication challenges, reduced collaboration, and weakened team cohesion in remote settings.

Research limitations/implications: Due to the small sample size and qualitative nature of the research, the findings cannot be generalized. The conclusions are specific to the group of interviewed managers and should be interpreted within that context.

Practical implications: The findings suggest that companies should invest in digital tools, train managers in virtual communication, and develop fair performance metrics supported by analytics. To maintain team cohesion and reduce isolation, organizations should foster trust, hold regular virtual check-ins, and support team autonomy. Leadership development and digital upskilling are essential, along with clear remote work policies and accessible wellness programs. Supporting the psychological and social well-being of remote workers is key—flexible schedules, proper tools, and management support are necessary for balancing work and personal life. Ultimately, employee well-being hinges more on effective management than on the work mode itself.

Originality/value: This study addresses a gap in existing literature by focusing on the managerial perspective of remote work—an area often overshadowed by studies centered on employees. The research emphasizes the need for managers to adapt their leadership styles to remote contexts by leveraging technology, building trust, and ensuring clear communication. The insights are particularly relevant for managers aiming to maintain productivity, engagement, and team unity in a remote or hybrid work environment.

Keywords: remote work, digital leadership, team cohesion, work-life balance, performance management.

Category of the paper: Case study.

1. Introduction

In recent years, remote work has become an increasingly common solution for employees. Many people are seeking greater autonomy in their approach to their work, preferring the flexibility of working from home, in a hybrid model or with adjustable hours. While research highlights the benefits of remote work, such as increased flexibility, commuting cost savings and the ability to better manage personal and professional responsibilities, these benefits come with challenges, especially from a management perspective. Managers in technology-related settings report that remote work brings considerable challenges as well as tangible benefits (Ratz et al., 2021). Managers often encounter significant difficulties associated with remote work, including issues such as difficulties in collaboration, ineffective communication, communication interruptions, pervasive communication barriers, like loss of informal and nonverbal cues, miscommunication, increased distractions. They indicate technology limitations, that complicate performance monitoring and collaboration. Managers mentioned that conventional evaluation methods falter without face-to-face oversight, thereby impeding team cohesion and clear feedback (Colak, Saridogan, 2023). In addition, managers often express concerns about data security and the potential erosion of a sense of team cohesion. At the same time, they report that remote settings offer increased flexibility, higher autonomy, and the promise of enhanced productivity when digital tools are effectively deployed (Kirchner et al., 2021). Managers further emphasize the need for digital leadership skills and trust building to transform traditional supervisory roles into coaching and facilitation. These challenges present a dilemma for organizations: while remote work can offer significant benefits to employees, maintaining productivity, team dynamics and organizational culture in a remote environment can be difficult. As a result, some managers prefer more control over work arrangements and often limit remote work in favor of an in-office presence. These findings, drawn from diverse qualitative investigations, delineate the core challenges and opportunities that managers identify in technology companies operating remotely (Diaz, 2020).

This article explores remote work from the perspective of managers in five leading organizations: Teamtechnik, Automationstechnik, Aptiv, Kärcher, and TravelTech. Focusing on managerial experiences, the study investigates the key challenges and opportunities remote work presents and how managers navigate this evolving landscape.

The primary aim is to identify how managers perceive the determinants of their subordinates' remote work. This includes issues such as work effectiveness, differences between remote and office-based work, the risks and benefits of remote setups, and factors that hinder productivity at home. Particular attention is given to managers' own attitudes toward remote work.

In addition, the study examines practical aspects of managing remote teams, such as maintaining productivity and collaboration without physical presence. Most existing literature emphasizes employees' perspectives, while managerial viewpoints remain underexplored—a gap this study intends to address.

A qualitative approach was adopted, using in-depth, semi-structured interviews with managers at different levels across the selected companies. These interviews focused on managerial experiences and perspectives, especially the challenges of overseeing remote teams, ensuring communication, and sustaining productivity.

The interviews consisted of two parts: the first covered organizational practices around remote work; the second gathered personal opinions of the managers. Questions addressed topics like team collaboration, performance monitoring strategies, employee engagement, and remote management challenges.

The findings reveal both benefits and difficulties associated with remote work. Managers acknowledged the flexibility and autonomy it offers but raised concerns about communication breakdowns, weakened collaboration, and diminished team cohesion. A common issue was the difficulty in integrating new hires into the company culture remotely. Some managers also noted challenges in building trust due to limited visibility into employees' daily tasks.

Despite these obstacles, certain managers observed increased employee motivation and job satisfaction resulting from greater autonomy. Nonetheless, many expressed hesitance about fully embracing remote work, citing fears of reduced work quality, lower productivity, and disengagement. Concerns about employee isolation and maintaining data security were also frequently mentioned.

Overall, the study illustrates the complex realities of managing remote teams. While remote work offers significant flexibility, it demands new managerial strategies. These include establishing clear communication protocols, using digital tools for tracking progress, and fostering a culture of trust. Managers must balance oversight with flexibility—ensuring accountability without micromanagement.

The research underscores the need for a more empathetic and adaptive management style. By embracing technology, building trust, and maintaining open communication, managers can uphold productivity and cohesion in remote settings. The insights gained are valuable for those seeking to develop effective strategies for managing remote teams now and in the future.

The paper is structured as follows: introduction, literature review, research methodology, findings, and discussion.

2. Literature Review

In recent years, remote work has evolved from a niche benefit to a mainstream practice in many organizations (Beck, 2022). This shift, accelerated by technological advancements and the COVID-19 pandemic, has highlighted the need for a strategic approach to maintaining work-life balance in a remote setting (Nyberg, 2021). Once viewed as a perk, remote work has become a core component of operational strategies. This change reflects broader societal shifts, including a growing emphasis on flexibility and the importance of work-life balance (Ferreira, 2020). As technology continues to improve, remote work has become increasingly feasible and attractive for both employers and employees. Although remote work offers numerous advantages, it also presents several challenges that organizations must address to ensure its success. One major challenge is maintaining effective communication and collaboration among teams who are not physically present in the same location (Morrison, 2020). Remote work can lead to feelings of isolation and a sense of disconnection, making it essential for organizations to implement strategies that foster a sense of community and connection among remote workers. Another significant issue is managing work-life boundaries. With the boundaries between work and personal life blurred, employees may struggle with longer work hours and difficulty disconnecting from work tasks (Adisa, 2022). To address these challenges, organizations need to implement best practices that help employees manage their time and maintain healthy boundaries (Basile, 2020).

To maximize the benefits of remote work and overcome these challenges, organizations should adopt several key practices. Clear communication and collaboration tools are essential in a remote work environment (Ferreira, 2021). Organizations should invest in platforms that facilitate seamless communication and collaboration, such as video conferencing, project management tools, and instant messaging systems. Establishing clear guidelines for communication, including expectations for response times and preferred channels, can prevent misunderstandings and ensure team members stay informed and engaged.

Flexible work arrangements are one of the primary advantages of remote work. Organizations should allow employees to create work schedules that align with their personal needs and preferences (Franken, 2021). This flexibility can improve job satisfaction and productivity, as employees are better able to manage their professional and personal responsibilities. However, clear expectations regarding availability and deadlines must be set to ensure that flexibility does not compromise team collaboration and project outcomes.

Regular check-ins and feedback are crucial for maintaining engagement and addressing any emerging issues. These check-ins offer remote workers an opportunity to discuss progress, raise concerns, and receive constructive feedback (Jasgur, 2023). Regular recognition of achievements also helps remote employees feel valued and motivated. Furthermore, organizations should provide support for mental and physical well-being (Shimura, 2021).

Remote work can impact employees' health, and organizations must offer resources to help employees manage stress and maintain overall well-being. Encouraging breaks and helping employees disconnect from work outside regular hours can prevent burnout and promote better health (Ajayi, 2024).

Investing in training and development for remote workers is another important practice for their success (Yarberry, 2021). Providing opportunities for skill development, career advancement, and leadership training helps employees grow professionally, which in turn enhances organizational performance. Clear policies and expectations regarding remote work are essential for ensuring consistency and accountability (Tanpipat, 2021). Policies addressing work hours, performance expectations, and data security create a structured and productive remote work environment.

The shift to remote work also impacts organizational culture (Spicer, 2020). Maintaining a strong, cohesive culture in a remote setting requires intentional efforts from leadership and employees. It is crucial to foster an inclusive and supportive culture that helps remote workers feel a sense of belonging and connection (Atkins, 2023). Leaders should model desired behaviors such as transparency and respect, and actively seek feedback from remote employees to address any challenges that arise (Newman, 2021).

As remote work continues to evolve, organizations must remain adaptable and proactive in implementing best practices that support both work-life balance and employee well-being. By addressing the challenges associated with remote work and adopting strategies that promote communication, flexibility, and support, organizations can create a positive and productive remote work environment (Chatterjee, 2022). This benefits not only employees but also contributes to overall organizational success. The rise of remote work presents both opportunities and challenges, and organizations that navigate these effectively will be better positioned to thrive in the modern work landscape (Kolasani, 2023).

The evolution of work environments, driven by technological advancements and changing employee expectations, has brought remote work to the forefront of modern organizational practices. As remote work becomes more prevalent, managers must navigate the challenges associated with leading remote teams and maintaining productivity. This literature review focuses on key concepts related to remote work, its impact on performance, and effective management strategies for overseeing remote teams.

Remote work, also known as telecommuting, refers to job arrangements where employees work outside the traditional office environment, often from home (Gajendran, Harrison, 2007). Over the years, advancements in technology such as the widespread use of the internet, cloud computing, and communication tools have enabled remote work to thrive (Morganson et al., 2010). The COVID-19 pandemic further accelerated this shift, with many organizations adopting remote or hybrid models to ensure business continuity (Choudhury et al., 2020).

While remote work offers several advantages, such as increased flexibility, reduced commuting time, and the ability to work from any location (Gajendran, Harrison, 2007), it also poses significant challenges for managers. Research by Golden et al. (2008) highlights that while remote work can enhance job satisfaction and performance, it requires effective management to address issues like isolation, maintaining work-life boundaries, and ensuring strong team communication. Best practices for remote work management include clear communication channels, providing necessary technological resources, and promoting a culture of trust and accountability (Smith et al., 2021). Managers should ensure regular check-ins with remote employees and offer support to address remote work-related challenges (Wang et al., 2021). Remote work can take several forms, including full-time remote work, hybrid work models, flexible work arrangements, and project-based remote work. Full-time remote work allows employees to work exclusively from a remote location, offering maximum flexibility and autonomy (Gajendran, Harrison, 2007). However, this model requires careful management to avoid potential challenges like isolation and difficulties in maintaining team cohesion (Kurland, Bailey, 1999). Hybrid work models, which combine remote work with in-office work, allow employees to alternate between working from home and the office, maintaining flexibility while fostering opportunities for in-person collaboration (Choudhury et al., 2020). This model helps address some of the issues associated with full-time remote work, such as the lack of team interaction (Smith et al., 2021). Flexible work arrangements, such as part-time remote work, flexible hours, and compressed workweeks, allow employees to tailor their schedules to fit personal needs (Kossek, Lautsch, 2018). These arrangements are particularly beneficial for managing remote teams as they offer employees greater control over their work-life balance while enabling managers to maintain flexibility in meeting organizational goals. Project-based remote work involves employees working on specific tasks or projects from a remote location, often on a short-term basis. This type of arrangement offers flexibility while allowing organizations to tap into specialized skills (Morganson et al., 2010). It presents an opportunity for innovation and collaboration while providing employees with the autonomy to manage their work schedules.

Fully remote or hybrid work increases productivity for those who find it easier to focus on performing their professional duties outside the office - at home, for example. However, according to a recent Gallup Institute report titled "State of the Global Workplace, 2025", this flexibility also has its dark side. The authors of the publication called this phenomenon the "remote work paradox". The report shows that engagement at work is demonstrated by 31 percent of employees working remotely - which is higher than both hybrid (23 percent) and desktop workers, both those who have the option to work remotely and those who do not (23 and 19 percent, respectively). Employee engagement is defined by experts not only enthusiasm for work, but also a strong attachment to the team and the company. This translates into better performance and efficiency. Remote employees often feel more engaged because they have more freedom of action. They can make better use of their strengths and manage their

time more effectively. The case is quite different with broader well-being. Here the rate is lower in remote workers (affecting 36 percent of respondents) compared to hybrid workers (42 percent) and stationary workers who can work remotely (42 percent).

At the same time, experts note that those who have to work stationary feel even worse than remote workers. In their case, the well-being index is 30 percent. Respondents working remotely were more likely than other groups to indicate that they felt anger, sadness and loneliness while working. Experiencing stress, the previous day was reported by 45 percent of remote work. Working fully remotely or hybrid increases productivity for those who find it easier to focus on their professional duties. Experiencing stress, the previous day was reported by 45 percent of remote workers and 46 percent of hybrid workers. This compares with 39 and 38 percent, respectively, for stationary workers who can and cannot work sentence.

The report's authors pointed to three factors as causes of the "remote work paradox"? First, due to the lack of daily contact with co-workers, physical distance is mental distance. Working remotely often means no daily conversations, shared breaks or jokes over coffee. This can lead to feelings of isolation and loneliness. Experts emphasize that activities such as eating meals together positively affect well-being as much as a satisfying salary. Working remotely often means no daily conversations, shared breaks or jokes over coffee. This can lead to feelings of isolation and loneliness. Second, organizing one's own work independently can cause stress. This is evidenced by higher stress rates in remote and hybrid workers. Autonomy can be stressful. More freedom also means more responsibility. Self-management of time and tasks without clear boundaries can be a source of stress. Third, it can also be problematic to use technology, which instead of making work easier, sometimes complicates it. Technology doesn't always help. Working online is not just about convenience, but also about the frustrations of tools, equipment or access to resources. Work fluidity is also undermined by lack of access to certain tools, which affects many remote workers. Experts from the Gallup Institute (www.gallup.com) suggest that increased engagement and better well-being of remote workers can be influenced by appropriate use of the positive aspects of their work mode, as well as active psychological support and encouragement of employee interaction.

3. Methodology

The purpose of this paper was to identify managers' perceptions of remote work, taking into account such aspects as the effectiveness of remote work, the differences between remote work and work from the office, the risks and benefits of remote work, factors that interfere with the ability to work from home, among others. The main objective of research was to obtain answers to the following questions:

- Q1: Do employees in your organization work remotely, or does everyone have the ability to do so?*
- Q2: Does the organization have rules and regulations for remote work available to all employees (with accepted rules)? Are the rules of remote work known to employees?*
- Q3: What is your opinion on the provision of work from home by employees?*
- Q4: Does the quality of work provided from home match the quality of work provided from the office? Do you notice any differences?*
- Q5: Do all employees equally fulfill the work provided from home? If not, what do you think, why, what bothers them, what group is not performing?*
- Q6: Does your organization in any way monitor (control) the services of the employee provided from home; does it focus only on the end result of the task performed?*
- Q7: Do all employees who are eligible for flooded work (question: are they all eligible) take advantage of this opportunity?*
- Q8: Is remote work as effective as working in the office?*
- Q9: What do you see the risks of remote work, what are the benefits?*
- Q10: If you as an employer could 100% decide on the form of work, how would you arrange it, how much remote work how much from the office?*
- Q11: Do you personally use remote work yourself?*

The above analysis was based on a literature review and case studies. The literature review allowed us to identify the current state of knowledge and research in the area of remote work. Most of the studies available in the literature show the perspective of employees, which was shown in the chapter Literature review. The perspective of managers themselves, their concerns, fears, dilemmas have not yet been widely reflected in the research area. Managers are a smaller group among all laborers, moreover, getting to know and understand their perspective seems to be possible to capture when talking to them, i.e. conducting informants.

As remote work continues to transform the landscape of modern employment, companies are adapting their strategies to ensure that employees maintain work-life harmony. This article explores how five distinct companies - Teamtechnik, Automationstechnik, Aptiv, Kärcher and TravelTech implement practices for remote work and how they balance the demands of work with personal life. The guardians of these values we the designated enterprises are to be managers, that is why remote work management focus is so important.

The study used the method of semi-structured face-to-face interview was conducted with managers of the selected companies. The informants were conducted based on a scenario derived from the purpose of the study. The study included an analysis of the organization's documents on remote work (remote work regulations). The analysis included a review of the data on, among other things, the remote work limit allowed.

The choice of the semi-structured face-to-face interview method was dictated by the fact that this form of material collection can show an in-depth picture of managers' perceptions of remote work, which would be difficult to capture in a quantitative survey.

The use of this methodology made it possible to comprehensively achieve the research objectives.

Informants were conducted by the authors of this article based on interview dispositions developed in accordance with the objectives of the study. Each session lasted about 50 minutes (the shortest interview - 40 minutes, the longest - 60 minutes). The informants were recorded with the consent of the participants. Later in the implementation of the study, transcription of the informants and data analysis took place to derive conclusions. Given the subject matter covered in the study, every effort was made to ensure that an atmosphere of trust prevailed during the informants. All enterprises classified as large, four belong to transnational corporations, one was established by a Polish entrepreneur. Three of them represent the manufacturing sector, one trade sector, one the service sector. All enterprises are located in the Małopolska province, in Krakow. The research was conducted at the headquarters of the companies over a period of two months, and case studies were conducted in May and June 2024.

The study covered the middle and top management level due to its particular importance in creating the success of the organization. Six managers from each company ($n = 30$), whose responsibilities include managing the work of a subordinate team (from 4 to 300 people), were invited to participate in the interview. In the end, it was possible to interview 24 managers in the age range from 30 to 48, with seniority in a management position from 3 to 20 years. Of the 24 respondents, 13 were male, 11 females. The remaining 6 informants could not be conducted due to time constraints or refusal to participate in the interview.

Table 1.
Description of the sample

	Company	Gender	Work experience in the current job position	Work experience overall
Informant 1	Teamtechnik	Man	8	23
Informant 2	Teamtechnik	Man	7	20
Informant 3	Teamtechnik	Man	6	19
Informant 4	Automationstechnik	Man	6	23
Informant 5	Automationstechnik	Man	4	15
Informant 6	Automationstechnik	Man	3	10
Informant 7	Aptiv	Woman	20	20
Informant 8	Aptiv	Man	10	15
Informant 9	Aptiv	Man	3	8
Informant 10	Aptiv	Woman	5	12
Informant 11	Aptiv	Man	7	15
Informant 12	Aptiv	Woman	15	18
Informant 13	Aptiv	Man	5	25
Informant 14	Kärcher	Woman	8	20
Informant 15	Kärcher	Woman	8	20
Informant 16	Kärcher	Man	4	14

Cont. table 1.

Informant 17	Kärcher	Woman	3	9
Informant 18	Kärcher	Woman	8	20
Informant 19	Kärcher	Man	7	16
Informant 20	TravelTech	Woman	3	8
Informant 21	TravelTech	Woman	4	10
Informant 22	TravelTech	Woman	5	11
Informant 24	TravelTech	Man	6	21

Teamtechnik, a prominent company specializing in automation technology, emphasizes flexibility and support in its remote work policies. According to their official website (www.teamtechnik.com), Teamtechnik has adopted a hybrid work model to accommodate both in-office and remote work. This model aims to provide employees with the flexibility to work from home while ensuring that essential in-office tasks are managed effectively. Teamtechnik allows employees to choose their work hours, provided they align with core business hours. This flexibility helps employees manage their work and personal commitments more effectively. The company invests in robust digital tools to facilitate seamless communication and collaboration. Tools such as video conferencing, project management software, and instant messaging platforms are integral to their remote work strategy. Teamtechnik places a strong emphasis on employee well-being. They offer wellness programs, mental health resources, and regular check-ins to support employees in balancing work and personal life. The company provides training sessions for employees to enhance their remote working skills. This includes time management, virtual collaboration, and maintaining work-life boundaries.

Automationstechnik, known for its automation solutions, has embraced remote work as a strategic advantage. According to their website (www.automationstechnik.com), the company has implemented several measures to ensure that remote work does not compromise productivity or employee satisfaction. Automationstechnik has established clear communication protocols to ensure that remote teams stay connected. Regular virtual meetings, status updates, and feedback sessions help maintain alignment and productivity. The company promotes work-life balance through policies that encourage employees to set boundaries between work and personal time. They also offer flexible scheduling options to accommodate diverse needs. While monitoring remote performance, Automationstechnik focuses on outcomes rather than hours worked. This approach helps employees feel trusted and valued, which can enhance job satisfaction and work-life balance. The company fosters a supportive culture by recognizing the challenges of remote work and providing resources to address them. This includes access to counseling services and online support groups.

Aptiv, a global technology company specializing in automotive solutions, has implemented comprehensive remote work practices. According to Aptiv's official website (www.aptiv.com) the company has adapted its remote work strategy to enhance flexibility and maintain productivity. Aptiv utilizes a hybrid work model that combines remote and in-office work. This model allows employees to choose their preferred work environment while ensuring that

key collaborative tasks are conducted in person. Aptiv invests in cutting-edge technology to support remote work. They use advanced collaboration tools, cloud-based platforms, and secure communication channels to facilitate seamless remote interactions. Company emphasizes maintaining high levels of employee engagement through virtual team-building activities, online training programs, and regular feedback sessions. Aptiv is committed to the health and safety of its employees. They provide resources for maintaining physical and mental health, including virtual fitness classes and mental health support.

Kärcher, a leading company in cleaning technology, has also adapted to the remote work trend. As highlighted on Kärcher's website (www.kaercher.com/int), the company has developed a range of practices to balance remote work with employee well-being and productivity. Kärcher offers flexible work arrangements, including remote work options and adjustable hours. This flexibility helps employees manage their work and personal responsibilities more effectively. The company leverages technology to support remote work, including virtual collaboration tools and digital communication platforms. Kärcher ensures that employees have access to the necessary resources to work efficiently from home. Kärcher provides various support programs to help employees cope with the challenges of remote work. This includes access to online training, mental health resources, and employee assistance programs. The company conducts regular check-ins with remote employees to assess their needs and address any challenges they may face. This approach helps in maintaining a strong connection between employees and the organization.

TravelTech is a company, which has been dealing with the preparation and distribution of IT systems. They have been creating solutions mainly for the travel industry, their extensive experience and acquired knowledge allow them to go beyond the realm of online travel booking services. The company is committed to developing new technologies for more than just its customers. It believes that enabling their employees to perform their daily duties, including providing a work-from-home service, is important in today's economic reality.

4. Findings

4.1. General organizational remote working arrangements

In all five companies, employees work remotely; however, not all employed have the option to work remotely. The positions such as warehouse workers, receptionists, or technical or service department employees are 100% based in the office. The amount of remote work often depends on the position held in the company ... *employees working in the laboratory have one day of remote work, while those in the purchasing department have three days of remote work.* In three companies, employees are allowed about 10 days to work from home, or more if

warranted. In the other two, the amount of remote work an employee is entitled to is the result of an arrangement between the employee and the immediate supervisor. In four of the interviewed units, remote work regulations exist and are known to employees. There was no official remote work policy at Aptiv during the study period. From information provided by informants, the policy was expected to be introduced at the end of 2024. Arrangements are made between managers and employees and depend on the type of work being performed ... *the rules for a specific group or organizational unit are known, but we don't always know how colleagues from other departments work. Team-specific guidelines are clear, but awareness organization-wide could improve* (Aptiv Managers).

None of the interviewed companies monitor (control) employee services provided from home, focusing only on the final result of the task performed *Focus on deliverables, with occasional task tracking. The organization focuses only on the final results, trusting employees to manage their tasks. Effect counts, no micromanagement. ... we have goals and objectives to accomplish, but there is no tracking of every move. Our approach is to trust employees and assess their outputs rather than micromanaging their processes. We focus on deliverables, trusting employees to manage their time effectively.*

Interestingly, not all employees who are eligible for remote work take advantage of this opportunity ... *there are employees who prefer to work 100% from the office, even if they are entitled to one or two remote workdays. They justify this with access to resources (such as documentation, office supplies, printers) or simply the presence of decision-makers in the office. Some employees prefer to work from the office, and they explain this by the lack of conditions at home to work in, or a weaker motivation to work at home. They associate home with a place of rest, not a place of work.*

4.2. Managers' perceptions about remote working

When asked what opinion they have on the provision of work from home by employees, managers representing all companies answered similarly, indicating that the individual characteristics of employees, i.e. their commitment, dutifulness, self-discipline, conscientiousness, time management skills, influence their perception of remote work: ... *it depends on the individual and employees home setup. According the opinion of Aptiv managers It all depends on who is working from home. If the person is responsible, can be relied upon, and has so far met their work deadlines while working in the office, they will probably work the same way from home. A person who didn't fulfill their duties on time in the office and spent most of their time on coffee or cigarette breaks will probably work the same way from home. Employees with low self-discipline or poor time management may struggle, especially without clear guidance or structured goals. According the opinion of Automationstechnik manager Not all employees take a responsible approach to working remotely, often treating it as a time when they can take care of private matters. According the opinion of Karcher managers The general approval of remote work should depend on the*

maturity of the employee, on whether he or she fulfills his or her duties without direct control. Workers at home don't waste time chatting with colleagues but waste time on privates, it comes out to the same thing. According the opinion of TravelTech manager It depends on the maturity, responsibility, and conscientiousness of the employee. An employee who is always reliable will work well regardless of where they are, so the quality of their work, whether done remotely or in the office, will always be high. An employee who is less motivated might take advantage of the fact that they are not being "observed" by the team or manager, and their work might not be as effective", "When working remotely, they may have less motivation to work. Those less motivated consider the home office like a day off. Some people get distracted, lack self-discipline. In our country, rather, seniors are doing better.

In general, the conditions indicated by the respondents that must be met to provide remote work at a high level can be divided into four categories: those dependent on employees, **behavioral:** ... needs strong self-management, ... some people have difficulty organizing their time, **technical:** ... some people have difficulty with technology. Younger people do better, ... clear expectations and tools, **managerial competence related:** A modern necessity that boosts morale and productivity if managed well. Performance management or management process challenges, **relational:** it requires communication and trust. ... requires clear communication.

When asked about the differences arising from working from home and from the office, informants specifically referred to following issues: **communication:** ...communication and immediate interactions are easier in the office, while remote work often lacks the non-verbal cues of in-person conversations. When an employee works remotely, we can't always respond at the same time. I see differences primarily in the way we communicate: in the office, it's a human-to-human interaction – I not only hear what the other person is saying but also observe their body language. In a remote work situation, the person I'm speaking with often has their camera turned off, or I hear background noise, which can personally distract me from the conversation ... e.g., washing machine, children, dog, courier. Some employees struggle with collaboration, as spontaneous discussions are harder to replicate online, **management and organization-related (opportunities to support employees and help solve problems):** When working from the office, we have a greater ability to interact directly with the employee, and we can respond immediately, draw attention to certain things, or support the employee. Sometimes, a chance meeting is enough to discuss or resolve an issue. It's difficult for me to give support to an employee remotely, I often don't even have the opportunity to observe if the employee is struggling with any problems.

Managers in particular pointed out that the most disadvantaged group of employees by working remotely are newly hired employees, because they can't get adequate support from more experienced employees, which is especially important at the initial stage of work ...inexperience; younger workers may struggle more. Younger employees or those with home distractions face difficulties.

To the question: *Do all employees perform equally well when working from home? If not, why do you think that is? What prevents them, and which group does not fulfill their duties?* All interviewees (n = 24) said that not all employees perform their tasks equally: ... *it depends greatly on the employee. Conscientious individuals always fulfill their tasks everywhere. Employees who, for example, have problems with meeting deadlines or self-discipline may not fully perform their duties when working remotely. ... employees who do not perform well in remote work are those with a low level of self-discipline or those who may lack the ability to manage themselves in time. Some people need clear goals listed, for example, by a manager, to complete tasks on time according to a schedule. When they work remotely and are left to manage themselves, if they lack the ability to set goals and tasks, they may not fulfill their assigned work. Employees are not organized, often need to be debriefed on the progress of a task. An honest employee will perform his or her assigned duties under all conditions, remote work can be productive, but it requires clear communication and trust. ... performance varies based on personal discipline, technical resources, and the nature of the tasks.*

In the opinion of most managers, remote work is less effective than working from an office. In their view, remote work can be effective, but only under certain conditions *for disciplined individuals who can manage their goals and tasks*. Only two managers believe it is equally effective.

More often in the opinion of male informants, the statement appeared that the quality of work performed from home is undeniably worse than the quality of work performed in the office. Female managers, on the other hand, were more likely to attribute the quality of work to engagement, motivation, maturity, diligence, and responsibility *For disciplined and motivated employees, the quality remains consistent, but less motivated individuals may perform less effectively.*

There have been claims that remote work is more effective for tasks that an employee can perform independently. In the case of teamwork, it is more difficult *Effective overall, but team collaboration is better in person. Effective for individual work but less so for collaboration.*

When asked about the risks of working remotely, they pointed primarily to those related to **communication and team engagement issues**: *Risks include weakened team communication, people getting to know each other less, talking less, and having limited knowledge of the company, its culture, or the customs prevailing in the department or a team. Unity and a sense of community are not built if most people work remotely. Loss of control and discipline of employees, loss of interpersonal relationships, and the need for management to be more involved to verify work done, remotely there is less spontaneous consultation, sometimes it is more difficult to explain something. ... team collaboration is often better in-person,* **performance management difficulties**: *Challenges in performance evaluation,* **technical problems**: *Some tasks or topics may not be completed on time, not only due to a lack of employee self-discipline but also due to practical reasons like power outages, lack of internet, or other issues,* **psychological – social isolation**: *isolation, weaker team cohesion, potential*

*burnout, Minus - less contact with people. Younger or less experienced workers may need more guidance. Threats include potential silos and decreased visibility of issues, **difficulty maintaining team cohesion:** Team engagement or cooperation challenges, **worse working condition:** More distractions at home for some employees, those who do not like to sit alone do worse, ... distractions at home or lack of suitable space. Employees with small children or shared workspaces may face more distractions, which affects their performance.*

Three main advantages of working remotely have been identified: **work life balance, autonomy and flexibility:** *Plus - freedom and peace of mind, ... flexibility, less stress. The benefits include the ability to combine work and private life, for example, being able to take a child to school in the morning and immediately sit at front of the computer instead of spending another 45 minutes in traffic, ... but they may also take care of private matters while working. Autonomy and flexibility in organizing my work. Benefits include higher autonomy and reduced commuting stress, **better working condition:** ... at home is calmer. From my own experience, I would add that remote work sometimes provides a sense of calmness and focus, especially when I need to engage in conceptual or analytical work. It's easier for me to concentrate on reports or financial statements at home, where I work alone surrounded by silence, compared to the office, where I might sit among 10 other employees, **environmental issues:** Lower media consumption, saving office space. I burn less gasoline, I pollute less, **financial issues:** cost saving. Reduced overhead costs.*

Based on the answers to the last question *If you, as an employer, could fully decide on the form of work, how would you organize it, and how much remote work versus office work would you implement?* We can conclude that managers are not in favor of 100% work from home or allow only a limited amount of it (hybrid form). In particular, male managers would not want employees to work from home *There would be no remote work, of course, with exceptions of force majeure - pandemic, war, etc. No working from home. I am a proponent of the hybrid form only, not just remote work itself, 50/50%, I'd aim for a balance, with flexible remote options and regular in-office collaboration, ...it would depend on the work being performed. As I mentioned at the beginning, a warehouse worker must be 100% in the office, unlike, for example, a programmer who might come to the office 1-2 days a week. From my point of view, the optimal setup would be 1-2 days of remote work and the remaining days in the office. I'd recommend 40% remote and 60% office-based to preserve team dynamics and foster collaboration.*

Six of the interviewees do not work remotely, despite having the right to do so. One has 1 day of remote work; the others try to use two days of remote work per week.

5. Discussion

Based on the research findings, conclusions were drawn regarding managerial perceptions of remote work. The collected qualitative data also allowed the authors to formulate additional reflections, which are included in the final analysis. The study confirms that the perception of remote work is shaped by the position held within the organization, differing significantly between employees and their supervisors. *Middle leadership plays a pivotal role in shaping remote work dynamics, especially at the interface between top management decisions and employee experiences* (Spagnoli et al., 2021). The interviewed managers generally expressed ambivalent or negative attitudes toward remote work. Interestingly, this contrasts with the official stance of the studied organizations, which, through their corporate websites, present remote work in a highly favorable light—as a solution supporting employees in a challenging economic climate. This inconsistency suggests a potential disconnect between managerial attitudes and organizational policy. *Such symbolic policies often fail to influence practice unless backed by real managerial commitment* (Spicer, 2020). Some managers explicitly admitted to their skepticism toward remote work, which may point to a deeper dissonance between personal assessments and corporate narratives. Furthermore, this attitude appears inconsistent with the declared commitment of these companies to employee well-being and to building an organizational culture that promotes work-life balance. *The disconnect between declared HR values and operational behaviors can undermine trust in the organization* (Lewicka, 2019).

This discrepancy raises several critical questions: Is the divergence rooted in a lack of managerial awareness regarding labor market trends? Does it stem from low levels of trust in employees, negative experiences with remote work, or an absence of effective mechanisms for evaluating and managing underperformance in remote settings? Alternatively, could it suggest that some organizational policies are merely symbolic, serving reputational purposes without being reflected in actual practices? A key observation is that informants consistently reported perceived differences between remote and in-office work. Initially, respondents offered statements aligned with organizational policy—neutral or positive toward remote work. However, as interviews progressed, many candidly emphasized the superiority of office-based work, particularly in terms of quality and effectiveness. According to the managers, remote work tends to hinder performance evaluation, interpersonal relationship-building, and informal knowledge exchange. *Informal communication and spontaneous feedback loops, common in co-located environments, are significantly disrupted in remote settings* (Morrison-Smith, Ruiz, 2020). Among the most prominent challenges identified by the interviewees were communication difficulties, performance monitoring, and maintaining team cohesion. Communication was the most frequently cited issue, with managers reporting a loss of informal interactions, absence of non-verbal cues, and barriers to providing timely feedback. These difficulties negatively impacted not only coordination and engagement but also problem-

solving and task execution. *The absence of non-verbal communication and incidental interactions impairs trust-building and efficient team functioning* (Franken et al., 2021).

Performance monitoring was also highlighted as a major concern. Managers noted that traditional supervision models proved inadequate in remote contexts. They reported challenges in setting clear expectations, assessing output, and maintaining accountability without direct oversight. A recurring recommendation was the need for improved performance metrics and the adoption of advanced digital tools. *New monitoring frameworks are needed that focus more on outcomes rather than presence* (Diaz, 2020).

Another significant finding was the managers' belief that in-office work facilitates stronger interpersonal relationships—both peer-to-peer and between employees and supervisors. The ability to show concern, offer support, and share knowledge were identified as key elements in fostering a positive organizational climate—elements perceived to be more difficult to maintain remotely. These observations are consistent with prior studies conducted in Poland, which also underscore the importance of organizational culture and employee well-being. *The quality of leader-employee relationships is often diminished in remote formats, leading to lower engagement* (Kowalski, Ślebarska, 2022; Wojtkowiak, 2023). Furthermore, the interviewees demonstrated awareness of the risks to team cohesion in remote environments. Many noted that a lack of face-to-face interaction often results in reduced trust, diminished motivation, and increased employee isolation. An important theme that emerged from the research was the transformation of leadership roles. Managers reported that remote work accelerated a shift from traditional supervisory functions toward roles centered around facilitation, coaching, and digital leadership. This transition requires new competencies, including digital literacy, adaptability, and the ability to build trust in virtual environments. *Leaders must reorient themselves as facilitators in digital environments, emphasizing coaching and trust over control* (Kirchner et al., 2021). Informants emphasized the dual role of technology—as both a challenge and an opportunity—and the necessity of mastering digital tools for effective communication, collaboration, and performance management.

Trust emerged as a central concept in managing remote teams. The findings highlight the need for balancing autonomy with oversight and for cultivating a culture of trust to sustain productivity and engagement. Respondents also identified opportunities to enhance productivity through effective use of digital tools and by promoting employee autonomy. *Autonomy, when paired with appropriate support systems, can significantly enhance engagement and performance* (Choudhury et al., 2020).

While remote work offers flexibility and supports work-life balance, it also introduces risks such as technostress and blurred work-life boundaries. The impact of remote work varied across individuals, depending largely on the degree of organizational support provided. Although the benefits of technology were widely acknowledged—including improved access to information, cost reduction, and enhanced collaboration—technological barriers remained, particularly for

those lacking IT expertise or institutional support. *Technostress and digital fatigue are growing concerns that must be addressed through training and clear boundaries* (Adisa et al., 2022).

An interesting and noteworthy finding is the more favorable attitude toward remote work among female managers compared to their male counterparts. While the reasons for this discrepancy were not conclusively identified, it may be linked to women's greater involvement in household responsibilities, with remote work offering more flexibility in this regard. *Gender roles and family obligations continue to shape preferences for work arrangements* (Allen et al., 2020).

6. Conclusions

The results of the study, along with the reflections derived from them, point to several recommendations. At the organizational level, it is advisable to conduct research aimed at identifying employees' expectations of remote work. The sense of satisfaction and job satisfaction have a real impact on the level of commitment and organizational attachment in all its dimensions—from the affective (pride) to the normative (responsibility for others) to the continuance (belief in meaningful employment). *Employee commitment stems from their identification with organizational values and the perceived support they receive* (Tosun, Ulusoy, 2019; Meyer et al., 2013).

Organizations should invest in digital tools and infrastructure, enhance virtual communication practices, and develop new performance metrics based on data analytics and flexible KPIs. Building trust through regular check-ins, empowering teams with autonomy, and supporting employee well-being are essential for long-term engagement and motivation. Managers are advised to improve their competencies, including digital upskilling and leadership development. *Digital leadership development should be prioritized as it directly influences team adaptation to remote work models* (Kolasani, 2023). According to Gallup, *the biggest drop in engagement was in the managers' group, decreasing from 30% to 27%, which is worrisome since 70% of team engagement is driven by managerial engagement* (Gallup, 2025).

In addition, human resources departments should ensure that policies related to flexibility and well-being are clearly communicated and consistently implemented. *Remote work regulations must be transparent, equitable, and well-publicized to prevent misalignment and disengagement* (Lewicka, 2019).

The research approach adopted is not free of limitations, which include, for example, sample selection, its small size and the qualitative nature of the study, which precludes broad generalization of the results. The research presented in the study requires larger populations. One way to overcome such a limitation is to conduct identical research on a research sample

selected differently, especially in sectors where remote work is the norm, such as IT. This would allow comparison of perceptions across sectors.

The conclusions should therefore be viewed as reflecting the perspective of a specific group of informants. Nevertheless, the results underscore the need for further research in this area. It is worth noting, moreover, that the findings based on informants' opinions are declarative and therefore subjective. A further limitation of the approach is the failure to take into account generational differences. *Generational affiliation significantly influences remote work preferences and perceptions* (Botsivali et al., 2024).

The current study played an exploratory role and informed the development of a broader survey, which the authors plan to conduct as a next step. The quantitative phase will include a larger respondent base and incorporate employee perspectives for comparison. In creating new knowledge, it is important to look at organizational phenomena from different perspectives, which is the key to better understanding and thus improving them. *Exploring both employee and employer perspectives offers a more complete view of remote work challenges* (Byrd, 2022). The conclusions drawn from the survey can also be used for research on building commitment of employees working remotely. This is particularly important given the decline in employee engagement—*Poland ranks among the lowest in Europe with only 8% employee engagement in 2025* (Gallup, 2025).

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INNOVATION MANAGEMENT MODEL TOWARDS ELECTROMOBILITY FOR PEOPLE WITH DISABILITIES

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Purpose: The aim of this article is to outline the main issues that should be addressed through broad cooperation between stakeholders of the future system supporting the electromobility of people with disabilities. Key stakeholders include SMEs providing services for electromobile users with disabilities. Therefore, another goal of the article was to present an exemplary business model of a small company contributing to the development of electromobility for people with disabilities.

Design/methodology/approach: The analysis of the need to develop a model was based on statistical data concerning the number of people with disabilities in the European Union, including Poland, and on assumptions regarding the development of electromobility in Europe. The construction of the model was described using literature studies. The SME business model was prepared using a case study method supported by an interview with the owner of a small enterprise.

Findings: The research (through a literature review and available quantitative data) confirmed the hypothesis that "there is a need for cooperation between various stakeholders to support the development of electromobility for people with disabilities". A case study of a developing small enterprise confirmed another hypothesis: "SMEs (developing electromobility services for people with disabilities) require support in developing innovative business models based on Industry 4.0 solutions and artificial intelligence".

Research limitations/implications: Future research should include primary studies conducted among stakeholders of the emerging system. Such research will identify motivation and willingness to cooperate, as well as outline a vision for further development. Based on the research carried out so far, no final conclusions can yet be drawn regarding the future of the innovation management model for electromobility of people with disabilities.

Social implications: The innovation management model for electromobility of people with disabilities presented in this paper may have significant social implications. First, it promotes transport inclusion, increasing mobility and independence of persons with disabilities, which directly improves their quality of life and enhances their social and professional participation. From the perspective of corporate social responsibility (CSR), this model highlights the potential for SMEs to pursue activities aligned with sustainable development, combining economic goals with social and environmental needs. It may also lead to the development of innovative services based on Industry 4.0 and AI technologies. Finally, the article may serve as a starting point for shaping public and industry policies that promote cross-sectoral cooperation (administration, SMEs, NGOs, emergency services) as well as the

creation of dedicated support programs for companies implementing technologies supporting electromobility for people with disabilities.

Keywords: electromobility, disability, management, innovation.

Category of the paper: Research article.

Introduction

In the face of advancing climate change and the European Union's efforts to achieve carbon neutrality, electromobility is becoming one of the pillars of modern transport policy. A particular area of concern is the need to take into account people with disabilities, for whom the development of infrastructure and electric vehicles should be tailored to their needs. This article presents a model for managing innovations developed for the electromobility of people with disabilities. The model is to be based on cooperation between European Union institutions, state administration, road infrastructure managers, public transport operators, emergency services, and the private sector (car manufacturers and service providers).

1. People with disabilities and their expectations regarding mobility

People with disabilities constitute a significant part of the EU population, and their participation in public life is comparable to that of able-bodied people. People with disabilities face various problems. There are people with: mobility disabilities (damaged right lower limb, damaged left lower limb, damaged right upper limb, damaged left upper limb, damaged cervical spine, damaged lumbar spine, etc.); people with sensory disabilities (vision); people with sensory disabilities (hearing) (Stawiarska, E., Stawiarski, M., 2023). Figures 1, 2, 3, and 4 show people with disabilities in the European Union.

Figure 1 shows the proportion of persons with disabilities (in general) – i.e., the percentage of the EU population that reports limitations in daily activities.

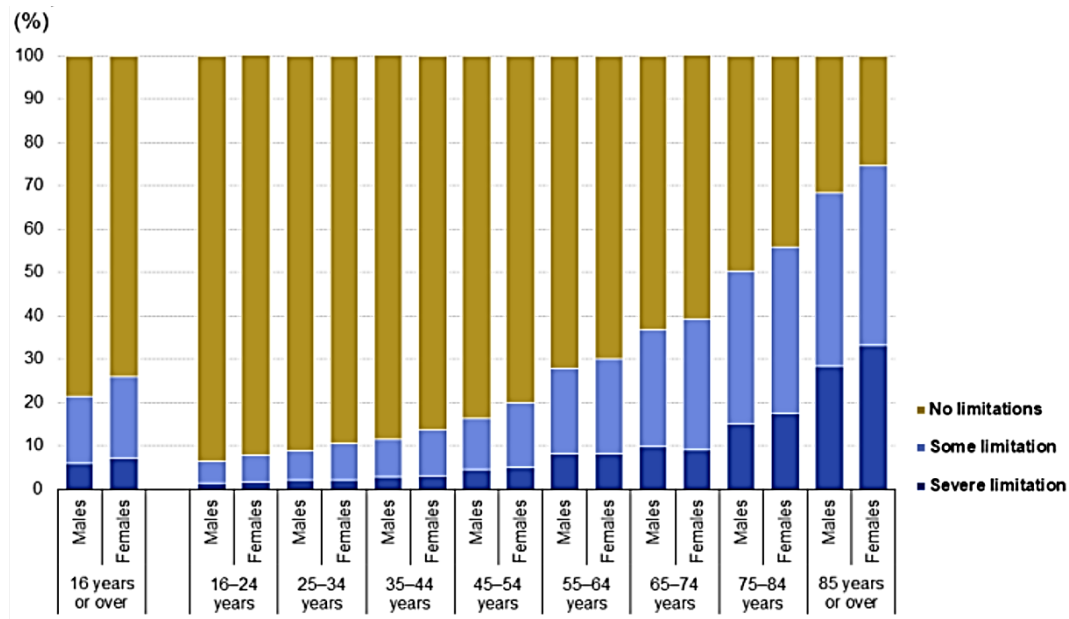


Figure 1. Share of persons with disabilities (total by age of respondents) in 2024.

Source: https://ec.europa.eu/eurostat/statistics-explained/images/thumb/9/96/Share_of_people_with_a_disability_%28activity_limitation%29%2C_by_sex_and_age%2C_EU%2C_2024_%28%25%29_Health2025.png/700px-Share_of_people_with_a_disability_%28activity_limitation%29%2C_by_sex_and_age%2C_EU%2C_2024_%28%25%29_Health2025.png

The figure 1 shows that the percentage of disabled people increases with the age of women and men. Figure 2 shows the percentage of people with difficulties in basic activities – percentage data on physical difficulties in daily activities.

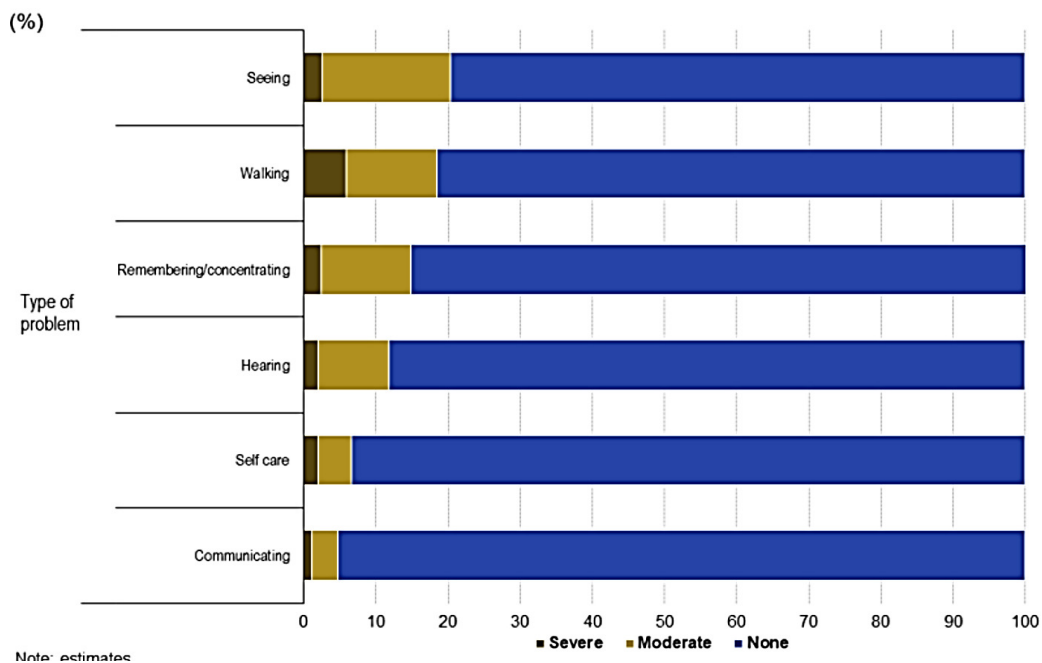


Figure 2. Percentage of people with difficulties in basic motor activities, UE, 2022.

Source: https://ec.europa.eu/eurostat/statistics-explained/images/thumb/c/c7/Share_of_people_aged_16_years_or_over_reporting_difficulties_in_basic_activities%2C_EU%2C_2022_%28%25%29.png/800px-Share_of_people_aged_16_years_or_over_reporting_difficulties_in_basic_activities%2C_EU%2C_2022_%28%25%29.png

The figure 2 shows that the largest group of disabled people are those with mobility disabilities. Figure 3 shows the proportion of persons with disabilities due to activity limitations (overall) – chart showing breakdown by country and level of limitations.

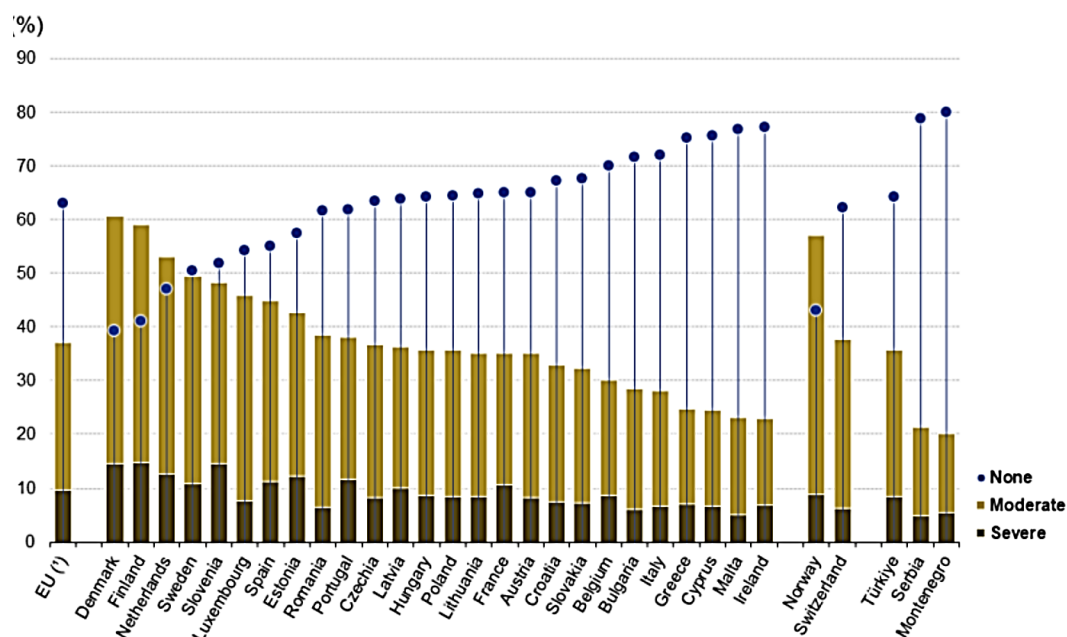


Figure 3. Share of persons with disabilities due to activity limitations (overall), 2022.

Source: https://ec.europa.eu/eurostat/statistics-explained/images/thumb/6/6d/Share_of_people_aged_16_years_or_over_reporting_difficulties_in_basic_activities%2C_2022_%28%25%29.png/800px-Share_of_people_aged_16_years_or_over_reporting_difficulties_in_basic_activities%2C_2022_%28%25%29.png

The figure 3 shows that the largest group of disabled people in relation to the entire population is in Germany and the Scandinavian countries. Figure 4 shows the proportion of persons with disabilities due to activity limitations (overall) – a chart showing the breakdown by country or level of limitations.

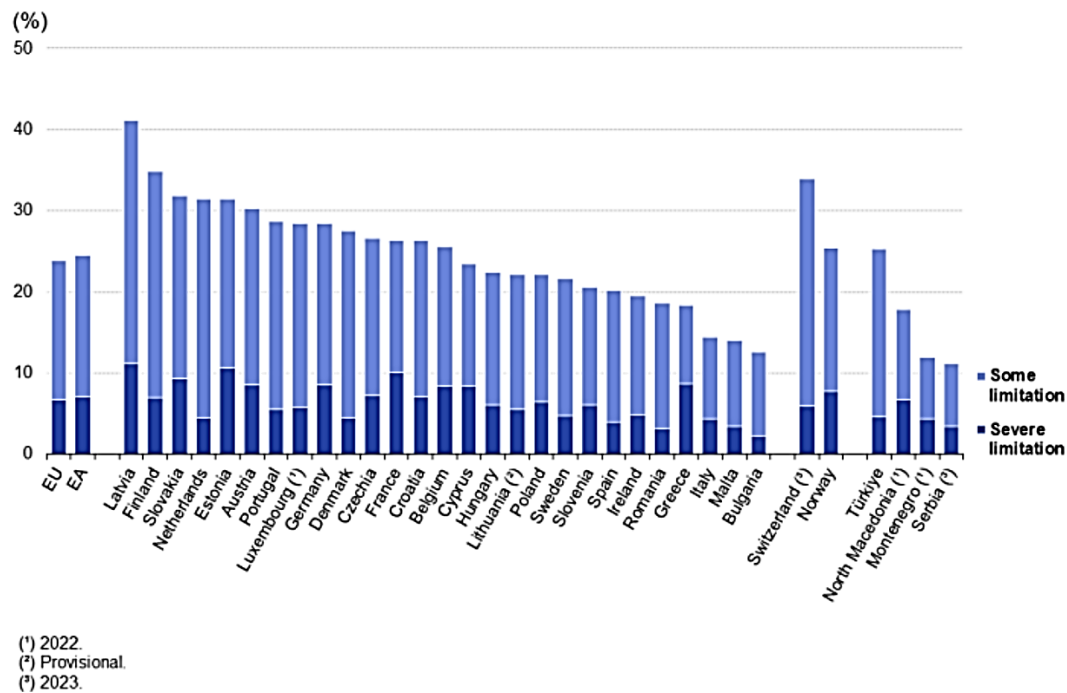


Figure 4. Share of persons with disabilities due to activity limitations (overall), 2024.

Source: https://ec.europa.eu/eurostat/statistics-explained/images/thumb/a/ad/Share_of_people_aged_16_years_or_over_with_a_disability_%28activity_limitation%29%2C_2024_%28%25%29_Health2025.png/700px-Share_of_people_aged_16_years_or_over_with_a_disability_%28activity_limitation%29%2C_2024_%28%25%29_Health2025.png

The figure 4 shows that the most severe disabilities affect people from Latvia and the Scandinavian countries.

The figures above show that in 2022–2023, around 27% of people (aged 16 and over) in the EU had some form of disability, i.e., activity limitations resulting from health problems. This equates to around 101 million adults across the EU. Disability increases with age:

- 16-19 years old: ~7% of the population has a disability,
- 45-64 years old: ~27% of the population has a disability,
- 65+ years old: over 50% of the population has a disability.

Women were more likely to report disability: ~29-30% compared to ~24% of men.

In Poland, musculoskeletal, cardiovascular, and neurological disorders are the most common causes of disability. Persistent hearing and vision impairments also occur, although less frequently (niepełnosprawni.gov.pl+1.). Unfortunately, Polish public statistics do not provide detailed data on specific impairments (e.g., limbs or spine).

The Irish example provides some approximate proportions:

- Blindness or visual impairment: 6% of the population, representing 27% of all people with long-term difficulties (cso.ie.).
- Deafness or hearing impairment: 5% of the population (21% of the total) (cso.ie.).
- Difficulties with physical activities (walking, climbing): ~7% of the population (31% of all difficulties) (cso.ie.).

People with disabilities constitute a significant part of society, and their participation in public and economic life requires adequate access to means of transport. Electromobility, as a new paradigm in the transport sector, offers opportunities to increase accessibility and comfort of travel, but requires integrated innovation management at multiple levels (Feldner, 2018).

Analysis of data on the number of people with disabilities confirms the need for collaboration between various stakeholders to support the development of electromobility for people with disabilities.

2. Legal and institutional framework for electromobility for persons with disabilities

The European Union plays a key role in shaping electromobility policy. The change in demand for services will result from the implementation of the European Transport Policy. The European Commission has set targets to be achieved and intends to use policy instruments to achieve them (Khurshid et al., 2023). Among other things, the following goals are to be achieved:

- Goal 1. Develop and introduce new fuels and propulsion systems that are compatible with the principle of sustainable development and will contribute to halving the number of conventionally powered cars in urban transport by 2030. As a result, it is assumed that they will be eliminated from cities by 2050, thus achieving essentially CO₂ - free logistics in large urban centers as early as 2030. Directives and regulations on sustainable transport and CO₂ reduction have already been established (e.g., Regulation (EU) 2019/631 on CO₂ emission standards for cars).
- Target 9. Achieve close to zero road traffic fatalities by 2050. In line with the above, the European Union aims to halve road accident fatalities by 2020. Financial programs and grants supporting innovation and infrastructure development include Horizon Europe and CEF – Connecting Europe Facility.
- Objective 10. Support for people with disabilities. Regulations on accessibility for people with disabilities (e.g., European Accessibility Act).

The objectives and already implemented instruments of the European Transport Policy suggest that the number of electric cars will increase (especially those serving cities). This fact will necessitate the creation of modern service points for electric vehicles. The requirements for car diagnostics will be tightened. This will necessitate the retrofitting of service stations with smart devices adapted to the needs of various market segments (including the disabled segment). The financial and non-financial instruments used will support people with disabilities (who want to purchase electric means of transport). Financial support is also accompanied by

other regulations, such as Directive 2007/46/EC and Regulation (EU) 2018/858 (on the approval of vehicles, including electric vehicles); Commission Regulation (EU) No. 1230/2012.

As can be seen from the above, in the model of innovation management towards electromobility for people with disabilities, the EU acts as a regulator, coordinator, and sponsor of innovation, imposing minimum standards of accessibility and energy efficiency.

The Polish government performs implementation, legislative, and supervisory functions, and also coordinates cooperation with local governments. The Polish government is responsible, among other things, for:

- transposing EU law into the national legal system,
- issuing executive regulations concerning technical conditions for vehicles, type-approval standards, and standards for electric car charging infrastructure,
- support programs for people with disabilities (e.g., subsidies for electric vehicles adapted to the needs of people with disabilities, e.g., from the “Mój Elektryk” program),
- regulations concerning the safety and approval of specialized vehicles.

Important documents supporting electromobility for people with disabilities in Poland include:

- Road Traffic Law (Journal of Laws 1997 No. 98 item 602).
- Regulation of the Minister of Infrastructure on technical conditions for vehicles (Journal of Laws 2016 item 2022).
- Polish law and regulations / AFIR: Journal of Laws “Electromobility and alternative fuels”.
- PN-ISO 7176-19:2013 and PN-EN 1756-2:2015 (technical standards).
- Act on ensuring the possibility of obtaining additional needs (Journal of Laws 2019, item 1696).
- Regulation of the Minister of Transport on vehicle type approval (Journal of Laws 2015, item 1475).
- Regulations on financing: PERON funding; disability allowance (DLA); increased mobility component of Personal Independence Payment (PIP); Armed Forces Independence Payment (AFIP); mobility allowance for war pensioners.

Analysis of the literature and legal acts confirms that there are grounds for organizing cooperation between various stakeholders to support the development of electromobility for people with disabilities.

3. Stakeholders in the innovation management model for the electromobility of persons with disabilities

In addition to the European Union institutions and the governments of the Member States, the following are important stakeholders in the model:

3.1. Road infrastructure managers

Their role includes:

- Designing and building charging infrastructure that takes into account the needs of people with disabilities (e.g., maneuvering space at charging stations).
- Adapting road infrastructure (sidewalks, crossings, P+R parking lots) for specialized vehicles.
- Ensuring digital integration with navigation systems (data on accessible charging points for people with disabilities).
- Implementation of AI-based Smart Traffic Management systems that automatically prioritize vehicles for people with disabilities in urban traffic (e.g., extending green lights, automatic opening of barriers).
- Integrating charging infrastructure with IoT technology – stations that recognize users with disabilities (e.g., through digital IDs, PFRON cards) and automatically adjust interfaces (e.g., lowered screens, voice assistant).
- Designing inclusive mobility hubs that combine EV charging with support services (e.g., medical equipment rental, digital passenger service kiosks).

3.2. Public transport operators.

They play a key role in the integration of public transport:

- Purchase and operation of fully accessible electric buses (low-floor, lifts, information systems).
- Integration of passenger information systems with solutions supporting people with disabilities (e.g., voice announcements, mobile applications) (Oladele et al., 2021).
- Creation of coordinated multimodal routes with disability-friendly transfers (Lee, Sener, 2023).
- Implementation of autonomous electric minibuses serving “last mile” routes dedicated to people with mobility impairments (Oladele et al., 2021).
- Integration of data from health and mobile applications – the possibility of automatic reservation of a seat on a bus/tram by persons with disabilities (e.g., notifying the driver of the need to use a ramp).
- Digital twins of the transport system – simulating the journeys of people with different types of disabilities to identify barriers and test solutions (Lee, Sener, 2023).

3.3. Emergency services.

They play a key role in ensuring safety, e.g.:

Fire department:

- Responsible for safety procedures in the event of fires in electric vehicles, especially those adapted for people with disabilities.
- Participation in training and testing of prototypes of specialized vehicles.
- Cooperating with manufacturers to develop rescue procedures.
- Developing VR/AR rescue simulations for training in the evacuation of people with disabilities from electric vehicles.
- Creating real-time EV battery monitoring sensors that send data to emergency services in the event of a breakdown or fire.

Medical rescue:

- Ensuring accessibility to rescue systems in EVs (e.g., e-Call systems, liftable seats, emergency opening).
- Consulting with vehicle and infrastructure designers.
- Developing smart stretchers and lifting systems integrated into EVs to facilitate the evacuation of people with reduced mobility.
- Applying telemedicine in EVs – an e-Health system that allows remote diagnosis of a passenger's health in an emergency.

3.4. Industry and the private sector.

Basic functions performed in the model by:

Electric car manufacturers:

- Design and implementation of EV platforms adapted for people with disabilities (e.g., manual operation, space for wheelchairs) (Golbabaie et al., 2024).
- Participation in pilot projects testing innovative solutions.
- Designing modular EV platforms that allow for quick adaptation of the vehicle to different types of disabilities (Golbabaie et al., 2024).
- Integration of AI assistance systems (e.g., voice control, eye-tracking, gestures) enabling touchless vehicle operation.
- Development of shared EVs designed specifically for users with disabilities.

Car tuning/refurbishment companies:

- Adaptation of production vehicles to the individual needs of users with disabilities.
- Cooperation with the National Health Fund, the State Fund for Rehabilitation of Disabled Persons, and the Ministry of Family, Labor, and Social Policy to standardize and finance vehicle adaptations.

- Introduction of digital adaptation configurators – the customer selects adaptations online (e.g., manual throttle, lift, information systems), and the system generates a digital model of the vehicle. (e.g., handles, control joysticks).
- Blockchain for transparency in adaptation financing – digital recording of subsidies, refunds, and service costs, which increases trust between companies and public institutions.

A literature review and a retrospective of possible activities of various organizations confirmed that there are opportunities for cooperation to support the development of electromobility for people with disabilities.

4. Cooperation model for the electromobility of people with disabilities – a systemic approach

The proposed model assumes vertical and horizontal cooperation (according to: Tidd, Bessant, 2018; Stawiarska, 2023, 2024) stakeholders supporting the development of electromobility for people with disabilities. The following can be distinguished:

- Vertical institutional cooperation:
EU → Polish Government → Local governments → Operators
- Horizontal sectoral cooperation:
Automotive industry ↔ Emergency services ↔ Users ↔ Scientific institutions ↔ Organizations of people with disabilities

The key elements of the innovation management model for the electromobility of people with disabilities are presented in Table 1.

Table 1.

Key elements of the innovation management model for electromobility for people with disabilities

System Element	Function	Cooperation with
EU	Legislation, funding	Government, industry
Government of the Republic of Poland	National legislation	EU, local governments
Local governments, road managers	Infrastructure	Government, companies
EV manufacturers	Production, innovation	Adaptation companies, emergency services
Tuning companies	Adaptation	Users, emergency services
Emergency services	Safety	Manufacturers, local governments
Organizations of people with disabilities	Consultations	All stakeholders

Source: Own work based on: (Stawiarska et al., 2024, 2025).

Electromobility for people with disabilities cannot be developed in isolation from a systemic approach to innovation. An effective innovation management model requires integrated cooperation between all stakeholders, from EU institutions to vehicle tuning companies.

A special role here falls to the bodies appointed by the Member States, which must ensure the implementation of regulations, as well as initiate local pilot projects and manage cross-sector cooperation (in Poland, this role is performed by the Polish Chamber of Electromobility Development).

The Polish Chamber of Electromobility Development (PIRE) does not offer direct support to SMEs, but acts as an organization promoting electromobility, identifying the sector's needs in terms of support policies (e.g., subsidies, preferential energy prices, infrastructure development) and cooperating with institutions such as PARP to create programs that may be available to companies. The Chamber conducts lobbying and educational activities and is also a member of the international organization CharIN, which supports the development of interoperable charging standards. PIRE actively monitors and publishes data on the development of electromobility, which is a valuable source of information for companies planning investments in this area.

How PIRE supports SMEs (indirectly):

- Identification of needs: The Chamber identifies which support measures are key to the development of electromobility in Poland, including subsidies and preferential conditions for entrepreneurs.
- Cooperation with institutions: As a supporting member of organizations such as CharIN, PIRE has an influence on shaping regulations and standards in electromobility, which may translate into better conditions for SMEs in the future.
- Providing information: PIRE regularly publishes analyses and reports on the electromobility market, which helps entrepreneurs make investment decisions and identify development opportunities.
- Activities for infrastructure development: The Chamber promotes the development of charging infrastructure, which is crucial for the accessibility and profitability of electromobility for companies.

Examples of organizations working in the field of electromobility are presented in the TRL/PIARC report *Managing Innovation in Transport Agencies*. There you can find practical materials on the implementation of innovation in transport agencies. It is a good source of examples of innovation project management and implementation barriers.

Entrepreneurs working to develop electromobility for people with disabilities should intensively model their businesses in this direction.

Chapters 1, 2, 3 and 4 of the article confirm the hypothesis that "there is a need for cooperation between various stakeholders to support the development of electromobility for people with disabilities".

5. A new business model focused on the development of electromobility for people with disabilities – a case study

In the context of the growing number of electric vehicles, ensuring the accessibility of transport for people with disabilities remains an important issue. This chapter presents a business model that integrates the adaptation of electric vehicles for people with disabilities with a short-term rental service for adapted vehicles, supported by process innovation and digitization.

A business model can be defined as the logic of creating, delivering, and capturing value by an organization (Osterwalder & Pigneur, 2010). It covers the key elements of a company's operations: customer segments, value proposition, distribution channels, customer relationships, revenue streams, key resources, key processes, strategic partners, and cost structure. In the context of electromobility for people with disabilities, the business model should be characterized by:

- flexibility (ability to serve different types of disabilities),
- transparency (clear cost and service rules),
- digitization (remote customer service),
- service integration (adaptation + rental + service).

Table 2 presents the Business Model Canvas – case studies. Table 2 shows the key elements of the business model according to the Business Model Canvas methodology.

Table 2.

Business model for adapting and renting electric vehicles for people with disabilities

Canvas Element	Case Study Description
Customer Segments	People with permanent and temporary mobility and sensory disabilities; tourists; public institutions; fleet management companies.
Value Proposition	Access to electromobility through adapted electric vehicles; short-term rental of adapted cars; digital end-to-end service and maintenance.
Channels	Adaptation workshop, online platform, mobile app, cooperation with airports (e.g., Modlin).
Customer Relationships	Empathetic and individual service; transparent pricing; 24/7 digital communication; loyalty program.
Revenue Streams	Fees for vehicle adaptation, car rental, service subscriptions, additional services (GPS monitoring, inspections).
Key Resources	Skilled employees, adaptive technologies, equipped workshop, IT system, brand and reputation.
Key Activities	Customer needs analysis, adaptation design, installation of devices, rental, service, digital support.
Key Partners	Suppliers of adaptive devices, financial institutions (e.g., PFRON, EU), organizations supporting people with disabilities, fleet rental companies.
Cost Structure	Investments in workshop and IT, staff training, equipment maintenance, marketing, software license costs.

Source: Own work based on: (Stawiarska et al., 2024, 2025).

The proposed business model is innovative on the Polish market because it combines the adaptation of electric cars with a short-term rental service. The integration of processes through an IT system that ensures the following is of key importance:

- automation of customer service,
- cost transparency,
- personalization of services,
- monitoring of vehicle safety and location.

The customer service process for both services has been developed in a comprehensive and digitized manner. It consists of eight stages: needs analysis, modification design, device installation, testing, training, monitoring, servicing, and vehicle return.

The implementation of an innovative IT system (e.g., FIRAMA2000 software) enables:

- automatic vehicle data acquisition (e.g., via Aztec code),
- transparent cost estimation of services,
- digital communication with the customer,
- monitoring of order progress,
- integration with the warehouse systems of parts suppliers,
- generation of reports, invoices, and JPK files.

This makes the customer service process more user-friendly, transparent, and time-efficient.

Implementing the model requires high investment costs, but at the same time allows the use of EU and PFRON funds, which reduces the financial risk. The new business model supports the development of inclusive electromobility, in line with the assumptions of the European Transport Policy. The inclusion of people with disabilities in the area of zero-emission transport requires not only technology, but also an appropriate organizational and business model. Thus, it is an example of how product, process, and organizational innovations can support sustainable transport development and social inclusion.

Chapter 5 of this article confirms the hypothesis that "SMEs (developing electromobility services for people with disabilities) require support in developing innovative business models based on Industry 4.0 solutions and artificial intelligence."

6. Discussion

The model of innovation management towards electromobility for people with disabilities presented in the article is part of a growing trend in research on transport inclusion and the development of services oriented towards the needs of specific user groups. The results of research by Lamedica et al. (2022) indicate that the creation of electromobility solutions for people with mobility limitations requires a systemic approach that integrates different

institutional levels and sectors of the economy. Similarly, the article emphasizes the need for multi-level cooperation—from EU institutions, through national and local authorities, to the private sector and SMEs.

There is a noticeable trend in the literature to extend the concept of electromobility to micromobility and alternative solutions. A review by Lee and Sener (2023) shows that e-bikes and other light vehicles can serve as a tool for inclusion, especially in the context of cost or infrastructure barriers. This article complements this theme by pointing to the potential of SMEs to create flexible business models that combine vehicle adaptation with rental services, thereby expanding the range of available forms of transport.

An important contribution of this work is the proposal of an innovative business model based on digitization and integrated services. In the literature on the subject, the role of Industry 4.0 technologies and the Internet of Things has been emphasized, among others, by Oladele et al. (2021), who pointed to the possibilities of integrating mobility assistance devices with digital and telemedicine systems. The customer service management system proposed in the article, based on transparency, personalization, and digital monitoring, is in line with this trend.

From a social perspective, the presented business model corresponds with the research of Feldner et al. (2018), which confirms that providing early access to mobility assistance solutions improves the quality of life and social integration of people with disabilities. The introduction of systemic EV adaptation and rental services can therefore significantly increase the independence and social participation of this group.

It is also worth noting the aspect of vehicle and infrastructure design. Golbabaie et al. (2024) emphasize that the development of accessible electric vehicles, including autonomous vehicles, requires consideration of universal design and consultation with end users. The article expands on this theme by pointing to the role of disability organizations as key stakeholders in the innovation management process.

7. Conclusion

Electromobility, understood as the development of transport based on electric drives, is one of the key areas of economic and social transformation. Its aim is to reduce greenhouse gas emissions, improve the quality of life of city dwellers, and increase transport safety. The development of electromobility must take into account the needs of people with disabilities in order to implement the idea of sustainable and inclusive transport. The presented model of innovation management towards electromobility for people with disabilities and an example of a selected business model based on the adaptation and rental of electric vehicles and digital support for the service process form the foundation for the mobility of people with disabilities. Their implementation will contribute to increasing the independence of people with disabilities, improving transport safety, and achieving the objectives of European transport policy.

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TOWARDS ORGANIZATIONAL RESILIENCE: DETERMINANTS OF EFFECTIVE COMMUNICATION IN ORGANIZATIONS – AN EXAMPLE FROM THE TELECOMMUNICATIONS INDUSTRY

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Purpose: The study aimed to identify and analyze factors that, according to the surveyed employees, shape the effectiveness of communication within their organization.

Design/methodology/approach: The study's data were collected using a dual approach, combining a diagnostic survey and in-depth interviews. A total of 41 employees from a telecommunications company participated in the research. The study was conducted from May to June 2025.

Findings: Employees are not only aware of the importance of communication for understanding their tasks and achieving organizational goals but also recognize areas in need of improvement and potential solutions. At the same time, they demonstrate openness and a development-oriented mindset, which may serve as a foundation for building organizational resilience through enhanced communication effectiveness.

Research limitations/implications: The study was conducted on a small sample, which limits the generalizability of the findings.

Practical implications: The article may serve as an inspiration for managers, who can directly influence the issues identified by employees as important, such as fostering a friendly climate and open attitudes, promoting direct contact, clarifying the division of roles, reducing time pressure, and developing and implementing clear communication procedures.

Originality/value: The article focuses on the underestimated importance of effective communication as a key factor shaping organizational resilience. The study provides a detailed analysis of the determinants of communication effectiveness in the specific context of a selected telecommunications company, which is important because the significance of these factors may vary considerably depending on the organization.

Keywords: effective communication, organizational resilience, communication barriers, managerial attitude.

Category of the paper: Research Paper.

1. Introduction

Organizational resilience is becoming an increasingly significant component of contemporary management discourse. Undoubtedly, this is a consequence of recurring disruptions, which tend to originate from unexpected domains and sources. Whether an organization survives and the extent to which it can cope more effectively with subsequent crises depends on its capacity to master the process of developing organizational resilience (McCarthy et al., 2017; Miceli et al., 2021; Napier et al., 2024; Pradana, Ekowati, 2024; Su, Junge, 2023). Among the factors shaping organizational resilience, communication deserves particular attention. On the one hand, it is the most common and pervasive element of all human activity; on the other, its importance is still often underestimated within organizations (Dahlman, Heide, 2020; Ruck, Welch, 2012). There is also evidence suggesting that communication constitutes one of the most critical factors reinforcing organizational resilience (Bui et al., 2019).

The study presented here concentrates on identifying and analyzing the factors that determine communication effectiveness within a selected telecommunications enterprise. The potential number of determinants influencing effective communication at the team and organizational levels is considerable. Consequently, it is the specific organizational context that ultimately shapes the relative significance of these factors in relation to the development of communication effectiveness and organizational resilience.

2. Organizational resilience in relation to communication effectiveness

Contemporary conceptualizations of resilience emphasize its critical role in managing risk and uncertainty. The prevailing perspective in the literature frames resilience as a multidimensional capability of a system to anticipate and mitigate threats while responding effectively to change. In the first case, the organization identifies risks and flexibly adjusts its process structures; in the second, it promptly restores functionality following a crisis and systematically develops adaptive competencies (Bhamra et al., 2011; Burnard, Bhamra, 2011; Ortiz-de-Mandojana, Bansal, 2016). Another essential attribute of resilience lies in the development of solutions that do not give rise to persistent, regressive behavioral patterns (Alliger et al., 2015; Bowers et al., 2017; Chapman et al., 2020). Analyzing organizational resilience through the lens of a dynamic process, encompassing practices across all organizational levels, such as fostering team cohesion, strengthening trust and solidarity, sharing leadership, and promoting open communication (Brykman, King, 2021; Mitchell et al., 2025; Morgan et al., 2015; Pavez et al., 2021; Varajão et al., 2023), appears to constitute the

foundation for cultivating the competencies necessary for resilience development. Attempting to capture the essence of organizational resilience also requires examining the dimension of individual resilience, as well as the dynamics occurring between individuals and organizational units (Hartwig et al., 2020; Stoverink et al., 2020). What happens within teams between individuals is invariably mediated by communication processes.

Team communication plays a critical role in supporting organizational resilience, enabling teams to adapt, respond effectively to challenges, and maintain performance under dynamic and demanding conditions. When an unexpected event arises during the execution of a complex task, team members must rapidly establish effective communication. This is essential for developing a shared understanding of the altered situation and for appropriately adjusting action strategies (Blanchard et al., 2023). Intensive communication by leaders supports teams in reducing stress, accelerating knowledge flow, and stimulating innovation. Collective creativity, in turn, proves critical for functioning effectively in an uncertain business environment (Wang et al., 2024). Teams' experiences during the COVID-19 pandemic accelerated organizational evolution, orienting it toward greater employee autonomy, mutual trust, and responsibility. The degree of team integration, as well as the role of intermediaries within communication networks assumed by certain employees, facilitated processes of coping with crises (Maurer et al., 2022). Communication serves as a central link within the system, enabling the sharing of critical information, which facilitates the interpretation of events, the establishment of order, and the definition of actions. The process of information exchange constitutes a fundamental mechanism for ascribing meaning to organizational activities. As a result, both efficiency and adaptability are enhanced. From a systems perspective, communication functions as a core integrative element through which goals, processes, schedules, outcomes, and the overall direction of the organization are understood (Home, Orr, 1997). A meta-analysis examining the role of communication in the coping and effectiveness of diverse teams demonstrated that communication is a critical intra-organizational process in developing organizational resilience (Bui et al., 2019). Communication functions as a core mechanism for building resilience through narrative processes, sharing experiences, the cultivation of collective identity, and sensemaking (Buzzanell, 2018). Narratives bind communities and teams together, enabling them to construct shared realities that appear inaccessible to groups unable to co-create collective stories (Brach, Wasilewski, 2024). These reinforcing practices, together with communication oriented toward crisis management (Kim, 2021) constitute a significant contribution to the development of organizational resilience.

Not all communication processes can, however, be considered effective. The effectiveness of intra-organizational communication is influenced by multiple factors, including the clarity and precision of the message (Bambacas, Patrickson, 2008; Bang et al., 2010; Pandey, Garnett, 2006; Park, Choi, 2020), responsibility, conciseness, and honesty in communication (Marques, 2010), the level of personal engagement in the process, manifested, for example, through active listening practices, emotional intelligence, and empathy (Clark et al., 2019; Fuller et al., 2021;

Hendon et al., 2017; Kiran Gupta, 2025; Muss et al., 2025), general cognitive openness, the ability to adapt communication style to the situation and the audience (Brown et al., 2019; Hicks, 2020; Oliveira et al., 2022), competence in providing and receiving feedback, as well as organizational structure (Chew et al., 2024; Maurer et al., 2023; Yazici, 2002), organizational culture (Brown, Starkey, 1994; Gochhayat et al., 2017; Men, Yue, 2019; Yue et al., 2021), and communication technologies (Chew et al., 2024; Yazici, 2002). In the context of a specific organization, it is therefore necessary to analyze the key factors shaping communication effectiveness within that particular team, at that specific time, and in that unique context. Only such an analysis can provide insights into what requires development, what needs to be fundamentally changed, and what should be maintained, enabling the organization to move systematically toward the cultivation of organizational resilience.

3. Research methodology

The subject of the study was a telecommunications company operating for 15 years. The enterprise specializes in providing high-speed fiber-optic internet, wireless internet services, and a wide range of television and telephony offerings. Its customer base includes individual clients, businesses, and public institutions. The company employs 47 people across two branches.

The following research question was formulated: What determinants shape communication effectiveness in the studied organization? The research aims to identify, based on employees' perceptions, the factors influencing communication effectiveness within their organization and to analyze these factors.

Effective communication is a complex process, and several factors that may influence its ultimate course appear difficult to predict. Among the main categories of these factors are the adaptation of messages to the informational needs of recipients, which is the responsibility of the sender; the allocation of communication roles, including the particular role of management in this process; the integrity of communication processes and organizational culture, which shapes interpersonal relationships and provides the often implicit backdrop for communication; and, finally, processes for monitoring communication effectiveness and its continuous improvement (Olsztyńska, 2002). The nature of the organization's activities also plays a significant role. The emphasis on communication effectiveness differs between virtual teams and on-site production environments, where direct, face-to-face interaction remains particularly important (Battiston et al., 2020). The first hypothesis was formulated as follows:

- H1.** According to employees' perceptions, the key factors of effective communication in the studied organization are a friendly team atmosphere, direct contact within the branch, and a clear task division.

Face-to-face communication and electronic channels, including email, are the most frequently used forms of communication within organizations (Kaneko, 2025; Lee, 2022; Major, Spalek, 2017). On this basis, the second hypothesis was formulated:

H2. The most frequently utilized communication channels in the studied organization are face-to-face communication and email.

Due to its complexity and the diversity of influencing factors, the communication process faces numerous challenges and barriers. Among these are organizational issues (Greer et al., 2018), cultural differences, individual-level factors (Dierdorff, Fisher, 2022; Vishnubhotla, Mendes, 2024), psychological safety (Edmondson, 1999), and information overload, which has taken on new significance in contemporary contexts (Eppler, Mengis, 2004). On this basis, the following hypothesis was formulated:

H3. The most frequently encountered communication barriers among employees in the studied organization are the diverse attitudes and individual communication competencies of those involved in the communication process.

The data were collected using a dual approach. First, the diagnostic survey method was employed, utilizing a questionnaire technique. The research instrument was a proprietary survey questionnaire, with items focusing on the assessment of communication effectiveness within the organization, the channels and tools used for communication in the studied organization, and the barriers encountered by respondents in this area. A five-point Likert scale was applied. The questionnaire also included demographic items and one open-ended question, designed to provide respondents with an opportunity to share their reflections on potential improvements to communication. Paper-based questionnaires were distributed within the organization, and data were collected between May and June 2025. Second, the interview method was employed, specifically the technique of in-depth individual interviews (IDI). The research tool applied was an interview guide. The interviews were semi-structured, which made it possible to compare results while at the same time maintaining the flexibility of responses and the opportunity to explore issues in more depth where it was considered relevant. The interviews were conducted in June 2025. The decision to employ two research methods, a questionnaire survey and in-depth individual interviews, was motivated by the intention to obtain the most comprehensive and multifaceted picture of the research problem.

A total of 31 employees participated in the questionnaire survey, including 27 women and 4 men. The respondents represented the following job positions: Assistant/Support Staff, Specialist, and Coordinator. In addition, 10 in-depth interviews were conducted, involving 3 men and 7 women.

4. Results

4.1. Quantitative data analysis

The overall assessment of communication (Table 1) does not appear to be at a satisfactory level (overall mean score – 3.16). At the same time, employees recognize the existence of a communication channel they perceive as effective; however, the responses in this regard were not consistent ($M = 4.06$; $SD = 1.26$). The lowest-rated aspect was access to key information regarding changes within the company ($M = 2.81$; $SD = 1.11$). This result may suggest that employees often do not receive information in a clear and timely manner.

Table 1.
Overall evaluation of organizational communication

Item	M	SD
Information about significant changes within the company (e.g., reorganizations, project modifications) reaches me in a clear and timely manner.	2.81	1.11
I have easy access to documents, procedures, or updates necessary for my work.	3.65	1.25
My supervisor regularly provides me with feedback regarding my work and the team's objectives.	3.48	1.39
There is an effective communication channel within the company that allows me to connect with other employees.	4.06	1.26
I am informed about decisions that directly pertain to my position or team.	3.23	1.43

Source: own elaboration.

The remaining elements assessed as part of the overall characterization of communication in the studied organization received average ratings, with mean scores ranging from 3.23 to 3.65. The similar standard deviations indicate a variability in how communication practices are perceived within the organization.

Interdepartmental communication received even lower ratings (Table 2). Respondents indicated that communication pathways that could facilitate problem-solving between departments are difficult to consider well-established ($M = 2.94$; $SD = 1.31$). Moreover, departments exchange key information to a less than satisfactory degree ($M = 3.03$; $SD = 1.22$). Among the elements assessed at this stage, the highest rating was given to the statement regarding the efficiency of conflict resolution between departments ($M = 3.45$; $SD = 1.29$). It is therefore possible that, despite the absence of established formal communication pathways, employees take the initiative to resolve conflict situations on their own. Such scenarios often occur in young or small organizations, where operational activities are prioritized over the creation of formal procedural guidelines. The assessment of interdepartmental collaboration is not consistent among the surveyed employees.

Table 2.*Evaluation of communication between departments*

Item	M	SD
Collaboration between departments takes place without unnecessary delays.	3.16	1.34
Departments transparently exchange key information.	3.03	1.22
Inter-team communication is well-organized and yields tangible results.	3.29	1.10
Established communication pathways exist for resolving interdepartmental issues.	2.94	1.31
Interdepartmental conflicts are resolved promptly and do not escalate.	3.45	1.29

Source: own elaboration.

Respondent employees were also asked to assess the impact of communication on work effectiveness within the organization (Table 3). The highest rating was given to the statement that clear and regular communication enhances individual work effectiveness, with employees showing greater consistency in their assessments compared to previous items ($M = 4.52$; $SD = 0.85$). Almost equally important, according to employees, was the speed of information flow ($M = 4.48$; $SD = 0.85$). Respondents also indicated that a lack of transparent communication can reduce work efficiency, although the variability in responses was somewhat higher in this case ($M = 4.16$; $SD = 1.29$). The lower mean rating of the positive impact of regular meetings on work pace and quality ($M = 3.84$; $SD = 1.21$), may result from both their frequency and perceived relevance.

Table 3.*Employees' assessment of the impact of communication on work effectiveness in the organization*

Item	M	SD
Clear and regular communication enhances my work effectiveness.	4.52	0.85
A fast flow of information within the company helps me perform my tasks more effectively.	4.48	0.85
A lack of transparent communication reduces my work efficiency.	4.16	1.29
Regular team meetings positively influence the pace and quality of my work.	3.84	1.21
Effective communication with supervisors motivates me to work more efficiently.	4.03	1.27

Source: own elaboration.

Employees of the studied organization use multiple communication channels in their daily work (Table 4). According to employees, the most frequently used communication channels are the company phone ($M = 4.45$; $SD = 1.06$) and email ($M = 4.26$; $SD = 0.99$). Both of these channels were also rated highly in terms of effectiveness - the company phone ($M = 4.23$; $SD = 1.36$) and email ($M = 4.35$; $SD = 0.87$). The slightly higher rating of email in this category, coupled with its lower standard deviation, may indicate that the ability to refer back to previous communications provided by this channel, which is clearly not afforded by phone conversations, is particularly important given the nature of the work performed by the respondents.

Table 4.*Employees' assessment of the frequency and effectiveness of communication channel use*

Communication channel	Frequency of use		Effectiveness	
	M	SD	M	SD
Email	4.26	0.99	4.35	0.87
Company phone	4.45	1.06	4.23	1.36
Corporate messenger	3.97	1.22	4.29	1.03
Face-to-face meetings	3.84	1.29	4.16	1.26

Source: own elaboration.

Although employees use the corporate messenger less frequently than the phone or email, they rate its effectiveness almost equally high. Face-to-face meetings are conducted somewhat less frequently ($M = 3.84$; $SD = 1.29$), and their perceived effectiveness is slightly lower as well ($M = 4.16$; $SD = 1.26$).

In addition to communication channels, respondents assessed the quality of the information they received in the context of their tasks (Table 5). Respondents reported the greatest difficulties in receiving information about project changes with sufficient lead time ($M = 2.65$; $SD = 1.45$). Although responses were highly variable in this regard, a similar pattern was observed in the assessment of the regularity of feedback on work performance ($M = 3.16$; $SD = 1.57$). Reactive communication behaviors on the part of managers received the highest rating ($M = 3.90$; $SD = 1.22$). Slightly lower ratings were given to the clarity of expectation-setting ($M = 3.68$; $SD = 1.28$), communication and updating of task priorities ($M = 3.61$; $SD = 1.26$).

Table 5.*Employees' assessment of the quality of information received related to task performance*

Item	M	SD
I receive clear and precise guidelines regarding expectations for my work.	3.68	1.28
Task priorities are clearly defined and regularly updated.	3.61	1.26
I regularly receive constructive feedback on my work.	3.16	1.57
I can count on a prompt response when I approach my supervisor with a question.	3.90	1.22
I am informed about project changes with sufficient lead time.	2.65	1.45

Source: own elaboration.

According to the respondents, effective communication is one of the key factors influencing the achievement of organizational goals (Table 6). Almost all items received scores above 4.5. The most important aspect, from the respondents' perspective, was the clarity of communication, which helps reduce the risk of errors during project execution ($M = 4.87$; $SD = 0.43$). Respondents were consistent in their views. According to them, effective communication helps to better understand the company's goals and facilitates the identification and resolution of problems ($M = 4.77$; $SD = 0.42$). Slightly lower ratings were assigned to regular updates on work progress in relation to maintaining focus on specific objectives ($M = 4.45$; $SD = 0.81$).

Table 6.

Employees' assessment of the importance of effective communication for achieving organizational goals

Item	M	SD
Clear communication reduces the risk of errors in project execution.	4.87	0.43
Effective communication helps me better understand the company's goals.	4.77	0.42
Efficient communication enables us to identify and resolve problems more quickly.	4.77	0.42
Open communication increases my engagement in achieving the company's objectives.	4.65	0.66
Regular updates on work progress help me maintain focus on specific goals.	4.45	0.81

Source: own elaboration.

Among the main barriers hindering effective communication (Table 7), respondents identified fatigue ($M = 3.06$; $SD = 1.39$), time pressure ($M = 2.84$; $SD = 1.28$), and differences in temperament ($M = 2.74$; $SD = 1.39$). In all cases, responses varied among the participants. Considering the level of ratings for the individual items, it can be concluded that communication barriers in the studied organization do not occur to a significant extent.

Table 7.

Employees' assessment of the intensity of communication barriers

Item	M	SD
Criticism	2.16	1.24
Name-calling	1.29	0.74
Premature judgment	2.29	1.31
Praise combined with evaluation	1.55	0.85
Dictating	1.84	0.93
Threatening	1.03	0.18
Moralizing	1.39	0.71
Asking too many or inappropriate questions	2.00	1.26
Unjustified advising	1.71	0.90
Distracting attention	1.48	0.68
Illogical reasoning	1.74	0.96
Ironic reassurance	1.42	0.67
Information distortion	2.16	1.29
Excessively large, rapid, or voluminous information	2.06	1.26
Unclear subject matter	1.97	1.14
Incomprehensible language	1.65	0.95
Negative attitude	2.03	1.2
Shyness	1.52	0.89
Lack of interest in the issue	2.29	1.13
Excessive emotional involvement	2.55	1.23
Lack of substantive preparation	2.29	1.24
Lack of concentration	1.94	0.99
Monotony of speech	1.61	0.71
Differences in temperament	2.74	1.39
Fatigue	3.06	1.39
Noise	1.90	1.16
Inappropriate meeting location	1.71	1.10
Too few/too many participants in the discussion	1.65	0.84
Time pressure	2.84	1.28
Poor room arrangement	1.23	0.50
Telecommunications network failure	1.90	1.16

Source: own elaboration.

4.2. Qualitative data analysis

Interviewees assessed the quality of communication in the organization as average [“Honestly, I would say it’s average, although recently one of our IT specialists has been trying to improve it”, PM6], good [“Communication between offices or between employees is, I think, at a good level”, PK3] or very good [“You could say it’s very good, (...). Basically, I don’t see any problems”, PK8].

According to the interviewees, the factors shaping communication effectiveness in the studied organization are:

- individual attitudes and competencies,
- the communication climate established by supervisors (“A closer relationship and a more relaxed atmosphere greatly facilitate the communication process” [PK2], “If a supervisor talks normally with their employees, then employees are open with them” [PM10]),
- organizational structure and division of responsibilities,
- communication methods and tools, with the greatest expectations placed on face-to-face meetings (“Meetings would help a lot, or some kind of accountability for what was done and what wasn’t, and why? More frequent conversations” [PK3], “Regular team meetings would help a lot. Everyone could report on their progress so others would know how things are going” [PK4], “I think it would be good to simply have a group meeting and discuss everything we are currently working on, what is a priority, and what needs to be done” [PK8]),
- fast, ongoing, and complete information flow,
- availability of key personnel involved in specific communication processes.

Among the major communication challenges identified by the respondents were:

- inadequate top-down information management between employees and supervisors, such as insufficient communication from supervisors, lack of time for detailed task discussions or duplication of tasks (unjustified delegation to two employees), absence of established communication procedures and pathways, and lack of personal culture in communication,
- insufficient flow and access to information, e.g., failure to communicate the completion of a given stage of work, poorly chosen communication channels, or incomplete information,
- challenges related to communication tools and their effective use, such as low user competence, underutilization or inadequate use of communication tools, and lack of employee readiness to adopt digital communication solutions,
- lack of clarity in roles, responsibilities, and task coordination,
- interpersonal and personality-related factors,

- time pressure and workload, e.g., lack of time and availability of key individuals, insufficient time for training, or excessive number of tasks within a short timeframe,
- conflicts and misunderstandings arising from missing, incomplete, or poorly executed tasks and insufficient information sharing.

Table 8 presents exemplifications of the above categories in excerpts from the collected data.

Table 8.

Communication challenges in the examined enterprise based on the conducted interviews

Challenge	Exemplification in collected data
Inadequate top-down information management in employee - supervisor relations	„There is a lack of communication between, let's say, the boss and the employees directly reporting to him. I think there is a lot that could be improved here. (...) I am very dependent on my supervisor's decisions. (...) and here what is really missing is time on his part to just sit down and thoroughly discuss a given issue, how it should be handled" [PK2]. „If they create chaos or are unable to communicate information properly, it later translates into individual departments, which then cannot reach an understanding or encounter problems" [PK3]. „Very often, while carrying out a task, I find out that, for example, my boss is already continuing this task, even though he assigned it to me, and when I call someone, I discover that he is already working on it" [PK4]. „If a supervisor is unpleasant or unsympathetic towards someone, no one will come to him with a problem or expect a solution, because they will be afraid of being shouted at. So the very form of conversation, kindness towards the other person, has in my opinion a fundamental impact" [PM10].
Insufficient flow and access to information	„However, there are certain difficulties, especially when someone does not pass on to others the information about the stage at which they finished their part of the task" [PK4]. „Information does not reach where it should; you tell someone, but the information is not retained, and later accusations arise like: 'I told you that,' 'No, I didn't hear it'" [PM10].
Challenges related to communication tools and their effective use	„One of our IT specialists in the company is trying to improve this by implementing program [x], but I don't think everyone is fully able to use it yet" [PM6]. „It works well for smaller projects, but for larger ones, there's so much that if we were to start using it, I think a separate person would be needed just to manage this platform and coordinate the tasks, deadlines, and so on" [PK7].
Lack of clarity in roles, responsibilities, an task coordination	„One person receives the same task, or no one receives it" [PK3]. „Overall, we have a problem with delegating the appropriate tasks to people; in my opinion, the scope of responsibilities is not properly defined, which disrupts communication from the very beginning because sometimes it's unclear who should be told what. Information reaches different people, not necessarily those it should, and I believe that the lack of clearly defined responsibilities can affect communication problems, as it is unclear where a given message should go" [PM10].
Interpersonal and personality-related factors	„If someone is introverted, they may not necessarily report problems at work or might be afraid to speak up. On the other hand, if someone has a difficult personality and cannot get along with others, it also affects efficiency, because interpersonal problems and conflicts arise, which in turn impact work" [PK3]. „I believe this is a direct personality trait and has a direct impact on communication. Not everyone will want to participate in a conversation. Some prefer to remain passive, so there is a group of people, even in our organization, who simply acknowledge information without engaging. Not everyone wants to discuss a given topic" [PM10].
Time pressure and workload	„If I don't have time, and they are still learning or facing new situations, problems can arise because there simply isn't enough time to train everything" [PK3]. „If someone responds nervously because they already have too many tasks, it definitely has a negative impact and makes everything more difficult" [PK4]. „In every company, there is pressure and stress imposed from above, whether through deadlines or from management insisting that something must be completed" [PM6]. „A major factor is the high workload and lack of time to simply meet, so that everyone could meet at the same time and discuss things" [PK7].

Cont. table 8.

Conflicts and misunderstandings	„Everyone is different; one person is so busy and didn't pass something on to another, which confused work” [PK1]. „I think there are sometimes misunderstandings, for example, when there are no clear divisions. It has happened that several people were working on the same task at the same time, wasting time and causing unnecessary conflicts” [PK2]. „Sometimes misunderstandings can occur because someone didn't do something, and someone else was waiting for it, or it wasn't communicated on time” [PK3].

Source: own elaboration.

5. Discussion

The research aimed to assess the factors shaping communication effectiveness in the studied organization from the employees' perspective. The hypothesis concerning the key factors of effective communication in the studied company, assuming that they include a friendly atmosphere in the group, direct contact, and a clear division of tasks, was confirmed by the collected data. Respondents highlighted kindness, warmth, and closeness of relationships as elements that not only are noticed but also, in their opinion, facilitate smooth and uninterrupted communication. „A closer relationship and a more relaxed atmosphere greatly facilitate the communication process” [PK2], „If a supervisor communicates normally with their employees, then the employees are open to them” [PM10]. In evaluating individual attitudes, openness also emerged as a factor promoting the development of a friendly atmosphere. These elements are consistent with existing literature, which emphasizes the role of emotional intelligence and empathy in organizational communication processes (Clark et al., 2019; Fuller et al., 2021; Hendon et al., 2017; Kiran Gupta, 2025; Muss et al., 2025), as well as organizational culture (Brown, Starkey, 1994; Gochhayat et al., 2017; Men, Yue, 2019; Yue et al., 2021) and the leader's communication style (Brown et al., 2019; Hicks, 2020). The obtained results are consistent with previous findings, indicating that kind and open attitudes contribute to more effective communication within the organization.

Both quantitative and qualitative data highlight direct contact as the form of communication that enhances work efficiency and provides employees with a clear understanding of their task: “Regular team meetings positively affect the pace and quality of my work” ($M = 3.84$; $SD = 1.21$). These findings are supported by the literature (Battiston et al., 2020). Moreover, direct contact is one of the elements that facilitates the development of trust, team cohesion, and open communication, all of which are crucial for building organizational resilience (Brykman, King, 2021; Mitchell et al., 2025; Morgan et al., 2015; Pavez et al., 2021; Varajão et al., 2023).

Interestingly, the *Resource model of team resilience capacity* (Brykman, King, 2021) suggests that the link between a team's learning capacity and its resilience runs in the direction of learning. The primary trigger in this process is *Voice Climate*, which provides employees

with the space to express their opinions and share their challenges. The effect of such an organizational climate can be reinforced by the leader's attitude and behavior, specifically their *Leader's Learning Goal Orientation*. A leader who actively promotes learning as a goal enables fuller use of the organizational climate by building *Team Resilience Capacity*. These links are visible in the collected material, although it is difficult to assess their direction.

In contrast, the division of roles emerges from the collected data as somewhat unclear in places, requiring clarification and hindering daily work. Therefore, the gaps noted by respondents can be regarded as an indication of the significance of this factor in enhancing or diminishing communication effectiveness. The importance of clarity in messaging and the clear assignment of tasks for communication effectiveness has been emphasized by numerous authors (Bambacas, Patrickson, 2008; Bang et al., 2010; Pandey, Garnett, 2006; Park, Choi, 2020), as well as the division of roles within the organizational structure (Chew et al., 2024; Maurer et al., 2023; Yazici, 2002).

The second hypothesis assumed that the most frequently used communication channels in the studied organization are direct communication and email. This hypothesis was partially confirmed. Email is indeed one of the most frequently used communication channels, with a mean usage frequency of $M = 4.26$. However, the company phone is used even more frequently than email, achieving the highest mean usage frequency of $M = 4.45$. Direct meetings are practiced slightly less often than the company phone, email, or corporate messenger, with a mean usage frequency of $M = 3.84$. These findings are partially supported by the literature, which identifies email and face-to-face meetings as the most common communication channels in organizations (Kaneko, 2025; Lee, 2022; Major, Spalek, 2017). The high frequency of company phone usage in this case may be related to the nature and dynamism of the business activities. It is also worth noting that telecommunication technologies are highlighted by researchers as important for communication effectiveness (Chew et al., 2024; Yazici, 2002).

The third hypothesis, concerning the most frequently occurring communication barriers and assuming that they are employees' attitudes and individual communication competencies, was not fully confirmed. Interpersonal factors are indeed significant and can constitute a barrier to communication; however, other factors were reported as occurring more frequently: „fatigue” ($M = 3.06$; $SD = 1.39$) and „time pressure” ($M = 2.84$; $SD = 1.28$). In third place were „differences in temperament” ($M = 2.74$; $SD = 1.39$), which relate to individual traits. These issues were also raised in the interview data, although no conclusions can be drawn regarding their greater significance relative to the other reported barriers. The literature indicates that individual traits and competencies can strongly influence communication effectiveness (Dierdorff, Fisher, 2022; Vishnubhotla, Mendes, 2024), which is consistent with the findings of this study. Researchers also indicate that information overload (Eppler, Mengis, 2004) and organizational factors (Greer et al., 2018), which are a frequent cause of time pressure during tasks, significantly affect communication processes within organizations. It is worth

noting here that communication within an organization can help build its resilience when it is symmetrical and gives both a sense of being heard and elicits a response from the supervisor (Kim, 2021). However, it is difficult to build such an environment without constantly working to remove communication barriers.

A primary limitation of the present study is the small sample size, which prevents the generalization of the findings to a larger population. Given the complex and multi-layered nature of communication within organizations, particularly from the perspective of building organizational resilience, it is important to examine organizations within their specific contexts, as these contexts may strongly influence the relative importance of different determinants of communication effectiveness. Other teams with a high degree of diversity among their members include, for example, teams working according to the Design Thinking methodology. These teams deliberately manage diversity and are therefore potentially an interesting field for observing the methods used to strengthen team resilience.

The practical implications of the present study focus primarily on actions that team managers can undertake. Measures such as fostering a friendly climate, promoting open attitudes and direct, task-oriented contact, as well as clarifying the division of roles, coordinating tasks, and developing clear communication procedures that can lead to a reduction in time pressure and employee fatigue, can be an effective recipe for improving communication efficiency in the organization and, as a result, also have a positive impact on strengthening its resilience.

6. Conclusion

Employees recognize the importance of effective communication for their personal ability to perform tasks efficiently, reduce the risk of errors, and understand organizational goals. The organization faces practical challenges in communication, particularly regarding role clarity and the management of employee workload. Addressing these issues through fostering a friendly climate, promoting direct contact, clarifying task distribution, and reducing time pressure and fatigue will be crucial for enhancing communication effectiveness and, consequently, for building and maintaining organizational resilience. Openness to discussion and the expressed willingness to develop organizational communication provide a fertile ground for active participation in strengthening organizational resilience, an outcome that may be difficult to achieve without effective communication.

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THE ROLE OF MANAGERS IN BUILDING TEAM RESILIENCE: THE CASE OF MULTICULTURAL TEAMS

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Purpose: This article aims to present the study's findings exploring the role of managers in building the resilience of multicultural teams.

Design/methodology/approach: The empirical study was conducted using in-depth individual interviews (IDI). The sample included 10 middle-level managers leading multicultural teams in London. The research was conducted between April and May 2025.

Findings: The research results indicate that managers perceive communication as the greatest challenge in multicultural teams. At the same time, creating conditions that enhance communication, particularly through open exchange of ideas, transparency, constructive feedback, and the promotion of trust and solidarity, is crucial for strengthening team resilience. Equally important is the manager's developmental orientation and their active efforts to foster this mindset among all team members.

Research limitations/implications: The primary limitation of the study is its small sample size, which restricts the generalizability of the findings. Future research could be conducted in other cultural and organizational contexts.

Practical implications: The study provides managers with concrete guidelines on how to build resilience in teams through fostering open communication, trust, and conscious management of differences. The findings can be used to design more effective training programs for leaders, which may contribute to greater efficiency and employee satisfaction in diverse teams.

Social implications: The study results may contribute to a better understanding of the role of managers in building resilience in diverse teams, as well as greater acceptance of diversity itself, which can be perceived as a resource. This, in turn, can support the development of more open and inclusive work environments.

Originality/value: The study explores the perspective of multicultural team managers, which can be considered extreme examples of diversity in teams. Examining such highly diverse teams provides valuable insights into managerial strategies aimed at building resilience in teams situated at the far end of the diversity spectrum.

Keywords: team resilience, team management, multiculturalism, team diversity, managerial attitude.

Category of the paper: Research Paper.

1. Introduction

Contemporary teams and organizations face increasingly rapid and complex challenges. The philosophy of continuous growth does not allow for pauses on the development path, which requires significant resources, primarily from individuals who constitute the source of created value. In the knowledge economy, people remain the principal source of value. Therefore, ensuring conditions under which individuals, teams, and organizations can work effectively and withstand successive disruptions appears to be of critical importance today. One of the qualities that can and should be developed in this regard is resilience. Resilience is one of the factors influencing task performance effectiveness (Meneghel, Martínez et al., 2016; Meneghel, Salanova et al., 2016; Varajão et al., 2023) and is also associated with a sense of meaning at work and with employee well-being (Alliger et al., 2015; Tugade, Fredrickson, 2004).

Resilience is a multidimensional and multilevel concept. Team diversity within an organization is one of the factors that can potentially support the development of organizational resilience (Duchek et al., 2020).

The present study focuses on the individual perspective of managers leading multicultural teams. Team resilience, diversity, and the challenges of multicultural teams have been explored for years. However, much remains to be discovered at the intersection of these areas. In teams characterized by high levels of diversity, such as multicultural teams, the number of factors disrupting everyday work is significantly greater - even in the absence of external turbulence or crises. Multiculturalism itself can be viewed as a lens through which to examine the challenges faced by contemporary leaders in their efforts to build resilience within internally diverse teams.

2. From team diversity to its resilience

The concept of organizational resilience has emerged from a broader understanding of resilience, which originally stems from psychology. This is highly relevant for management studies, as the individual perspective is necessary (Hartwig et al., 2020), although not sufficient, to fully comprehend the complexity of the phenomenon (Stoverink et al., 2020). Resilience is one of the essential characteristics of individuals, teams, organizations, and systems, enabling adaptation, recovery, the maintenance of performance, and other effective ways of coping with adversity, without falling into persistent, long-term regressive behavior patterns (Alliger et al., 2015; Bowers et al., 2017; Chapman et al., 2020; Hartwig et al., 2020; Home III, Orr, 1997).

Organizational and team resilience are not simply the sum of the individual resilience of the people who create these teams or entire organizations (Bowers et al., 2017; Chapman et al., 2020; Hartwig et al., 2020). Team resilience results from both individual characteristics and the processes occurring between individuals. Therefore, resilience should be examined not only as a static outcome, which can be defined as a capacity or characteristic. Above all, resilience is an ongoing process. Individuals, teams, and organizations develop resilience through a dynamic process of interaction with environments that are often unpredictable and difficult to understand¹. This occurs through building trust and solidarity, shared leadership, open communication, and the cultivation of team cohesion, without implying the formation of monolithic groups at the team or organizational level (Brykman, King, 2021; Mitchell et al., 2025; Morgan et al., 2015; Pavez et al., 2021; Varajão et al., 2021). The more variable the reality, the more important it becomes to understand the factors that support the development and maintenance of resilience. Resilience cannot be regarded as a permanently acquired individual or organizational competency that requires no further attention. Its benefits are hard to overestimate, including the maintenance or improvement of task performance, innovation, employee well-being, and even reliability (Hartmann et al., 2020; Hartwig et al., 2020; Meneghel, Martínez et al., 2016; Varajão et al., 2023).

2.1. Multiculturalism as one dimension of team diversity

Contemporary organizations, particularly those operating globally or located in multicultural urban areas, increasingly leverage the potential of multicultural teams, recognizing them as a key factor in stimulating creativity and innovation. However, managing multicultural teams requires substantial engagement and effort from both team members and leaders. “Appropriate management” can serve as an effective means of overcoming distrust, stress, and lack of cohesion, thereby enabling better utilization of team diversity (Bueno, Freitas, 2015; Freitas, 2008). Cultural diversity fosters creativity by allowing team members to perceive problems from multiple perspectives, leading to a greater number of solutions and unconventional approaches. Collaboration in such an environment also promotes experiences that contribute to individual professional development and overall organizational effectiveness (Chevrier, 2004; Freitas, 2008). Such a team structure allows more effective responses to dynamic and complex challenges (Bueno, Freitas, 2015) while simultaneously shaping team and organizational resilience. The effective functioning of diverse teams (e.g., multicultural teams) requires the development of efficient communication channels, which is a fundamental task for the manager. Communication challenges in teams go beyond language barriers,

¹ Describing the complexity of socio-economic reality today is so challenging that both practitioners and researchers use acronyms to facilitate communication about this complexity and unpredictability, for example: VUCA – Volatility, Uncertainty, Complexity, Ambiguity, BANI – Brittle, Anxious, Nonlinear, Incomprehensible, TUNA – Turbulent, Uncertain, Novel, Ambiguous, RUPT – Rapid, Unpredictable, Paradoxical, Tangled.

also encompassing differences in nonverbal communication deeply rooted in cultural contexts (Heinz, 2014). These contexts can be analyzed across multiple dimensions. Diversity related to multiculturalism can concern several dimensions (Hofstede et al., 2011):

- power distance, which refers to the extent to which members of a society accept and reinforce inequalities in power distribution; within a team, this manifests as variation ranging from unconditional acceptance of organizational hierarchy to collaborative interactions between employees at different hierarchical levels on a partnership basis,
- individualism versus collectivism, which may be reflected in a team in differing degrees of emphasis on individual autonomy versus group belonging,
- masculinity, which relates to the individual importance placed on success and achievement; at the opposite end of the cultural variation continuum lies concern for others and cooperation,
- uncertainty avoidance, which translates into the degree of risk acceptance and openness to innovation,
- long-term orientation, reflected in future-focused behaviors, versus short-term orientation, which emphasizes the present and the past, including traditions,
- indulgence, which in a team may range from strict adherence to social norms to joyful expression and the satisfaction of immediate individual needs.

Multiculturalism within a team thus serves as an excellent example of diversity across multiple aspects of team functioning, ranging from interactions among its members to the ways tasks are performed. Such diversity poses challenges, particularly for the direct supervisor. However, it can become a source of strength and resilience, provided that both individual and team potential are managed appropriately.

2.2. Diversity and multiculturalism as sources of team resilience – the role of the manager

Managers play a crucial role in building team resilience by influencing employees' individual attitudes, managing group dynamics, and implementing organizational practices. Strategic human resource management should focus on modifying leadership methods, procedures, and personnel policies. Such actions aim to develop core employee competencies, which directly contribute to strengthening the entire organization's resilience (Lengnick-Hall et al., 2011). Psychological safety fosters employee engagement, innovation, and team effectiveness, ultimately leading to organizational success. The manager's role is to encourage and support processes such as free exchange of ideas, expression of emotions, and constructive feedback, as well as identifying and leveraging employees' strengths (Ashkanasy, 2003; Kinnunen et al., 2024). An effective manager of a multicultural team thus acts as a mediator, facilitator, and architect of group processes, managing the process and directing members' potential toward the completion of assigned tasks (Heinz, 2014). The same applies to other dimensions of team member diversity. It is the leader's actions that most strongly influence the

team's adaptive capacity, recovery of energy and potential, and development. Even if a team consists of individuals who maintain their own personal resilience, without managerial involvement, these individual practices often cannot be translated into the team space.

In addition, individual leader resilience appears to be important for promoting resilient behavior by demonstrating ways of coping with difficult situations (Malini et al., 2025; McEwen, 2022). A leader can also influence team resilience by developing and promoting team members' attitudes related to trust, solidarity, open communication, and a positive team atmosphere (Meneghel, Salanova et al., 2016; Pavez et al., 2021; Varajão et al., 2021). Social support climate, team coordination (Morgan et al., 2013; Stephens et al., 2013), and other social resources within the team (Meneghel, Martínez et al., 2016), which should be at least partially managed by the manager, are also important for team resilience. Furthermore, the manager is also a key agent in giving meaning to the team's activities, which positively impacts its resilience (Talat, Riaz, 2020).

Among the specific actions a team leader can undertake to enhance the team's resilience potential are creating opportunities for collective learning, reflection, and experience sharing (McCray et al., 2016; Nzinga et al., 2021). Mindfulness training, emotional intelligence development, and communication skills training may also prove beneficial (Malini et al., 2025; McEwen, 2022; Nzinga et al., 2021). As previously noted, team resilience is linked to both team effectiveness and the quality of group experiences. The manner in which leadership is enacted within the team plays a crucial role in promoting and developing team resilience. Transformational and servant leadership are conducive models in this regard (Dimas et al., 2018; Dwidienawati et al., 2022; McEwen, 2022; Siddiquei et al., 2025).

3. Research methodology

3.1. Research design and context

To understand managers' perspectives on their roles in building team resilience, the individual in-depth interviews (IDI) method was employed. This approach allows for the exploration of personal perspectives and ways of understanding a specific segment of the participants' reality (Glinka, Czakon, 2021). It is therefore not a method suitable for uncovering broader patterns or mechanisms, although at various stages of research projects, it can help refine assumptions, adjust directions of inquiry, or reveal actors' motivations. As a standalone method, particularly in areas where systematic research is still lacking, it enables a closer understanding of the situation and the identification of its essential components. Interpretation of data collected in this manner can also contribute to uncovering important constitutive or identity-related work undertaken by the study participants (Alvesson, 2003).

In multicultural teams, it is important to be particularly sensitive to individual interpretations and even more cautious about the researcher's own beliefs. To take these issues into account, discussions were held within the research team at every stage of the study. During the scenario preparation stage, the wording of individual questions was discussed in order to ensure maximum neutrality and openness.

The research conducted aimed to understand how the actions of managers of multicultural teams guide these teams toward greater resilience. The findings from such a study can serve as a basis for expanding the practices already employed by middle-level managers overseeing various teams.

The research sample was selected purposefully. The survey involved 10 male and female middle managers who manage culturally diverse teams. To ensure the greatest possible diversity, participants were recruited from London, where the level of cultural diversity is significantly higher than in Polish enterprises. Detailed information on the subjects is provided in Table 1.

Table 1.
Detailed data on the surveyed group of managers

CODE	Gender	Industry	Team size
Id1	Male	IT	10 people
Id2	Female	Architecture	15 people
Id3	Female	Fashion	9 people
Id4	Female	Catering	18 people
Id5	Female	Advertising	11 people
Id6	Female	Gastronomy	14 people
Id7	Male	Hospitality	25 people
Id8	Female	Creative	11 people
Id9	Male	Retail	11 people
Id10	Male	Gastronomy	9 people

Note. All participants were middle-level managers.

Source: own elaboration.

3.2. Data collection and analysis

The interviews were semi-structured, primarily comprising open-ended questions. Their duration ranged from 30 to 58 minutes. All interviews were conducted remotely between April and May 2025. While conducting interviews via electronic communication has certain limitations, it allows for the inclusion of participants from different parts of the world, and many potential limitations can be mitigated when using videoconferencing (Lobe et al., 2020). With the consent of all participants, Google Meet was used to conduct and record the video conferences. The recordings were then transcribed.

The transcription data was translated into Polish. All data was coded in Polish, and randomly selected fragments were also coded in English. A hybrid approach to coding was used, where some of the codes were generated based on an analysis of the literature on resilience, and some emerged from the data. Parallel coding by two researchers and discussion to agree on meanings in the process were intended to minimize the influence of the researchers' individual beliefs. The data were analyzed and synthesized using MAXQDA software. To ensure anonymity, all information that could potentially identify participants was removed.

4. Results

The themes emerging from the statements of the surveyed managers were aggregated into several categories, which are reflected in the structure of the following subsection.

4.1. Challenges related to cultural diversity

Managers participating in the survey recognize the challenges associated with the cultural diversity of the teams they lead. The most common category of everyday challenges involves communication problems. Interpretative differences are particularly significant because they form the fundamental basis of all processes within the team, including those that underpin the completion of both individual and team tasks. Among the communication challenges, managers mentioned both verbal (e.g., accent, idioms, jargon, slang) and nonverbal (e.g., tone of voice, eye contact) language barriers, which can lead not only to misunderstandings but also to feelings of exclusion. A particularly sensitive communication category involved jokes and sarcasm, which are always strongly culturally marked and can easily be misinterpreted by individual team members. Silence also proved to be a significant challenge, as it is perceived in some cultures as a lack of engagement and in others as a sign of respect. Another category concerned expectations regarding work execution and related attitudes, including punctuality, approaches to hierarchy, time management, feedback provision, initiative-taking, and the degree of directness in communication. These differences led team members to conflicts of varying intensity. Table 2 presents a list of quotes exemplifying the various categories of challenges.

Table 2.

Everyday challenges related to team cultural diversity, according to accounts of surveyed managers - examples from the survey

Challenge	Exemplification in collected data
Communication difficulties	"The biggest challenge is communication – both linguistic and cultural. For example, some colleagues are very direct in communication, others are more reserved and diplomatic. Some jump straight into tasks, while others prefer to build a relationship first. These differences are subtle but significant" [Id 1]. "I remember a situation when a new employee misunderstood the expression 'touch base' and thought it referred to a problem with results. Another time, a joke made by a British colleague was taken very seriously by someone from a different cultural background" [Id 1]. "Although everyone in the team speaks English, for most it is not their native language. This sometimes leads to misunderstandings, especially when discussing complex technical issues" [Id 2]. "Another problem is that the way feedback is received differs depending on culture. In some, directness is the norm - even necessary - while in others it may be perceived as aggression or disrespect" [Id 4]. "One of the main challenges is different expectations regarding feedback. Some are used to direct statements - 'do this better,' 'fix this' - and are fine with it. Others perceive it as harsh or rude" [Id 6]. "There are also differences in sense of humor - jokes do not always translate well, and sometimes someone gets unintentionally offended" [Id 9]. "The biggest challenges are communication and expectations. Sometimes people interpret instructions differently depending on where they come from and what experiences they have" [Id 10]. "We had a waiter from Turkey who misunderstood the instruction 'cover the section' - he thought it meant physically covering the tables!" [Id 10].
Diverse work expectations and norms	"Some team members are very respectful of authority and are reluctant to question decisions. Others speak freely and ask questions" [Id 1]. "For example, our Polish and Indian team members are very task-oriented and punctual. Some British employees have a more flexible approach, especially regarding deadlines. Regarding hierarchy, I noticed that some colleagues from Asia expect clear instructions from managers, whereas others - for example from Spain or the UK - feel comfortable questioning ideas and speaking freely, even to superiors" [Id 2]. "In my view, the biggest challenge is assumptions - both mine and the team members'. Sometimes people assume that their way of working is the normal or correct way" [Id 3]. "For example, during meetings I noticed that some people do not speak up, even if they have good ideas - particularly those from cultures where questioning a superior is seen as disrespectful. Others, such as some younger employees born in the UK, are very open and forthcoming" [Id 3]. "Employees from more hierarchical cultures often expect direct instructions and hesitate to act independently, fearing they might overstep. Conversely, those from more egalitarian cultures can act without asking managers" [Id 4]. "Some cultures emphasize speed, others precision. I had a Spanish colleague who loved talking to clients - he spent more time serving them, which seemed to slow things down for the British. But he built client loyalty like no one else" [Id 6]. "An employee from Vietnam made a mistake, and I corrected him publicly during a meeting. Afterwards, he became withdrawn and distant. I then learned that public correction can be perceived as highly embarrassing in his culture" [Id 7]. "A recurring challenge is balancing cultural sensitivity with operational efficiency. For example, some employees may feel uncomfortable working with pork or alcohol due to religious beliefs, which can be limiting in hospitality" [Id 7]. "Perceptions of time are another difference. Some are very punctual and adhere to strict schedules, while others have a more flexible approach. This can be problematic for deadlines or client meetings. And humor - it is not always universal" [Id 8]. "The main challenge is communication - both linguistic and cultural. For example, someone might say 'yes' during a briefing but actually not understand the task. This used to frustrate me until I realized that in some cultures, saying 'no' directly to a manager may be considered disrespectful" [Id 9]. "Employees from Eastern Europe are usually very punctual and task-focused. Those from Southern Europe or Latin America have a more 'relaxed' approach to time - not due to laziness, but simply a different working pace" [Id 10].

Cont. table 2.

Cultural conflicts	"A few months ago, we had a misunderstanding between a Spanish developer and a Polish tester. The developer felt that the tester was too critical and rigid in her bug reports, using phrases like 'this feature doesn't work' or 'this is wrong' [Id 1]. "A few years ago, a British team member gave quite direct feedback to a Nigerian colleague during a project review. He felt publicly embarrassed and began withdrawing from participating in meetings" [Id 2]. "Once, a Spanish bartender and a British kitchen assistant argued about cleanliness. The Brit thought the Spaniard was lazy for not cleaning up a spill immediately, while the Spaniard was simply waiting for the rush to pass. One saw it as negligence, the other as 'not urgent [Id 4]. "We had a conflict between a Polish chef and a Turkish bar assistant regarding cleaning. One felt it wasn't his responsibility, the other called him lazy. Tension arose" [Id 6]. "Last year, there was a tense situation between a French employee and a Kenyan employee in the kitchen. The Frenchman was very direct and liked giving orders, whereas the Kenyan strongly valued group harmony and felt disregarded" [Id 7]. „A Brazilian employee greeted people very warmly - sometimes hugging or placing a hand on the shoulder. A British colleague found it uncomfortable and perceived it as an invasion of personal space" [Id 9].

Source: own elaboration.

4.2. Promoting interpersonal trust

The managers participating in the survey emphasized the importance of creating an environment open to diversity and differing perspectives, one that fosters trust in the sense that personal worldviews are, on the one hand, accepted but, on the other, not assumed to be the default perspective for other team members. Developing such an approach requires numerous small managerial interventions, as well as high levels of sensitivity and attentiveness from the leader. Employees gradually become able to engage in interactions that go beyond their culturally conditioned ways of perceiving reality. Managers promote trust among team members by, for instance:

- encouraging open communication, asking questions, and conducting individual conversations that foster an atmosphere of safety,
- adapting communication styles and encouraging the expansion of communication behavior repertoires,
- simplifying communication by avoiding idioms, providing clear instructions, explaining key concepts, paraphrasing, and summarizing to ensure messages are correctly understood,
- encouraging the adoption of different perspectives,
- implementing a "buddy system" for new members, which helps them integrate, understand processes, and build a sense of competence.

A set of selected quotes exemplifying the individual groups of actions is presented in Table 3.

Table 3.*Managerial actions in promoting interpersonal trust – examples from the survey*

Manager's actions	Exemplification in collected data
Encouraging questions and open communication	„In my opinion, the key is open communication and empathy. I try to be very clear in both written and spoken communication - avoid idioms, explain key terms and make sure everyone understands, especially new team members. I also encourage people to ask questions and make it clear that there is no shame in not knowing something. We also introduced the practice of paraphrasing and summarizing during meetings” [Id1]. „We also use visualization. [...] drawings, sketches, models - which help overcome language barriers” [Id2]. „We introduced the practice of encouraging follow-up questions. I always say: <There is nothing wrong with asking twice>. We also try to write everything down after meetings - summary emails in bullet points are very helpful. I also regularly hold one-on-one meetings with team members to give them space to ask questions or raise issues they wouldn't want to bring up in a larger group” [Id5]. „We offer language support and organize workshops <Workplace communication in an intercultural context>. During the sessions, we show how the same phrases can be interpreted differently depending on one's background. [...] I try to be a role model of open and respectful communication. I encourage asking questions, requesting clarifications, and I always repeat the most important information” [Id7].
Building a climate of psychological safety	„The key is patience. I also encourage team members to pair up informally - someone more fluent in English can help a colleague who is still learning. This builds trust. I also regularly organize short feedback sessions in a more relaxed atmosphere, where different issues can be raised” [Id3]. „I take time to get to know what motivates each person, how they prefer to receive feedback, and what makes them feel safe at work. I talk openly with the team about cultural differences - sometimes with humor, sometimes more seriously” [Id4]. „Above all - patience. I have learned to slow down and check whether someone really understood, rather than assuming they did. I repeat key information in several ways - verbally, in writing, and visually. We also do short role-plays during training, which help to understand situations in practice” [Id9].
Adapting communication style	„In some [cultures], directness is the norm - or even a necessity - while in others it can be perceived as aggression or disrespect. As a manager, I had to learn to adapt my communication style to the person I was speaking with” [Id4]. „I now speak in a more neutral and structured way. Instead of asking, <Are there any questions?>, I prefer to say, <Could you explain how you see your next steps?>. This way, I can ensure we have a shared understanding” [Id5]. „We set clear standards: punctuality, hygiene, customer service - these are non-negotiable. But the way we communicate these expectations can vary. I tell some people more firmly, others with more support. A leader must be flexible” [Id7].

Source: own elaboration.

4.3. Integration and building a sense of group agency

Communication appears to be the fundamental determinant enabling teamwork. However, to build team effectiveness and resilience in the face of numerous challenges, including those arising from internal diversity, it is also necessary to undertake additional efforts. The managers interviewed devote considerable time and energy to activities aimed at fostering pro-team attitudes and cultivating a sense of collective agency, which underpins the success of every team. Within this category of activities, the following practices were identified:

- encouraging initiative and responsibility,
- appreciating diverse viewpoints and contributions to teamwork,
- strengthening the sense of individual competence,

- ensuring equal participation in team activities, including rotation of responsibilities,
- organizing intercultural meetings and celebrating various holidays, which foster a sense of equality and significance of belonging within the team.

A set of selected quotations exemplifying the respective groups of activities is presented in Table 4.

Table 4.

Managerial actions in the area of integration and fostering a sense of collective agency – examples from the survey

Manager's actions	Exemplification in collected data
Encouraging initiative and responsibility	„Equal participation in meetings - I make sure that everyone has a chance to speak, especially those who are quieter or less confident in their language skills” [Id1]. „I make sure that everyone has equal opportunities for responsibility - without favoritism” [Id3]. „For example, during meetings I noticed that some people don’t speak up, even if they have good ideas - especially those who come from cultures where questioning a manager is seen as disrespectful. Others, such as some younger employees born in the UK, are very open and outspoken. Maintaining balance in this dynamic, so that no one feels dominated or overlooked, is a constant task” [Id3]. „We make sure that everyone has the opportunity to participate in decision-making. It’s not symbolic - it truly impacts our projects” [Id5]. „I also make a point of inviting employees from different cultures to decision-making meetings - not only those who speak English as their native language or have more outgoing personalities” [Id7]. „We also try to rotate responsibilities so that closed nationality-based groups don’t form” [Id10].
Recognizing diverse contributions	„Fair evaluation process - we make sure that assessments are based on results and contributions, not on how confident someone is during meetings. We remind managers not to confuse silence with a lack of leadership potential. We want everyone to have equal growth opportunities - regardless of their background” [Id1]. „I also try to recognize individual achievements - especially of those who are less confident or less outspoken. They also deserve recognition” [Id3]. „I challenge the belief that leadership roles are only for native speakers or those with a Western education” [Id7]. „We also value different aspects of work - not only speed or client feedback, but also teamwork, helping others, and a positive attitude. This creates a fairer sense of worth” [Id10].
Team integration	„I try to celebrate cultural events from different backgrounds. For example, last year we set up a shop window display for Diwali, and a few months later we organized a lunch for employees for Eid. These may seem like small things, but they matter” [Id3]. „We organize meetings - dinners where everyone brings something from their own country, quizzes, and employee birthdays. But I always emphasize: participation is voluntary. Building relationships has to be natural” [Id6].

Source: own elaboration.

4.4. Supporting development processes

All the managers in the study approached situations requiring their intervention with humility. These were usually situations arising from cultural differences. In the teams studied, numerous systemic actions are implemented to help onboard new employees and continuously improve the way people from different cultural backgrounds collaborate. Among such actions, managers mentioned:

- training sessions organized in collaboration with experts from within or outside the organization,
- mentoring and coaching programs, both at the group and individual levels,

- support systems for junior employees by assigning them mentors at the beginning of their organizational journey.

Among less formal activities were individual conversations, sharing experiences, and presenting one's own country and customs. All of these elements, according to the managers interviewed, contribute to a corporate culture built on openness, respect, and the understanding of the need for continuous development. This is reflected, among other things, in the mindset of the managers themselves, who interpret conflict situations as opportunities for discussion, learning, and improving individual competencies, as well as for strengthening and developing the team as a whole. This, in turn, provides an excellent foundation for building team resilience. A selection of quotes exemplifying these groups of activities is presented in Table 5.

Table 5.

Managerial actions in supporting development processes – examples from the survey

Manager's actions	Exemplification in collected data
Supporting individual development	„We take various actions: Individual coaching sessions to help people from outside the UK understand how career development works in the British context - with a focus on visibility, communication, and self-promotion. Language and communication support - if someone wants to improve their business English or presentation skills, we provide time and resources. A mentoring program - we connect less experienced employees with more senior ones who help them not only technically but also culturally” [Id1]. „We make sure everyone has access to the same mentoring and training opportunities. I also encourage younger employees to set their own development goals and help them find the right resources” [Id2]. „I try to regularly discuss career goals during performance reviews. I also connect team members with mentors outside their immediate circle, especially if they might have limited access to such networks in the UK” [Id5]. „Each person has an individual development plan. But we also know that cultural background influences how people talk about their achievements. That's why we give feedback on an ongoing basis, not just once a year. We have promoted people from underrepresented backgrounds into leadership roles, giving them support - assigning mentors, offering them client-facing roles, and increasing their visibility. We also collaborate with organizations such as Creative Access that support creators from minority groups. Our goal is not just to hire diverse people but to help them become decision-makers” [Id8].
Supporting team development	[after a conflict situation] „We met together and agreed on a new way of reporting bugs - fact-based but using neutral language (e.g., 'Expected action: X. Actual result: Y.'). It worked - now they get along well” [Id1]. „Once a year we work with a diversity consultant who runs intercultural communication workshops. They cover topics such as unconscious bias and cultural aspects of behavior. We also use online platforms that offer short e-learning modules on cultural sensitivity, available at any time” [Id5]. „Twice a year we invite external trainers specializing in intercultural communication. They run engaging workshops - with simulations, role-playing, and scenarios where you have to collaborate with someone with a different communication style. We also use the 'Culture Map' tool based on Erin Meyer's research. It helps leaders understand where a person is positioned on different cultural scales - how directly they speak, how they react to confrontation, how they give feedback, etc” [Id8].

Cont. table 5.

Reinterpreting events to foster development	„Some colleagues are very direct in communication, others more reserved and diplomatic. Some jump straight into tasks, others prefer to build a relationship first. These differences are subtle but significant - and the ability to navigate between them is part of our development as a team. [...] Managing a multicultural team in one place, like London, is both a challenge and a privilege. It requires awareness, flexibility, and empathy - but it brings huge benefits. We learn from each other every day. We build stronger and more creative teams. We create a workplace where everyone - regardless of background - can feel part of it and succeed. If I were to add one more thing, I would say: diversity doesn't work without inclusion. The mere fact of having many nationalities in one room is not enough. You need to make sure every voice is heard and respected. That is the real work - and it's worth doing" [Id1]. „I treat them as opportunities to learn. Most conflicts don't come from bad intentions - someone offended someone else unintentionally. I try to mediate, listen to both sides, and explain perspectives" [Id6]. „The first step is realizing that not every conflict is bad - sometimes it's simply an expression of the development process" [Id8]. „The most important thing is that I treat conflict resolution as part of the team's learning proces" [Id9].

Source: own elaboration.

Diversity in these teams is not perceived as a barrier. The success of these teams depends on the extent to which the manager is able to reinterpret this reality as a source of development and potential, both in relation to individuals and to the team as a whole.

5. Conclusions

The challenges arising from the cultural diversity of team members, as experienced by the managers surveyed, may seem minor compared to those brought about by the COVID-19 pandemic. However, by treating these difficulties as resilience training, both the team and the manager can be better prepared to activate adaptive behaviors at the right moment, regardless of the scale of the challenges they may face in the future.

The difficulties faced by members of multicultural teams and their managers constitute an excellent field for shaping attitudes and behaviors associated in the literature with enhancing team resilience. First, these include cognitive and affective trust, which together form interpersonal trust (Pavez et al., 2021). In multicultural teams, this trust is developed, among other ways, through systematic learning about other cultures and perspectives. Second, open communication and empathy, which, according to the concept of Emotional Carrying Capacity (ECC), constitute the basis of a key mechanism explaining the resilience of individuals and teams (Stephens et al., 2013). The ability to express emotions has also been highlighted by other authors as an important factor in fostering team resilience (Brykman, King, 2021; Duchek et al., 2020; Nzinga et al., 2021). In multicultural teams, where the ways of expressing emotions are highly diverse due to the cultural backgrounds of individual team members, such openness and the manager's sensitivity to these issues become extremely important. Third, shared leadership (Hartwig et al., 2020), which in the studied teams manifested as encouragement to take greater responsibility and decision-making. Finally, a focus on continuous development

and interpreting reality through the lens of learning opportunities - both individual and team-based (Hartmann et al., 2020; Hartwig et al., 2020; Luthans et al., 2007; Mitchell et al., 2025; Nzinga et al., 2021; Stephens et al., 2013; Tugade, Fredrickson, 2004).

The individual attitude of the manager plays a crucial role, particularly in terms of demonstrating adaptive behaviors and, in this way, modeling the behaviors of individual team members (Malini et al., 2025; McEwen, 2022). In the case of the managers studied, this primarily involved calmness, patience, showing respect, including team members in decision-making processes, encouraging them to take responsibility, and adhering to collectively agreed-upon rules while simultaneously being flexible and open to adjustments or revisiting these rules when necessary.

A Resource Model of Team Resilience Capacity (Brykman, King, 2021) assumes that the Voice Climate (openness to expressing opinions and emotions, feeling of being heard, and receiving an appropriate response from the supervisor) prevailing in the team is the basic factor enabling the building of Team Resilience Capacity, which in turn leads to effective Team Learning. This model, therefore, suggests that resilience is necessary for learning, and not the other way around. The picture obtained from the stories of the managers participating in the study also highlights these connections. However, the individual role of the manager in creating a climate conducive to learning is strongly emphasized here, which Brykman and King refer to as Leader's Learning Goal Orientation and point to its mediating role in building Team Resilience Capacity.

The theoretical implications arising from the presented analyses thus confirm the current state of knowledge regarding managerial factors and strategies that strengthen team resilience. This confirmation specifically pertains to the management of culturally diverse teams. Among the practical implications, it is particularly important to emphasize recommendations concerning managerial attitudes that support team development.

The primary limitation of this study is the small number of participants. However, this allowed for an in-depth examination of the perspectives of managers of multicultural teams regarding their personal attitudes that enhance the resilience of the individuals they manage. The specific conditions present in multicultural teams can serve as an inspiration for further research on diverse teams, aimed at identifying and comparing managerial strategies for building team resilience.

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PROFESSIONAL PROFILE OF A TOP MANAGER IN A PROCESS AND PROJECT ORGANIZATION

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Purpose: There is a gap in knowledge in the literature on process and project management, even though it is emphasized that processes and projects are complementary elements in modern organizations. The authors of this publication present selected research results, the main objective of which was to define the professional profile of a top-level manager of a process and project organization, by characterizing their role and the competencies necessary for effective management of these organization and the implementation of reactive and proactive strategies.

Design/methodology/approach: The main objective was achieved in three stages. Stage 1. involved analyzing the literature on the subject and conducting targeted interviews using quantitative research methods such as CAPI, CATI, CAWI. In stage 2. a panel of experts discussed the results of the interviews. In stage 3. the results of the interviews were related to related scientific considerations conducted as part of other research trends.

Findings: Based on research, it has been assumed that the top manager in a process and project organization should primarily act as an ambidextrous leader. However, the importance of this manager's competencies may vary depending on the size of the organization, the subject and specificity of its activities, process and project maturity or the level of internationalization, technological progress, forms of work organization, the pace of change, and the uncertainty of the environment. The results obtained are quite consistent with considerations on leadership in ambidextrous organizations that have been conducted as part of other research trends.

Research limitations/implications: The opinion of the research group of 204 internationalized companies may differ from others, especially non-internationalized entities. The survey also did not take into account the respondents' business focus and size.

Practical implications: The research results obtained, can provide a basis for determining the roles and competencies of managers for organizations that want to move to a process-project orientation.

Originality/value: The scientific value of the publication lies in identifying the professional profile of top managers in process and project organizations. The publication is aimed at both academics and management practitioners.

Keywords: process-project organization, top managers, professional profile.

Category of the paper: Research paper.

1. Introduction

The growing complexity of the business environment has meant that many modern organizations, in order to function properly, develop, and achieve success in the future, focus simultaneously on processes and projects (Nowosielski, 2017, 2018; Osbert-Pociecha, 2019; Strojny, 2019; Szpitter, 2020; Sliż, 2021). These organizations are called process-project organizations. The literature does not describe many comprehensive scientific research results on the problems of managing these organizations, as they have only been presented in more detail in two books (Szpitter, 2020; Sliż, 2021). They assume that managing such organizations requires ambidexterity.

In general terms, the concept of organizational ambidexterity is described as the ability to simultaneously apply two contradictory but not mutually exclusive approaches – exploitative and exploratory (Raisch et al., 2009), which is associated with the implementation of competing strategic orientations (Hu, Chen, 2016; Zhang et al., 2016). The first of these orientations – reactive – refers to exploitation and is focused on productivity, efficiency, updates, modifications, and improvement of current activities to adapt to market needs (Kohtamäki et al., 2010). The second orientation, proactive, refers to exploration and is focused on change, searching for and investigating new opportunities (Raisch et al., 2009).

Ambidexterity is difficult and involves paradoxes, because reconciling exploitation and exploration requires, among other things, the simultaneous implementation of radical and incremental innovations, single and double learning loops, stability and transformation, and induced and autonomous strategic processes. A synthetic summary of considerations regarding these contradictions can be found in many publications (e.g., Raisch, Birkinshaw, 2008; Raisch et al., 2009; Rosing, Zacher, 2023).

It can be assumed that ambidexterity is even more difficult in organizations that are simultaneously process- and project-oriented, because managing them requires, among other things, different roles and competencies of managers and employees, organizational solutions, and the tools and methods used. To date, the literature has mainly described them separately, focusing on process-oriented organizations and project-oriented organizations. The exceptions are the considerations contained in the books mentioned above (Szpitter, 2020; Sliż, 2021) and a few other, more narrow publications on process and project management. The authors of this publication wish to contribute to these considerations by pointing out the problems of process and project management and the results of research that support their solution.

2. Basis for the research, its purpose, research process, and methods used

The basis for the research was the adopted model of a ambidextrous process and project organization (Fig. 1). The model assumes that achieving the overarching strategic objective of such an organization, which is to increase value through proper functioning and development, requires management focused on the implementation of:

- 1) a reactive strategy related to operations, including the ability to implement incremental changes – improvements for the effective implementation of existing processes and projects,
- 2) a proactive strategy, relating to exploration, including the ability to implement radical changes – new solutions, innovations in processes or new processes, as well as new and innovative projects.

The implementation of these strategies involves many problems that pose challenges for the management of process and project organizations. It has been assumed that these problems concern interrelated and overlapping areas, which include: 1. human capital, 2. organization, 3. finance, 4. knowledge, 5. methods and tools.

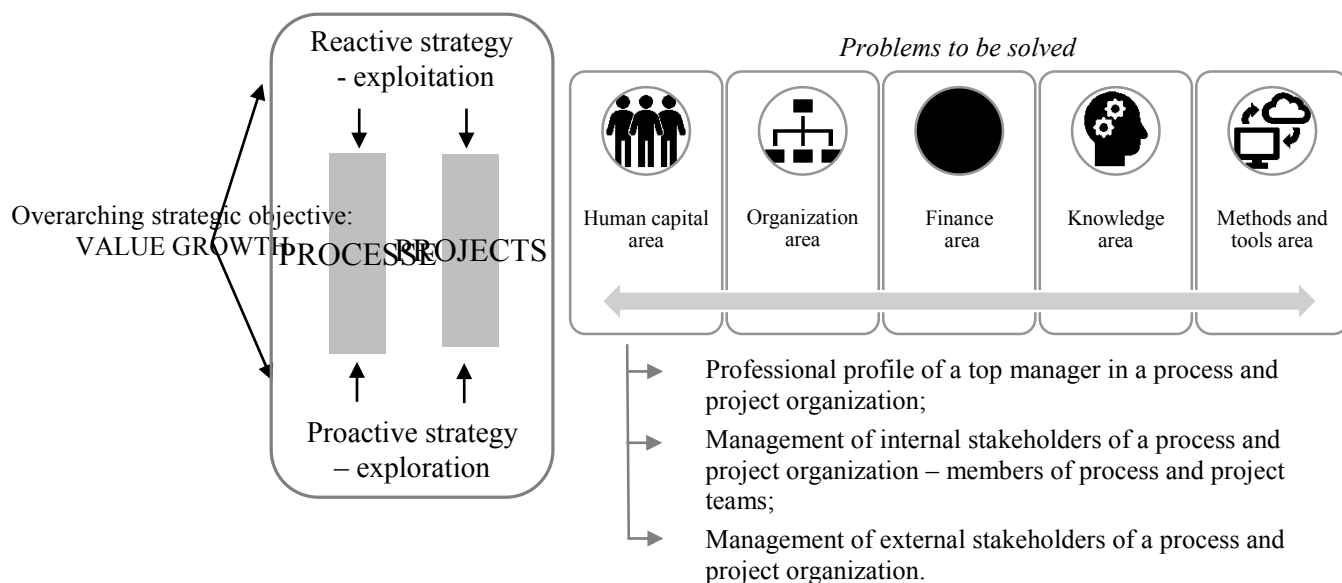


Figure 1. Generalized model of a ambidextrous process and project organization, taking into account selected issues in the area of human capital.

Source: own work.

This publication presents the results of research in the area of human capital, which covered only issues related to top managers, referring to the definition of their role and the competencies necessary for the effective management of a process and project organization and the implementation of reactive and proactive strategies. The aim of this research was to define the professional profile of a top manager in a process and project organization. Considerations regarding other issues in the area of human capital will be presented in a separate publication.

The research was conducted in three stages. Stage 1 involved analyzing the literature on the subject and conducting targeted interviews using quantitative research methods such as CAPI (Computer Assisted Personal Interview), CATI (Computer Assisted Telephone Interview), and CAWI (Computer Assisted Web Interview). In stage 2, a panel of experts discussed the results of the interviews. In stage 3, the results of the interviews were compared with related scientific considerations presented in the literature on the subject.

3. Research results

3.1. Interviews

In order to achieve the research objective, which was to define the professional profile of a top manager in a process and project organization, the first step was to develop an interview questionnaire.

First, several dozen publications were analyzed that referred to the roles and competencies that should characterize managers of modern organizations. It was noted that there is a knowledge gap in this area with regard to process and project management. A synthesis of the considerations contained in the analyzed literature is presented in a separate publication (Skubis, Bijańska, 2024). It was emphasized there that the top manager of a process and project organization fulfills different roles and has different competencies than the leaders of process or project teams who operate in an environment oriented towards self-organization and self-control of colleagues, and whose leadership is characterized by impermanence and transience.

Next, based on the roles and competencies of managers in contemporary organizations identified in the literature, an interview questionnaire was developed (Skubis, Bijańska, 2024). It served as the basis for assessing the importance of the roles and competencies of top managers in process and project organizations. The questionnaire distinguished such contemporary roles as: professional, manager in an international environment, explorer, agent of change, rescuer, entrepreneur, democrat – servant leader, knowledge propagator, ambidextrous leader, creator of success. Each role was characterized by appropriate competencies.

Next, interviews were conducted in several phases. The first phase, described in detail in an earlier publication (Skubis, Bijańska, 2024), involved 175 managers of process- and project-based organizations based in Poland (Silesian Province) and characterized by internationalization. The sample for the study was selected in a non-random manner – based on the researcher's subjective assessment, quota – from a population of representative units. CAPI and CATI methods were used in this phase. The second phase involved another 73 managers from abroad (EU) who managed process and project organizations related to Polish companies (these were mainly partners or branches or subsidiaries of organizations from the

previous phase of the study). In this phase, CAPI, CATI, and CAWI methods were used (the latter method was used in only 11 cases, at the express request of the respondents). The choice of these quantitative data collection methods was based on their characteristics, which include, among others, the quick acquisition of high-quality information and a satisfactory response rate. When using CAPI and CATI, any doubts were clarified to the respondents in order to ensure an unambiguous interpretation of the assessed roles¹ and competencies.

Previously, all respondents were assessed in terms of their process and project maturity level, based on a model (Sliż, 2021) that included five levels and was based on project maturity assessment (PMMM) and process maturity assessment (MMPM) models. The research results included responses from managers only from those organizations that were at levels 3, 4, and 5 of process and project maturity (Sliż, 2021, pp. 201-211). This was a total of 204 managers from:

- 1) 89 organizations (66 Polish and 23 foreign) at level 5, defined as a "Process and Project Organization", which means that their:
 - organizational structure is characterized by a process-project layout,
 - projects are implemented in a process-based convention,
 - the level of maturity of process and project management is high in the operational and exploratory layers,
- 2) 63 organizations (45 Polish and 18 foreign) are at level 4, defined as "Process organization with a high level of project management maturity", which means that their:
 - organizational structure is characterized by a matrix system,
 - their activities are aimed at implementing a pure process structure with project organization or a process-project structure,
 - management consciously uses the benefits of implementing process and project solutions and recognizes the need to group and integrate them in the operational and exploratory layers,
- 3) 52 (41 Polish and 11 foreign) are at level 3, defined as "Process and project-oriented organization", which means that their:
 - activities are aimed at implementing a matrix organizational structure,
 - the system for measuring process and project results is the basis for management decisions,
 - the operational layer is clearly defined and management activities are aimed at improving the efficiency and quality of process results,
 - exploratory projects are carried out on the basis of formalized process documentation.

¹ The most doubts were related to the concept of "ambidexterity," which was unfamiliar to practitioners (some replaced it with the concept of "duality").

The obtained assessments of the importance of roles and competencies (on a scale from 0 to 3)² were multiplied by the respondents' competency coefficient, referring to the level of process and project maturity of the organization they represented (1.0, 0.95, 0.9 for maturity levels 5, 4, and 3, respectively), then summed and converted into percentages. This allowed us to present the importance of the roles and competencies of top managers in a process-project organization.

The responses given during the interviews show that the role of the ambidextrous leader is of paramount importance in a process-project organization (Fig. 1). The research results are therefore consistent with the assumption that process-project organizations require ambidextrous management. In addition, the roles of success creator, professional, and manager in an international environment are also very important.

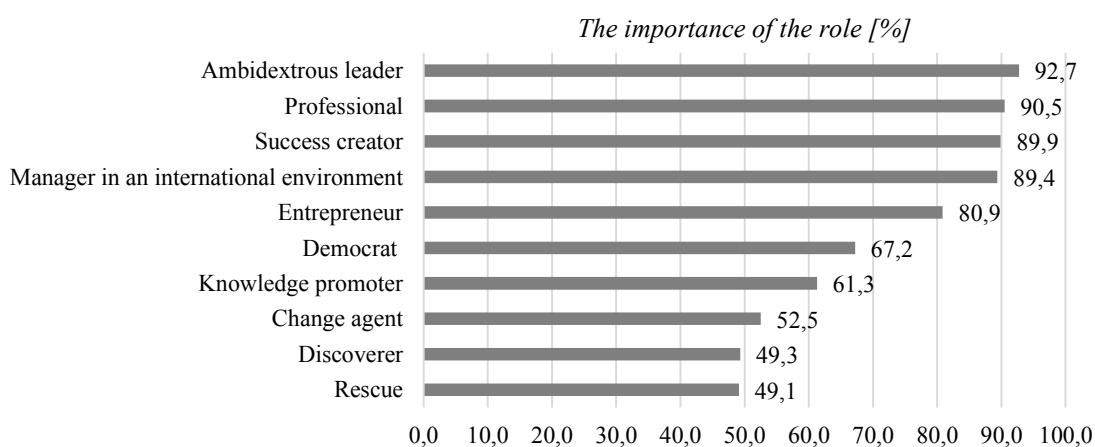


Figure 1. Results of the assessment of the importance of top managers' roles in a process-project organization.

Source: own study.

Based on the analysis of the research results, it can be concluded that the importance of the role of the ambidextrous leader increased with the level of process and project maturity (Fig. 2).

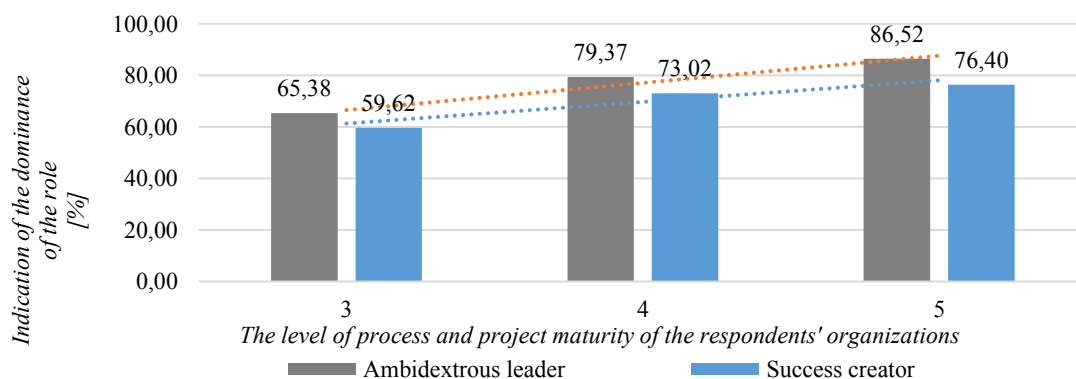


Figure 2. The level of process and project maturity of the respondents' organizations and their indication of the dominant roles of the ambidextrous leader and success creator.

Source: own study.

² Scale for assessing the importance of roles and competencies: 3. high importance; 2. medium importance; 1. low importance; 0. no importance for the organization.

In organizations with the lowest, i.e., level 3, 65.38% of respondents (34 out of 52) indicated the significant importance of this role, and in organizations at level 4, 79.37% (50 out of 63) did so. However, 86.52% (77 out of 89) of respondents from organizations with the highest level of process and project maturity emphasized the greatest importance of this role. A similar relationship exists with regard to the role of success creator, whose importance increases with the level of process and project maturity of the respondents' organizations.

The presented results, which are expanded to include the assessments of foreign respondents, differ slightly from previous research results (Skubis, Bijańska, 2024). Polish respondents first indicated the greatest importance of the role of a professional (92.3%), followed by an ambidextrous leader (92%), a success creator (90.1%), and a manager in an international environment (88.4%). The order of most of the other roles also differs slightly.

As part of the discussion, it is worth noting that the emphasis on the importance of the manager's role in an international environment is likely due to the selection of respondents who were characterized by internationalization. In the sample, 57 entities were characterized by a high degree of internationalization, 88 by a medium degree, and 59 by a low degree, as assessed on the basis of the DOI model_{INTS}³ (Sullivan, 1994). The analysis of the responses shows that almost 74% of respondents with a high degree of internationalization (42 out of 57) indicated the high importance of the role of the manager in an international environment.

Respondents were also asked which competencies, among all those dedicated to top managers of modern organizations, are most important for the effective management of a process- and project-based organization and the implementation of reactive and proactive strategies. Based on their assessments, a ranking of the competencies of a top manager of a process- and project-based organization was developed (Fig. 3).

The presented results of the assessment of the importance of competencies, which are expanded to include the opinions of foreign respondents, were compared with previous studies (Skubis, Bijańska, 2024). On this basis, it was concluded that these results are consistent in the case of the most important competencies – nos. 1, 2, and 3 – and the less important competencies – nos. 24, 39, and 42 (Table 1). The assessment of the importance of most of the other competencies differs slightly, but in the case of a few, it differs significantly. Thus, foreign respondents:

1. rated the importance of the following competencies significantly higher:
 - ability to solve large-scale problems – No. 12,
 - ability to see through the interests of the entire organization, rather than focusing on individual processes and projects – No. 13,
 - ability to build trust and overcome resistance to change – No. 28,
 - emotional and social intelligence – No. 34,
 - ability to communicate when planning and implementing change – No. 38,

³DOI_{INTS} = Foreign Sales to Total Sales, Foreign Assets to Total Assets, Overseas Subsidiaries to Total Subsidiaries, Top Managers' International Experience, Psychic Dispersion of International Operations.

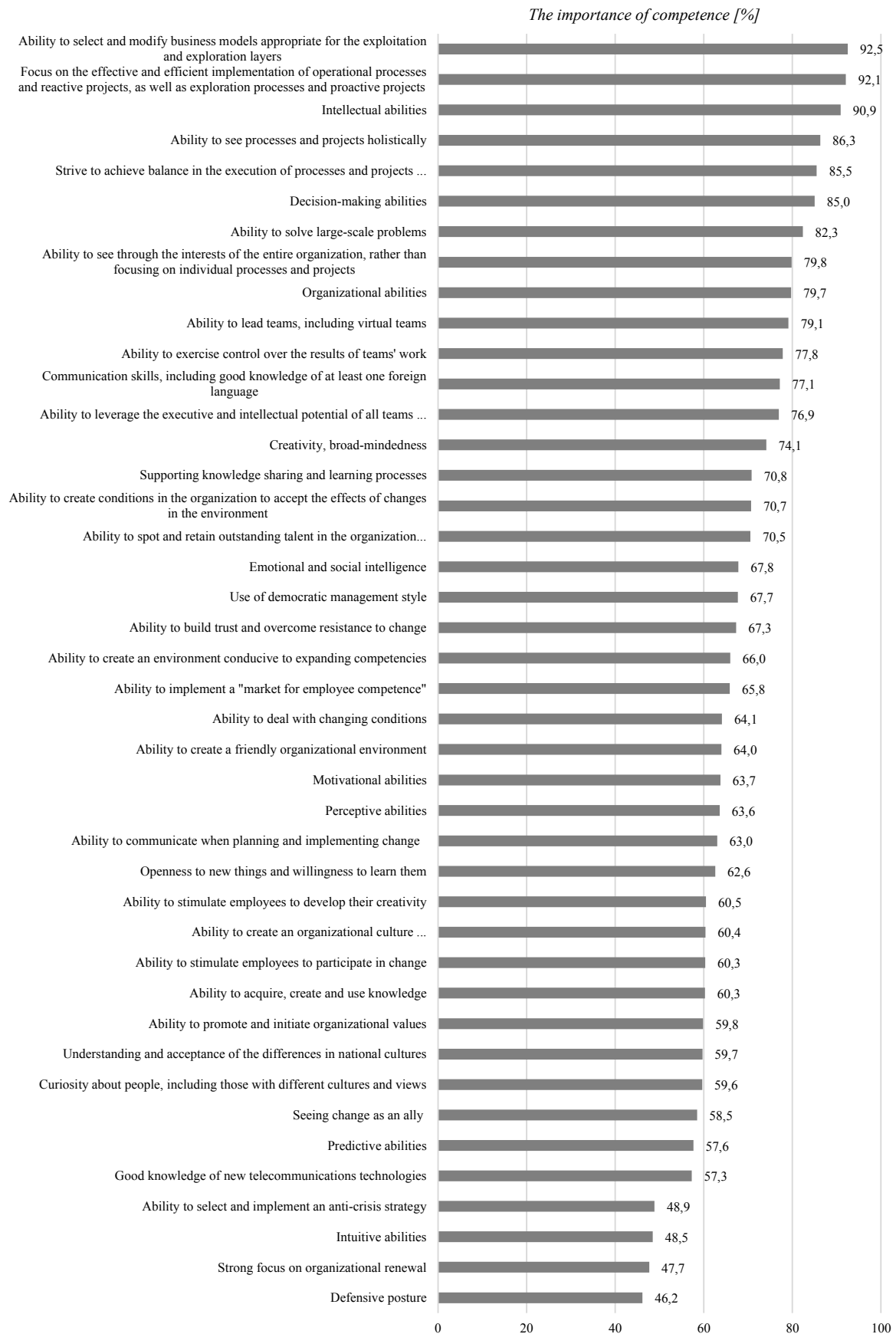


Figure 3. Results of the assessment of the importance of top managers' competence in a process and project organization.

Source: own study.

2. rated the importance of the following competencies significantly lower:

- ability to leverage the executive and intellectual potential of all process and project teams – No. 4,
- ability to use a democratic leadership style – No. 14,
- good knowledge of new telecommunications technologies – No. 21,
- ability to create an organizational culture that emphasizes the functioning of the market mechanism in the organization – No. 25.

To summarize this part of the study, after conducting the interviews, it was assumed that a top manager in a process and project organization should primarily play the role of ambidextrous leader, and the person performing this role should possess the indicated competencies, the importance of which is based on the assessment of 204 respondents.

Table 1.

The importance of the competencies of a top manager in a process and project organization, without and after including the opinions of foreign respondents

The importance of competencies				
according to Polish respondents	including foreign respondents			
<i>Number and name of competence</i>	<i>Assessment (%)*</i>	<i>Ranking position</i>		<i>Assessment (%)*</i>
1. Ability to select and modify business models appropriate for the exploitation and exploration layers	93.8	1	1	92.5
2. Focus on the effective and efficient implementation of exploitation processes and reactive projects, as well as exploration processes and proactive projects	93.6	2	2	92.1
3. Intellectual abilities	90.1	3	3	90.9
4. Ability to leverage the executive and intellectual potential of all process and project teams	87.5	4	13	76.9
5. Decision-making abilities	87.2	5	6	85.0
6. Ability to see processes and projects holistically	84.2	6	4	86.3
7. Strive to achieve balance in the execution of processes and projects	83.8	7	5	85.5
8. Organizational abilities	83.3	8	9	79.7
9. Ability to lead teams, including virtual teams	83.2	9	10	79.1
10. Ability to exercise control over the results of team's work	82.9	10	11	77.8
11. Communication skills, including a good knowledge of at least one foreign language	80.5	11	12	77.1
12. Ability to solve large-scale problems	80.1	12	7	82.3
13. Ability to see through the interests of the entire organization, rather than focusing on individual processes and projects	72.9	13	8	79.8
14. Ability to use a democratic leadership style	72.2	14	19	67.7
15. Creativity, broad-mindedness	72.0	15	14	74.1
16. Ability to spot and retain outstanding talent within the organization, regardless of their nationality	69.4	16	17	70.5
17. Supporting knowledge sharing and learning processes	69.4	17	15	70.7
18. Ability to create an environment conducive to expanding competences of employees and generating initiatives by them	68.3	18	21	66.0
19. Ability to implement a 'market for employee competences'	68.2	19	22	65.8
20. Ability to create conditions in the organization to accept the effects of changes in the environment	66.4	20	16	70.7
21. Good knowledge of new telecommunications technologies	66.4	21	38	57.3
22. Perceptive abilities	65.6	22	26	63.6
23. Motivational abilities	64.5	23	25	63.7

Cont. table 1.

24. Ability to create a friendly organizational environment for good performance	63.6	24	24	64.0
25. Ability to create an organizational culture that emphasizes the functioning of the market mechanism in the organization	63.4	25	30	64.0
26. Ability to deal with changing conditions	63.3	26	23	64.1
27. Openness to new things and willingness to learn them	63.2	27	28	62.6
28. Ability to build trust and overcome resistance to change	62.6	28	20	67.3
29. Ability to acquire, create and use knowledge	60.7	29	31	60.3
30. Ability to stimulate employees to participate in change	59.9	30	31	60.3
31. Curiosity about people, including those with different cultures and views	59.7	31	35	59.6
32. Ability to promote and initiate organizational values	59.2	32	33	59.8
33. Ability to stimulate employees to develop their creativity	59.2	33	29	60.5
34. Emotional and social intelligence	59.2	34	18	67.8
35. Understanding and acceptance of the differences in national cultures	58.6	35	34	59.7
36. Predictive abilities	58.3	36	37	57.6
37. Seeing change as an ally	58.2	37	36	58.5
38. Ability to communicate when planning and implementing change	57.8	38	27	63.0
39. Ability to select and implement an anti-crisis strategy	55.9	39	39	48.9
40. Strong focus on organizational renewal	52.4	40	41	47.7
41. Intuitive abilities	50.2	41	40	48.5
42. Defensive posture	45.8	42	42	46.2

*(100%= maximum importance of competence).

Source: own study.

3.2. Expert panel

The results of the study were presented to 11 top managers of Polish organizations at level 5 of process and project maturity who were interested in them and wanted to participate further. These managers were referred to as experts. Next, a discussion of these results was held within the expert panel. During the discussion, the experts exchanged views and shared their own experiences regarding the most important role that top managers must play and the competencies that are crucial for the effective management of a process and project organization and for the implementation of reactive and proactive strategies.

During the discussion, the authors of the publication asked the experts for their opinion on the results of the study. All experts agreed that the top manager of a process and project organization should act as an ambidextrous leader. However, with regard to the assessment of competencies, the experts stated that their importance will change, depending, among other things, on the size of the organization, the subject and specificity of its activities, and its process and project maturity. The impact of internationalization was also noted – in view of the growing international activity of process and project organizations, competencies related to managing employee diversity will become increasingly important, although the current assessment results do not indicate their significant importance. Experts also noted that strong technological progress (especially the development of artificial intelligence, automation, and digital tools) will increase the importance of competencies related to perceiving change as an opportunity, which were not considered significant in the research. However, according to the experts, the importance of

readiness to test and understand new technological solutions will continue to grow, whereby the point is not that top managers should have specialized competencies in this area, but that they should be able to interpret the results of their use. In addition, experts pointed out that projects are often carried out by hybrid, dispersed teams (working on-site and remotely from different locations). In such cases, knowledge of telecommunications technologies will become increasingly important for collaboration with a dispersed team (e.g., through platforms such as Microsoft Teams, Notion, or Jira). Soft skills related to emotional and social intelligence, motivating and building trust in hybrid teams, as well as the ability to resolve conflicts, especially between process and project teams, will also become important. In this context, the authors of the publication also asked about the relatively low rating of the importance of the role of democrat and the competencies associated with it. The experts agreed with this assessment, stating that in practice, process and project organizations tend to use a situational approach, tailored primarily to the importance of the process or project for the organization, the conditions for their implementation, and the competencies of the employees. They emphasized that their leadership is usually based on delegating the role of process manager (process owner) or project manager (project manager) to competent employees, assuming the possibility of supporting them, co-deciding, and sharing responsibility. The ability to apply a democratic management style is therefore important (as confirmed by the results of the assessment of this competence), but it is not crucial for the effective management of a process and project organization and the implementation of reactive and proactive strategies. Similar comments were made about the other competencies related to the role of a democrat. Views were also exchanged on the competencies rated lowest by respondents. In their case, according to experts, the importance of skills related to renewal and resilience building will grow, as modern process and project organizations operate in conditions of rapid change and an uncertain environment, which implies many threats.

To summarize this part of the study, following the expert panel discussion, it was agreed that the professional profile of a top manager in a process and project organization can be described as that of an ambidextrous leader who should possess the indicated competencies, but their importance is arbitrary and may change.

3.3. Literature review

A literature review was conducted to verify the research results. As mentioned earlier, no considerations regarding the role and competencies of a process and project organization manager have been presented to date. However, there are many considerations about leadership in ambidextrous organizations that have been conducted as part of other research trends, relating, among other things, to how these organizations achieve a balance between exploration and exploitation – that is, how to achieve ambidexterity and how to manage contradictions.

In the research trend related to ways of achieving ambidexterity, contemporary considerations focus, among other things, on three complementary approaches: structural, contextual, and leadership (Zakrzewska-Bielawska, 2016).

In discussions concerning structural ambidexterity, it is assumed that it is necessary to create separate structures and units for exploratory and exploitative activities, which must be linked at the top management level. Its role is therefore to integrate them strategically, which requires it to build a common set of cultural values, a shared vision, and an overarching management process (O'Reilly, Tushman, 2004, 2008; Jansen et al., 2009). Contextual ambidexterity, on the other hand, assumes the simultaneity of exploratory and exploitative activities at the individual level and refers to an individual's behavioral ability to perform them simultaneously (Raisch, Birkinshaw, 2008). Top managers should reconcile the conflicting requirements of these activities by building an organizational context of defined by a combination of hard elements (discipline and scope of tasks) and soft elements (support and trust), which is intended to encourage employees to make their own decisions on how to divide their time between exploitation and exploration (Gibson, Birkinshaw, 2004; Miron et al., 2004; Carmeli, Halevi, 2009). Both structural and contextual ambidexterity emphasize the inherent importance of ambidextrous leadership. Leadership ambidexterity emphasizes the particular importance of top management in making decisions about exploration and exploitation in order to achieve short-term and long-term goals in the future, as well as reconciling their strategic contradictions, related conflicts, and problems (Lubatkin et al., 2006; Raisch, Birkinshaw, 2008; Cao et al., 2010; Keller, Weibler, 2015). Considerations related to ways of achieving ambidexterity can be linked to the following competencies identified by respondents, which include:

- ability to promote and initiate organizational values,
- ability to create an organizational culture that emphasizes the functioning of market mechanisms within the organization,
- ability to select and modify business models appropriate for the exploitative and exploratory layers,
- ability to see through the interests of the entire organization, rather than focusing on individual processes and projects,
- the ability to see processes and projects holistically,
- decision-making abilities,
- predictive abilities,
- forecasting skills,
- ability to solve large-scale problems,
- intellectual abilities,
- perceptive abilities.

In another line of research related to the ability to manage contradictions, studies were conducted in contexts such as: 1) innovation, 2) organizational learning and related knowledge, 3) organizational adaptation, 4) strategic management, 5) diversity management in the paradoxes of exploitation and exploration.

Re 1) There are many research results conducted in the context of radical and incremental innovation implementation, related exploration and exploitation (e.g., Smith, Tushman, 2005; Atuahene-Gima, 2005; Cantarello et al., 2012), as well as the importance of ambidextrous leadership (e.g., Rosing et al., 2010, 2011; Zacher, Wilden, 2014; Zacher, Rosing, 2015; Zacher et al., 2016; Rosing, Zacher, 2017, 2023). In this context, it is assumed that top managers must be strongly committed to both open and closed behaviors in order to encourage their employees to explore and exploit. Exploration involves trying new things, experimenting, and seeking innovative solutions, so top managers should not only be creative and intuitive themselves, but also strongly inspire and motivate employees to think and act creatively. Exploitation, on the other hand, involves relying on well-learned actions or following established procedures, so leadership behavior in this area should be well organized and focused on supporting employees not only in maintaining but also in increasing efficiency and productivity through incremental changes. Taking these considerations into account, it can be assumed that they are quite consistent with the competencies indicated by the respondents, which include:

- ability to leverage the executive and intellectual potential of all process and project teams,
- creativity, broad-mindedness,
- intuitive abilities,
- the ability to stimulate employees to develop their creativity,
- organizational abilities,
- motivational abilities.

In addition, in discussions on dual leadership in the context of innovation, the aspect of behavioral flexibility was also emphasized – the adaptation of a manager's behavior to situational requirements (Rosing et al., 2018). These considerations can be related to the competencies indicated by the respondents, which include:

- ability to deal with changing conditions,
- ability to create conditions in the organization to accept the effects of changes in the environment.

In other considerations, also in terms of innovation, it was stated that ambidextrous leadership should not consist of the top manager's own involvement in the exploratory and exploitative behaviors of employees, but should focus on "behavioral integration" (Lubatkin et al., 2006). Empirical evidence has been found for the impact of this integration on both exploitation and exploration, depending on the level of cooperation between the top manager and the team – their communication skills, as well as the use of a participatory approach to management and an emphasis on joint decision-making. It can be assumed that this is quite consistent with the competencies indicated by the respondents, which include:

- the ability to communicate when planning and implementing change,
- communication skills, including a good knowledge of at least one foreign language,
- good knowledge of new telecommunications technologies,

- emotional and social intelligence,
- ability to use a democratic leadership style.

Re 2) Many scientific research results have been published on learning processes and related knowledge in ambidextrous organizations. Initially, it was believed (March, 1991) that exploration and exploitation were related to different types of learning that were essentially incompatible, but later studies often conceptualized exploitation and exploration as orthogonal variables that, with proper management, could be achieved simultaneously (e.g., Baum et al., 2000; Katila, Ahuja, 2002; Auh, Menguc, 2005). The results of many studies indicate a close relationship between learning processes and related knowledge with the effective implementation of simultaneous exploration and exploitation (Zakrzewska-Bielawska, 2016). Some of them relate this to leadership, emphasizing that the behavior of top managers influences the level of exploration and exploitation by engaging in and promoting top-down and horizontal or bottom-up knowledge flows (Mom et al., 2007). Top-down knowledge flows from top managers are positively associated with exploitation. Conversely, horizontal and bottom-up knowledge flows from employees at the same or lower levels of the hierarchy are positively associated with exploration. Furthermore, it is emphasized that in order to achieve a balance between exploration and exploitation, top managers should be able to leverage existing, well-developed employee competencies and create conditions for acquiring new ones (Cao et al., 2009). These considerations can be linked to the competencies indicated by the respondents, which include:

- supporting knowledge sharing and learning processes,
- ability to acquire, create, and use knowledge.
- ability to create an environment conducive to expanding employees' competencies and generating initiatives by them,
- ability to implement a "market of employee competencies",
- openness to new things and willingness to learn them.

Re 3) With regard to organizational adaptation, it is emphasized that long-term success requires balancing the need to implement change with the need to maintain daily activities – their continuity (Huy, 2002; Meyer, Stensaker, 2006). Too many radical changes can cause organizational chaos and even crisis if continuity is not taken into account, while the opposite situation can lead to inertia, which in the long run can also lead to crisis. Therefore, an important characteristic of top managers is maintaining continuity and implementing change with the involvement of employees. It is also important to be able to skilfully overcome crises that may arise. These considerations can be related to the competencies indicated by the respondents, which include:

- seeing change as an ally,
- ability to stimulate employees to participate in change,
- ability to build trust and overcome resistance to change,

- ability to select and implement an anti-crisis strategy,
- strong focus on organizational renewal,
- defensive posture.

Re 4). In the area of strategic management, research was conducted in the context of induced and autonomous processes. Induced processes refer to initiatives that fall within the scope of the organization's current strategy and are related to exploitation, while autonomous processes refer to initiatives that fall outside the scope of the current strategy and are related to exploration (Burgelman, 2002). The task of top managers is to ensure that they are balanced, which can be related to the competencies indicated by the respondents, which include:

- focus on the effective and efficient implementation of exploitation processes and reactive projects, as well as exploratory processes and proactive projects,
- strivi to achieve balance in the execution processes and reactive projects, as well as exploration processes and proactive projects.
- the ability to control the results of the work of process and project teams.

Re. 5) With regard to diversity management, the importance of top managers in creating an environment in which employees who differ in terms of gender, skin color, national origin, or education, among other things, feel respected and appreciated, and thus use their potential for the organization, is emphasized. The task of top managers is therefore to develop strategies, policies, and programs that create a climate of respect and leverage this diversity for the benefit of the organization (Gruszczyńska-Malec, Waligóra, 2008). These considerations are quite consistent with the competencies, which include:

- the ability to create a friendly organizational environment for achieving good work results,
- curiosity about people, including those who differ in culture and views,
- understanding and acceptance of different national cultures,
- the ability to notice and retain highly talented people in the organization, regardless of their nationality,
- ability to manage teams, including virtual ones.

To sum up this stage of the research, after reviewing the literature on the subject, it was concluded that the results obtained in the course of interviews and expert panels concerning the professional profile of a top manager of a proces and project organizationare quite consistent with the considerations on leadership in ambidextrous organizations, which were conducted as part of research trends relating to how these organizations achieve a balance between exploration and exploitation and how they manage contradictions.

Summary

The article presents the results of research aimed at defining the professional profile of a top manager in a process-project organization. These results were obtained after conducting three stages of research.

Based on the first stage, which involved conducting interviews with 204 Polish and foreign managers of organizations at the 3rd, 4th, and 5th levels of process and project maturity, it was assumed that the top manager of such organizations should primarily play the role of an ambidextrous leader, characterized by 42 competencies, among which the most important are:

- ability to select and modify business models appropriate for the exploitation and exploration layers,
- focus on the effective and efficient implementation of operational processes and reactive projects, as well as exploration processes and proactive projects,
- intellectual abilities,
- ability to see processes and projects holistically,
- strive to achieve balance in the execution of processes and projects,
- decision-making abilities,
- ability to solve large-scale problems.

The second stage of the research, involving an expert panel of 11 managers from organizations at level 5 of process and project maturity, allows us to conclude that the professional profile of a top manager in a process and project organization can be described as that of an ambidextrous leader, who should be characterized by the 42 competencies indicated, but their importance is arbitrary and may vary depending on the size of the organization, the subject and specificity of its activities, or process and project maturity, as well as the level of internationalization, technological progress, forms of work organization, the pace of change, and the uncertainty of the environment.

In the third stage of the research, after reviewing the literature on the subject, it was found that the results obtained in the course of interviews and expert panels concerning the professional profile of a top manager of a process-oriented organization are quite consistent with the considerations on leadership in ambidextrous organizations, which were conducted as part of other research trends relating to how these organizations achieve a balance between exploration and exploitation and how they manage contradictions.

The presented research is only part of the considerations concerning the management of contemporary process and project organizations. It contributes knowledge that fills an existing cognitive gap in this field and may be significant for both science and management practice. For researchers, the publication may serve as a basis for further research on process and project organizations, while for practitioners, it may be useful in the context of management issues in today's dynamic and uncertain environment.

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ON THE ISSUE OF PERIODIC TESTING THE COMPETENCE OF FORENSIC EXPERTS

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Purpose: The purpose of this article is to draw attention to the important role of periodic testing of the competence of court experts in the context of quality management of court expert opinions in the justice system. The introduction of this type of testing requires answers to a number of questions. Who should conduct this type of competency testing? What should be its subject matter? Should it be mandatory? What consequences should it entail?

Design/methodology/approach: The article employs the method of in-depth literature studies, the document analysis method and the synthesis method.

Findings: Current legal regulations in Poland do not prohibit periodic testing of the competence of court experts. In practice, however, such tests are not carried out. This has negative consequences for the justice system, as experts are not subject to any quality control of their expert opinions beyond the assessment of their opinions in a specific case by the trial authority. In the future, such testing should be conducted by a state institution. In this way, court experts could learn from their mistakes, and decision-makers could select experts for specific court cases who want to improve their qualifications and are not afraid to have their competence tested.

Research limitations/implications: A significant limitation is the lack of publicly available information on periodic competency tests carried out in state forensic laboratories.

Practical implications: The introduction of periodic competency testing for court experts in Poland would allow experts to learn from their mistakes, thereby reducing the number of erroneous conclusions in their reports.

Social implications: The introduction of periodic testing of the competence of court experts in Poland would allow judicial authorities to select experts who make fewer mistakes. This would increase public confidence in the justice system in Poland.

Originality/value: Introduction to the scientific discourse of a broad approach to the issue of periodic testing of the competence of court experts within the Polish justice system. This article is addressed to entities managing quality control within the justice system.

Keywords: court experts, periodic competence assessment testing, quality management of court expert reports.

Category of the paper: Research paper.

1. Introduction

Polish literature on the subject, as well as government reports, mention competency tests for court experts. Such testing is considered an important element of quality management in court expertise. However, the role of testing the competence of experts in the decision-making process by the relevant authority (in Poland, this is currently the president of one of the district courts) regarding entry on the list of court experts is emphasized above all. Less attention is paid to the periodic testing of the competence of court experts, i.e., the testing of the competence of persons who have already been entered on the list of court experts. While this type of testing takes place in Poland in the case of public forensic institutions, such as the Institute of Forensic Expertise in Krakow or the Central Forensic Laboratory of the Police Headquarters in Warsaw (although the results of such tests usually do not go beyond the institution), thousands of experts operating in Poland as court experts do not participate in any periodic competency tests. It is worth emphasizing this problem, especially in the context of the ongoing debate on the shape of the law on experts, which is intended to comprehensively regulate the situation of court experts in Poland.

In the context of introducing periodic competency tests for court experts who work outside state opinion-giving institutions in Poland, many questions arise that cannot be answered in the literature on the subject. Therefore, the first objective of this study is to formulate the questions that need to be answered when introducing periodic proficiency tests for court experts in Poland. The second objective is to attempt to answer the questions posed. Sometimes this requires formulating alternative answers with examples of the positive and negative consequences of introducing a particular option. In the context of the issue at hand, it is particularly important to answer the following questions:

- What components are included in the competence of an **court** expert? Which of them should be subject to periodic testing?
- Which entity should conduct periodic testing of the competence of court experts?
- Should such tests be mandatory or optional? Paid or free of charge?
- What benefits can the introduction of periodic testing of court experts bring and to whom?

2. Research methodology

In order to answer the research questions, archival data analysis was used, taking into account reports from Polish and foreign public institutions. In particular, reports from the field of quality management of forensic expertise were used. These reports diagnose current

problems and formulate proposals for the future aimed at reducing the margin of error in expert opinions in specific areas of forensic science. Subsequently, a dogmatic method was used to determine the admissibility of periodic testing of the competence of court experts in the light of the law currently in force in Poland. Today, various aspects of the functioning of court experts are covered by many legal acts. At the same time, work is underway on a law on court experts, which would be a legal act comprehensively regulating the legal situation of court experts. On the basis of the published assumptions of the draft law, an attempt was made to determine whether the new law would bring new elements in the context of the issues raised. Next, an in-depth review of the literature on the subject was conducted. The elements that constitute the competences of court experts were identified. Those that play a special role in the context of periodic testing of the competences of court experts were highlighted. Finally, information was collected to justify the answers to the research questions.

3. Results

The classic model of competence distinguishes three basic elements: knowledge, skills, and attitudes (Czapla, 2016). Knowledge is a structured set of information, combined with rules for interpreting it. Skills are related to effective action in the context of achieving a set goal. Attitudes are related, among other things, to the motivation to take specific actions. When testing the competencies of court experts, it is possible to test, in particular, elements of knowledge and skills. In the case of the optional model of periodic competency testing, participation in such testing is a feature of attitude. Similarly, participation in thematic training courses or scientific conferences is not enforced by legal regulations or organizational requirements.

In Polish criminal proceedings (the same applies to civil proceedings), an expert witness plays a subservient role to the decision-maker in the proceedings. Using specialist knowledge (defined as knowledge not available to the average educated person), they interpret facts that are important for the resolution of the case. The scope and subject matter of the examination is determined by the procedural authority (the prosecutor in preparatory proceedings or the court in court proceedings). The procedural authority is also responsible for evaluating the expert's opinion. The preparation of an opinion by a court expert usually involves many stages, among which the following are most commonly distinguished (Widła, 2017; Leśniak, 2012, pp. 349, 350; Achrem, Sołtyszewski, 2022, pp. 32-33):

- Identification of the problem by the expert. The scope of the examination is indicated by the procedural decision-maker by formulating questions to the expert. The expert should be able to transform the questions of the procedural authority into questions formulated on the basis of his discipline. Only then can the expert determine whether

they can answer the questions of the procedural decision-maker. In particular: Do they have the relevant knowledge or skills? Do they have access to the appropriate research methods? Is it even possible to answer the questions of the procedural authority in light of the research capabilities of the specific field? There are situations when the trial authorities formulate questions that experts cannot answer due to applicable legal regulations (Szmit, 2024).

- Collecting research material. In the case of forensic identification tests, this may concern both the material in question and the comparative material. In the case of the work of a forensic psychiatrist or psychologist, on the other hand, it is usually a matter of gathering information from a large collection of various sources.
- Conducting research on the collected material using appropriate research methods. Analysis of research results.
- Interpretation of the research results obtained. Formulation of conclusions.
- Preparing a research report (usually in writing). Information about the chosen research method and its margin of error. If a less common method is chosen or the dominant method is not chosen, the expert should also include a description of the method and a detailed justification for its selection. A report on the research activities undertaken and their results.
- Presentation of the opinion before the court. This stage also includes: citing the most important arguments for their conclusions, answering questions from the decision-maker, and responding to the opinions of other experts.

The question arises: which of these stages should the competence check cover? In this context, it should be remembered that the expert does not always carry out all of the above stages himself. He often relies on information gathered by other entities, in particular information obtained by the prosecutor, the police, and officers of other services. Traces for comparative testing are secured at the scene of the incident by forensic technicians (police officers); the location of the traces at the scene of the incident is described in a report prepared by the prosecutor. However, there are also areas of expertise, such as polygraph testing, where the same expert performs all of the above activities.

In Poland, legal regulations concerning expert opinions are contained in many different legal acts. These provisions are contained in particular in: the Code of Criminal Proceedings, the Code of Civil Proceedings, the Code of Administrative Proceedings, the Act on the Common Courts System and the Ordinance of the Minister of Justice on court experts (Skubisz-Ślusarczyk, 2021). A distinction should be made between being a court expert as a person entered on the list of court experts and the procedural role of an expert in specific proceedings (e.g., a criminal or civil proceeding). In Poland, a separate list of court experts is maintained by the president of each of the 47 district courts. According to Polish law (the Ordinance of the Minister of Justice), a person may be included in the list of experts if they “have theoretical and practical specialist knowledge in a given branch of science, technology, art, craft, or other skill

for which they are to be appointed” and “guarantee the proper performance of their duties as an expert”. The expert’s “special knowledge” is verified by the president of the district court; the expert should demonstrate their relevant qualifications with “documents and other evidence”. The procedural role in a specific proceeding is determined by the procedural authority, which usually first considers selecting an expert for the case from among the persons entered on the list of court experts, but may select a person who is not on the list of experts as an expert for a specific case too. The content of reports on the functioning of experts in Poland prepared by the Supreme Audit Office (Najwyższa Izba Kontroli) and the Helsinki Foundation for Human Rights (Helsińska Fundacja Praw Człowieka) indicates that district court presidents do not have the appropriate tools to properly verify the competence of court experts, and that persons who do not have the appropriate qualifications often end up on the list of court experts (and, consequently, as experts for specific cases). Literature in the field of forensic science similarly gives a negative assessment of the model currently in use in Poland for verifying the competence of candidates for court experts and describes examples of opinions prepared for court cases by persons without the appropriate qualifications (Tomaszewski, 2024B; Gruza, 2023; Karsek, Rybicki, 2016). The legal regulations currently in force in Poland do not refer at all to the periodic testing of the competence of court experts already entered on the lists kept by the presidents of regional courts. The authors of the above-mentioned reports also focus on verifying the competence of experts when they are entered on the list of court experts and ignore the importance of periodic testing of qualifications. Within the literature on the subject, few publications emphasize the importance of introducing periodic testing of court experts (Leśniak, 2012, pp. 263-267, 349; Gruza, 2023). The situation is different in the case of state forensic laboratories; in accordance with the requirements of the PN-EN ISO/IEC 17011:2006 standard, they participate in periodic competence tests and in this way, among other things, demonstrate their competence to the accreditation body (Gruza, 2023). In summary, the regulations in force in Poland do not prohibit the periodic testing of the competence of court experts. At the same time, these regulations do not provide for such tests and do not contain guidelines as to who, and how such tests could be conducted.

In Poland, numerous attempts have been made to comprehensively regulate the legal status of court experts in a single legislative act (Tomaszewski, 2024A). Despite the preparation and consultation of many drafts of such a law, none of them has even been submitted to the Polish parliament to date. The most recent attempt to prepare a law on experts was made in December 2023, when the Minister of Justice appointed his representative for court experts, whose tasks include, among others: developing proposals and coordinating work on the status and activities of court experts, monitoring and analyzing the needs of court experts, as well as preparing preliminary assumptions for a law on experts. The representative was assisted by a working group appointed to develop the assumptions for the law, and the prepared assumptions were published in July 2024. These assumptions do not change the legal status of court experts. They indicate that the function of court experts should be performed by persons who have

sufficiently high competences in various fields of science or knowledge and who can use these competences for the purposes of the administration of justice. The new law on experts is intended to introduce certification of court experts and forensic institutions. In specific cases, the procedural authorities should primarily use certified court experts, and only in exceptional cases (e.g., the lack of a certified expert in a specific field) may they use court experts without certification. The representative and his team considered a model similar to the Dutch model (Dutch register of Court Experts – NRGD) to be the “most effective and objective” model for verifying the competence of experts. This model involves the establishment of a Certification Council, composed of members appointed by the Minister of Justice (judges, prosecutors, representatives of expert communities and public institutions that prepare court expert opinions). The main task of the Council would be to manage the certification process for court experts and opinion-giving institutions, including supervising the process of verifying the competence of candidates for experts (in particular by preparing verification criteria and considering appeals against the decisions of the Assessment Teams). Under the discussed assumptions, a single central list of certified court experts (maintained by the Ministry of Justice) would replace the 47 lists maintained by the presidents of individual district courts. When analyzing the assumptions of the draft law on court experts, it should be noted that these assumptions do not provide for the introduction of periodic testing of the competence of experts who receive the appropriate certificate and are entered on the central list. However, a public entity (Certification Council) would be established, which could also appoint teams to periodically test the competence of court experts and supervise the testing process itself. From a legal point of view, this would only require a minor editorial amendment (for example, the introduction of an appropriate subparagraph when defining the powers of the Council). In the discussed draft of the act, the certification process is a paid process, and after the introduction of the above-suggested changes, periodic testing of experts' competences would probably also be a paid process

4. Discussion

Assuming that periodic testing of court experts' competence may primarily concern knowledge and skills, the subject matter of such testing should be specified in more detail. Two approaches are possible (President's Council of Advisors on Science and Technology). The first focuses on the accuracy of the expert's final conclusions; under this approach, the body administering the tests obtains information on the margin of error in expert opinions in a given field. The second approach pays more attention to how experts arrive at their conclusions, what methods they use, and how they apply them in solving the problem identified by the procedural body. This approach prolongs the analysis of the results of expert tests, but provides

experts with more valuable feedback (on how they apply their methods). The second approach also gives those managing the justice system more information about the errors made by experts and the circumstances conducive to making errors. There is no problem in combining the first and second approaches. All the more so because even experienced experts make many methodological errors (Konieczny, p. 61), for example: they only use the methods they learned during their first training (ignoring others), they use certain methods incorrectly, they use their own methods (based solely on personal experience) of unknown accuracy. In every field of forensic expertise, there is a subjective element to the assessments made by experts (Moszczyński, 2011) – as in every area of human decision-making. The cases submitted to experts as part of proficiency tests and the scope of the questions asked must not differ in difficulty from the cases most commonly encountered in a given area of expertise (i.e., they must not be too simple or extremely difficult). The testing conditions must be standardized, i.e., presented in the same way to all experts participating in the testing. This often limits the scope of testing (depending on the nature of the objects examined by the experts), for example, due to the need to send copies of the objects to be examined (for example, a larger number of test participants does not allow the same original object to be sent to them in turn – if several dozen experts were to examine the same original manuscript, testing their proficiency would take many months) or the susceptibility of the original objects to changes as a result of subsequent examinations. Proficiency testing may apply to each of the stages of assessment mentioned above: identifying the problem, collecting material for examination, conducting examinations using appropriate methods, interpreting the results of the examinations, formulating conclusions, preparing an examination report, and defending the conclusions of the opinion in court. In a specific periodic examination of the competence of court experts, the procedural authority will probably select some of the elements described, most often focusing on the methodology of conducting the research itself and the accuracy of the conclusions. Testing competence in presenting opinions in court would require the entity conducting the test to faithfully recreate the conditions of a courtroom and involve lawyers in the roles of judges, public prosecutors, or attorneys for the parties.

Another issue concerns the selection of an entity that would organize periodic proficiency tests. In some countries, these are private entities or scientific associations in the field of forensic science (Leśniak, 2012; Gruza, 2023). In Poland, however, the solution should be to assign such competences exclusively to a state institution. At present, there are no legal obstacles to a private institution certifying experts in a specific field of forensic science or conducting periodic proficiency tests. It does not need to have any formal powers. Any person or group of persons, regardless of their competence, can create such an entity. The literature describes an example of an institution called the Supreme Council of Handwriting Experts (Tomaszewski, 2021). In reality, it is a commercial law company run by two people (a married couple), advertising its training courses as “comprehensive preparation for the profession of graphologist and the role of expert handwriting expert”. The company emphasizes that “every

year, its supervisory department evaluates experts and members of the NRP”, but in Tomaszewski's opinion, the people who give opinions on behalf of this private institution have low competence. In the case of associations of experts (even those bringing together experienced court experts), the question may always arise (especially in fields where there are more associations) as to why these associations should conduct proficiency tests on people from other associations or those who are not members. In order to rule out this type of situation, and taking into account the work described on the new draft law on court experts, the optimal solution would be to grant the appropriate powers to the Certification Council. This commission could develop periodic proficiency tests in specific areas of expertise, as well as appoint appropriate persons to the assessment teams and supervise the testing process itself.

The proposed granting of powers to periodically test the competence of certified court experts involves determining whether such tests should be mandatory or optional. There are significant arguments in favor of the latter solution. The central list of court experts will include persons who have already passed the relevant competency tests and obtained a certificate. Therefore, assuming that the qualifications of experts are reliably verified in the process of obtaining a certificate, there is no reason to impose an additional obligation on experts. Such tests could, for example, be conducted on an optional basis each year (with different types of cases) and experts with high aspirations (wishing to test or improve their skills) could participate in them at their discretion. Since the certification process itself is proposed to be fee-based, periodic competency testing should also be fee-based. Participation itself should be treated as a sign of motivation to provide “better” opinions and should be taken into account by the procedural authorities when selecting a court expert in a specific case.

5. Summary

Periodic testing of the competence of court experts can bring significant benefits to many entities: trial decision-makers (in particular judges and prosecutors), trial representatives of the litigants, decision-makers in the area of justice management (and thus also in the area of quality management of court expert opinions in general), the experts themselves. For procedural decision-makers, the results of the competence assessment should be relevant in the context of selecting an expert. Procedural authorities should select experts who simply perform better in competence tests (the conclusions of their opinions have a smaller margin of error) or who are not afraid to undergo periodic competence tests (in cases where such tests are not mandatory). For the parties to the proceedings (or their professional representatives), the issue of an expert witness's participation in competency tests provides arguments (they may ask the court: why is the expert witness not participating in periodic competency tests?). Decision-makers in the justice system management process could obtain information on: areas of expert opinions

with a higher number of errors, factors contributing to errors made by court experts, and types of errors made by experts. Such a diagnosis in the future (provided that the relevant actions are ordered and financed by those governing the justice system in Poland) could in the future result in fewer judicial errors in Poland, and thus reduce the amount of compensation paid by the State Treasury, as well as increase the level of trust in the justice system among the public. The court experts themselves would finally have the opportunity to learn from their mistakes and deepen their expertise. If decision-makers preferred experts who underwent periodic testing, the experts themselves would perform a greater number of expert opinions, thereby more than compensating for the cost of the fees charged for such tests.

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