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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 26 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: leadership; quality management; finances; environmental management; innovativeness; product management; artificial intelligence in management; public management; smart city; business process; entrepreneurship; sustainability; Education 5.0; supply chain management and production management.

*Bożena Skotnicka-Zasadzień
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THE PERCEIVED SUPERVISOR LEADERSHIP STYLE QUESTIONNAIRE (PSLSQ): CONSTRUCTION AND PSYCHOMETRIC VALIDATION

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Purpose: The purpose of this paper is to develop and psychometrically validate the Perceived Supervisor Leadership Style Questionnaire (PSLSQ), designed to measure employees' perceptions of their direct supervisor's leadership behaviors.

Design/methodology/approach: The study applied a multi-stage psychometric validation procedure grounded in leadership and job characteristics theories. After item development, expert review, and assessment of content validity using Lawshe's method, pilot testing was conducted. Next, the internal structure of the questionnaire was examined using exploratory factor analysis, followed by confirmatory factor analysis to verify the proposed model. Model fit was evaluated using standard fit indices. Reliability was assessed with Cronbach's alpha and test-retest analysis, and theoretical validity was examined via correlations with job characteristics, supervisor support, job satisfaction, and Big Five traits.

Findings: The validation results confirm that the PSLSQ can be successfully used to measure four dimensions of perceived supervisor leadership: friendliness, autonomy, feedback, and justice. The scale showed high reliability and strong test-retest stability. Convergent validity was supported by correlations with supervisor support, job satisfaction, and job characteristics, discriminant validity was largely confirmed.

Research limitations/implications: The study relies exclusively on self-report measures, which may introduce common method bias. Future research should explore longitudinal effects of perceived leadership style on employee outcomes.

Practical implications: The PSLSQ provides organizations with a reliable diagnostic tool for assessing employees' perceptions of supervisory behaviors. It may be used in leadership development programs, organizational climate assessments, and performance management systems. The questionnaire allows organizations to identify strengths and weaknesses in managerial behaviors and implement targeted interventions to enhance feedback quality, fairness practices, relational leadership, and autonomy support.

Social implications: By promoting relational and fairness-based leadership, the tool supports more ethical and employee-centered management. Strengthening friendliness, autonomy, feedback, and justice may enhance well-being, psychological safety, trust, and overall quality of working life.

Originality/value: The paper presents an original Polish measure of perceived supervisor leadership from the employee's perspective. Unlike self-report leadership tools, it focuses on employees' subjective perceptions. The study offers comprehensive psychometric validation and integrates relational and structural aspects of leadership into a unified four-factor model.

Keywords: Perceived leadership style; Supervisor behavior; Leadership measurement; Psychometric validation.

Category of the paper: Research paper.

1. Introduction

Leadership style has been widely studied in the fields of organizational psychology and management, as it plays a crucial role in shaping employee motivation, job satisfaction, and organizational effectiveness (Bass, 2000; Avolio, Bass, 1991; Hackman, Oldham, 1980). Numerous studies indicate that the quality of the relationship between supervisors and employees significantly influences work engagement, psychological well-being, and performance outcomes.

Despite the extensive literature on leadership, many existing measurement tools rely primarily on self-reports completed by leaders, rather than on employees' perceptions of managerial behavior. However, research suggests that employees' subjective perceptions of leadership behaviors may be particularly important because they directly shape attitudes toward work and the organization.

Contemporary research on organizational functioning emphasizes the importance of the quality of supervisor-employee relationships for employee well-being, motivation, and performance. Particular attention is paid to leadership style, which can be analyzed through dimensions such as friendliness, autonomy, feedback, and justice. These dimensions reflect both the relational aspect of leadership and its structural-organizational component. At the same time, an increasing number of organizations are shifting focus toward employees, providing opportunities for bottom-up initiatives proposed by staff. Therefore, discussions of leadership styles cannot omit how managerial actions are perceived by employees. It should be noted that supervisors are not always aware of which aspects of work can be modified to meet employee needs. The author of this article developed a model of perceived leadership style based on four components: friendliness, autonomy, feedback, and justice with the aim of creating a tool aligned with contemporary theoretical approaches to perceived supervisor leadership and establishing its psychometric properties, including validity and reliability.

Although several leadership questionnaires exist, there is still a limited number of validated questionnaires designed specifically to measure employees' perceptions of their direct supervisor's leadership style, especially within the Polish organizational context. Moreover, many available tools focus mainly on transformational or transactional leadership, while fewer integrate both relational and structural aspects of managerial behavior. Therefore, the main aim of this study was to develop and psychometrically validate a new questionnaire - the Perceived Supervisor Leadership Style Questionnaire (PSLSQ) designed to measure employees' perceptions of their direct supervisor's leadership behaviors. The specific objectives of the

study were: to develop items describing key components of perceived supervisor leadership style, examine the internal structure of the questionnaire, assess the reliability and stability of the questionnaire, and evaluate its construct validity through relationships with selected organizational and personality variables. In this article, the term “questionnaire” is used consistently to refer to the Perceived Supervisor Leadership Style Questionnaire (PSLSQ). In some contexts it may also be described as a research “tool”, however these terms refer to the same measurement questionnaire.

Based on theoretical assumptions, the following hypotheses were formulated:

H1: The PSLSQ will demonstrate a four-factor structure corresponding to the components: friendliness, autonomy, feedback, and justice.

H2: The PSLSQ will demonstrate high internal consistency and stability over time.

H3: The PSLSQ dimensions will show positive correlations with theoretically related constructs, such as supervisor support, job satisfaction, and selected job characteristics (convergent validity).

H4: The PSLSQ dimensions will show low or non-significant correlations with unrelated personality traits, confirming discriminant validity.

The remainder of the article is organized as follows. The next section presents the conceptual framework of perceived supervisor leadership and the operationalization of the construct. The subsequent sections describe the methodology and results of the multi-stage validation process, including exploratory and confirmatory factor analyses, reliability assessment, and validity testing. The article concludes with a discussion of the results, limitations of the study, and directions for future research.

2. Conceptualization and Operationalization of the Perceived Supervisor Leadership Style Construct

The development of the Perceived Supervisor Leadership Style Questionnaire (PSLSQ) was conducted in accordance with methodological guidelines for psychological test construction described in the relevant literature (Brzeziński, 1985, 2000, 2004; Hornowska, 2001; Shaughnessy, Zechmeister, Zechmeister, 2002). First, a theoretical definition was established, followed by item generation and statistical verification of the questionnaire. Based on the results, the final test items were selected for inclusion in the questionnaire. The next step involved examining theoretical and criterion validity.

In constructing the tool, it was necessary to adopt a theoretical framework for supervisor leadership style. Based on the literature review, four components of perceived supervisor leadership were identified, drawing on: the Situational Leadership Theory by Paul Hersey and Ken Blanchard (1969), the Job Characteristics Model by Richard Hackman and Greg Oldham

(1980), and the Full Range Leadership Model (Avolio, Bass, 1991; Bass, 2000). The following behavioral components of supervisors were formulated: friendliness, autonomy, feedback, and justice.

These components are described in detail below:

- friendliness - the supervisor listens, provides psychological support, and evokes positive emotions. They approach employees with empathy, strive to create a positive work atmosphere, maintain good relationships with colleagues, take time to listen, and show genuine interest in the employee and their role within the organization.
- autonomy - the degree of independence an employee has in the workplace, allowing freedom in decision-making regarding task execution. The employee controls actions and outcomes within the scope of assigned tasks.
- feedback - the extent to which the supervisor provides direct and clear information regarding the quality, effectiveness, and perception of employee actions. It also refers to the consistency and frequency of feedback, with the supervisor clearly and objectively reporting on progress or goal attainment.
- justice - based on clear and equitable organizational rules regarding evaluation, compensation, recognition, and promotion of employees, which supervisors follow and enforce. Supervisors ensure that these rules are respected by employees and accepted by them, applying equality among staff.

Previous concepts focused on identifying and evaluating the supervisor's leadership style from their own perspective. The author of this article suggests analyzing supervisor behavior from the employee's perspective, as the employee's perception of managerial actions directly affects their performance and productivity at work. The above section provides a theoretical background and literature-based conceptual framework for the development of the PSLSQ questionnaire. It integrates selected concepts from leadership and job design research that guided the operationalization of the construct.

3. Procedure for constructing the Perceived Supervisor Leadership Style Questionnaire (PSLSQ)

3.1. Methodology

The development and validation of the Perceived Supervisor Leadership Style Questionnaire (PSLSQ) followed a multi-stage research procedure, commonly recommended in psychometric test construction. The research process consisted of four consecutive studies, each focusing on a different aspect of the questionnaire validation. The individual stages of the research procedure were designed to verify the hypotheses formulated in the introduction. In particular, Study 1 and Study 3 examined the factorial structure of the questionnaire (H1),

Study 2 assessed the temporal stability of the scale (H2), while Study 4 tested the construct validity of the questionnaire by examining its relationships with theoretically related and unrelated variables (H3 and H4).

Table 1.

Stages of the PSLSQ validation procedure

Stage	Objective	Sample size	Method
Study 1	Exploration of factor structure	N = 224	Exploratory Factor Analysis
Study 2	Assessment of temporal stability	N = 33	Test-retest reliability
Study 3	Verification of factor structure	N = 827	Confirmatory Factor Analysis
Study 4	Assessment of construct validity	N = 100	Correlation analysis

Source: own work.

The differences in sample sizes reflect the multi-stage validation design of the study. Different participant groups were used for exploratory factor analysis (Study 1), confirmatory factor analysis (Study 3), and validity testing (Study 4) to ensure independent verification of the questionnaire's psychometric properties. The following statistical procedures were applied: content validity assessment using Lawshe's method, exploratory factor analysis, confirmatory factor analysis, internal consistency reliability (Cronbach's alpha). Test-retest reliability, Pearson correlation analysis

This multi-stage procedure allowed for a comprehensive evaluation of the questionnaire's structure, reliability, and construct validity.

3.2. Exploration of the internal structure of the Perceived Supervisor Leadership Style Questionnaire (PSLSQ)

The development of the questionnaire for measuring perceived supervisor leadership style proceeded in several stages. In the first stage, an initial pool of 124 test items was generated, intended to represent behaviors a direct supervisor might exhibit, with 31 items for each leadership style factor. In the second stage, these items were reviewed for linguistic correctness (12 items modified) and content validity (25 items removed) by a panel of five competent judges (two faculty members and three PhD students). This evaluation resulted in a preliminary version of the questionnaire containing 94 items.

Next, content validity was assessed using Lawshe's method. Forty judges evaluated the items based on definitions of the four leadership styles. Following Lawshe (1975), judges rated each item on a 3-point scale: 1 – “essential for the test”, 2 – “useful but not essential”, 3 – “should not be included”. The content validity ratio (CVR) for each item was calculated as the difference between the number of judges rating it “1” and half of the total number of judges, divided by half the total number of judges. According to Lawshe's recommendations, items were eliminated if agreement could be attributed to chance or exceeded a 5% threshold. For 40 judges, the minimum CVR for statistical significance at $\alpha = 0.05$ was 0.29 (Lawshe, 1975; Hornowska, 2007).

The questionnaire was further validated by 23 competent judges (psychology students) to obtain Kendall's W coefficient for agreement. The mean content validity scores ranged from 2.96 to 4.96, with an overall mean of 4.32. Kendall's W was 0.238, $p < 0.001$ ($\chi^2 = 487.19$, $df = 93$). Based on CVR and Kendall's W, the items with the highest values were selected for the pilot version of the Perceived Supervisor Leadership Style Questionnaire, comprising 40 items: 10 per factor.

Theoretical validity of the new questionnaire was assessed using exploratory factor analysis (EFA) followed by confirmatory factor analysis (CFA). Factor analysis is a set of statistical methods aimed at estimating the covariation (correlations) among multiple variables to extract underlying factors. It helps explain observed relationships between variables, allowing interpretation of multiple measurements as manifestations of a smaller number of factors. Using exploratory factor analysis with a redundancy function allowed identification of correlated items measuring the same factor, while reducing the total number of items without losing information. Ultimately, items with the highest factor loadings were included in the final questionnaire (Ferguson, Takane, 1999; Kline, 2000).

Study 1. For factor analysis, a sample of 224 participants was collected (125 women, 99 men), aged 18-62 years ($M = 37.46$, $SD = 11.45$), including employees of public institutions (teachers, civil servants, nurses) and private companies (IT corporate employees, technical staff in mobile networks, security personnel).

Before conducting factor analysis, the suitability of the data for factor extraction was assessed. A correlation matrix of the variables was generated, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were calculated. Bartlett's test examines the null hypothesis that the correlation matrix is an identity matrix, which would indicate that the variables are unrelated and therefore unsuitable for factor analysis. The obtained results confirmed that the data were appropriate for factor analysis (Table 2).

Table 2.

Results of the Kaiser–Meyer–Olkin (KMO) Measure and Bartlett's Test of Sphericity Assessing the Suitability of the PSLSQ Item Correlation Matrix for Factor Analysis (Study 1, $N = 224$)

KMO Measure of Sampling Adequacy		0,96
Bartlett's Test of Sphericity	Approximate χ^2	10960,78
	df	780
	p	0,001

Note. df - degrees of freedom, p -value $< 0,001$.

Source: own work.

Bartlett's test of sphericity was statistically significant, indicating that the correlation matrix differed significantly from an identity matrix and that the variables were sufficiently correlated to justify factor analysis. The Kaiser-Meyer-Olkin (KMO) measure was also high at 0.96, indicating sampling adequacy. Data with KMO values above 0.8 are considered appropriate for

factor analysis (Kaiser, 1970). These results justified conducting principal component analysis. Factor loadings revealed the presence of four factors (Table 3): for the first factor (friendliness), loadings ranged from 0.77 to 0.89; for the second factor (autonomy), from 0.85 to 0.90; for the third factor (feedback), from 0.56 to 0.90; and for the fourth factor (justice), from 0.55 to 0.75.

Table 3.

Exploratory Factor Analysis Showing Factor Loadings of PSLSQ Items for an Four-Factor Solution (N= 224)

Item	Factor loadings				M	SD
	1	2	3	4		
1. Responds to employees' needs.	0,89*	0,08	-0,04	-0,02	3,78	1,48
2. Fosters a positive attitude among employees.	0,87*	-0,09	0,02	0,13	3,59	1,63
3. Listens to employees.	0,83*	0,02	0,07	0,10	3,79	1,60
4. Shows genuine interest in the employee and their role in the organization.	0,77*	0,18	0,04	0,02	3,60	1,65
5. Enables employees to plan their work independently.	-0,01	0,93*	-0,06	-0,07	4,42	1,59
6. Allows employees to organize their working time independently.	-0,05	0,90*	0,09	-0,10	4,32	1,56
7. Allows employees freedom to choose strategies for completing tasks.	-0,04	0,89*	0,04	0,07	3,99	1,49
8. Allows independence in how employees perform their work.	-0,01	0,85*	-0,08	0,09	4,29	1,46
9. Informs employees about the quality of task performance.	-0,06	0,03	0,90*	0,14	3,68	1,55
10. Provides information on progress toward goal achievement.	0,18	0,07	0,65*	0,15	3,61	1,60
11. Gives feedback that is clear and objective.	0,17	0,05	0,60*	0,26	3,37	1,57
12. Informs employees whether they meet expectations, about their results, and how they carry out their tasks.	0,17	0,19	0,56*	0,17	3,58	1,56
13. Expresses recognition in a fair manner.	0,02	0,07	0,17	0,75*	3,66	1,56
14. Adheres to established rules for rewarding and promoting employees.	0,19	0,11	0,13	0,66*	3,67	1,57
15. Evaluates employees' work effort justice.	0,18	0,11	0,28	0,57*	3,60	1,59
16. Bases task evaluation on reliable and transparent criteria.	0,20	0,18	0,17	0,55*	3,64	1,60

* Factor loading values for individual dimensions: friendliness, autonomy, feedback, justice. Items for each factor are listed in descending order based on loadings. The boldfaced text indicates items assigned to each factor.

Source: own work.

The conducted factor analysis using the principal components extraction method (rotation method: Oblimin with Kaiser normalization) also allowed for the identification of four factors explaining a total of 75.68% of the variance. Table 2 presents the means and standard deviations for individual items of the Perceived Supervisor Leadership Style Questionnaire. For further analyses, 16 items were selected that demonstrated the highest factor loadings (> 0.55).

The first factor consists of items referring to the **friendliness** component (four items, with reliability measured by Cronbach's alpha equal to 0.95). The second factor comprises items related to the autonomy component (four items, Cronbach's alpha = 0.94). The third factor includes items representing the feedback component (four items, with reliability measured by Cronbach's alpha equal to 0.92). The fourth factor represents the justice

component (Cronbach's $\alpha = 0.95$). The Cronbach's α reliability coefficient for all 16 items of the scale was 0.96, which should be considered very high. Cronbach's α coefficient of internal consistency indicates the degree of homogeneity of items comprising particular test scales (Brzeziński, 2004). Reliability analysis of a scale is based on the correlations between individual items forming the scale in relation to item variance. If the items do not reflect true scores but only error, the variance of the total score will be equal to the sum of the variances of individual items, and the α coefficient will be equal to zero. Conversely, the α coefficient equals 1 when all items are perfectly reliable and measure exactly the same construct.

The obtained results support the hypothesis H1, which assumed a four-factor structure of the PSLSQ corresponding to the components: friendliness, autonomy, feedback, and justice.

The reliability of the tool was also assessed using test-retest method.

Study 2. The assessment of the questionnaire's absolute stability was conducted among 33 employed pedagogy students who completed the questionnaire twice, with a four-week interval between measurements. The correlation coefficients between the two measurements were high and amounted to: $r = 0.88$ for friendliness, $r = 0.85$ for autonomy, $r = 0.85$ for feedback, and $r = 0.87$ for justice. These results support hypothesis H2, indicating that the PSLSQ demonstrates satisfactory temporal stability.

Despite accounting for individual and situational factors that may modify the perception of behaviors over the course of a month, the obtained results indicate a very good and positive evaluation of the questionnaires absolute stability. The Kaiser criterion has several limitations; for example, it tends to overestimate the number of components and is viewed as arbitrary (Hayton et al., 2004) in connection with applied other criteria to evaluate the number of PSLSQ components -Cattell's Scree Plot. Figure 1 presents the scree plot obtained from the exploratory factor analysis of the PSLSQ items. The X-axis represents the extracted components, while the Y-axis shows their corresponding eigenvalues. The scree plot illustrates a clear break after the fourth component, indicating that four factors should be retained. This pattern supports the theoretical assumption of a four-dimensional structure of the questionnaire.

In summary, the exploration of the factor structure based on the initial pool of test items allowed for the identification of 16 items, which were included in the final version of the PSLSQ. The results of the scree test suggested the presence of four factors.

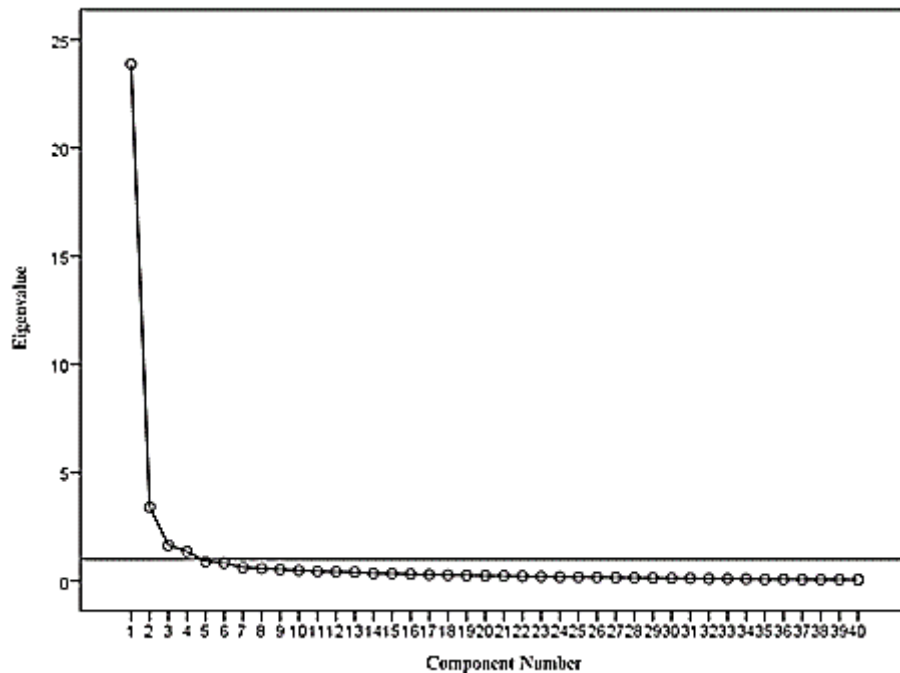


Figure 1. Scree Plot for the PSLSQ data.

Source: own work.

Based on the results of Study 1, it was concluded that the PSLSQ has four factors: friendliness, autonomy, feedback and justice. Therefore, it was decided to verify the existence of a four-factor structure using confirmatory factor analysis (CFA). Further studies were conducted with the aim of validating the questionnaire structure on a different sample of participants.

3.3. Confirmation of the internal structure of the Perceived Supervisor Leadership Style Questionnaire (PSLSQ)

The next step in evaluating the structure of the questionnaire was the analysis of factorial validity. Confirmatory factor analysis (CFA) was selected as the method for assessing the questionnaire's factorial validity (Bollen, 1989; Konarski, 2009). The aim was to examine the fit of the four-factor model.

Study 3. The study included a nationwide sample of employees from public institutions (teachers, civil servants, nurses) as well as private companies (employees of IT corporations, technical mobile network companies, and security services). For the CFA, a sample of 827 employees from various organizations was collected (479 women and 438 men), aged 18-66 years ($M = 37.25$; $SD = 10.51$). In the conducted confirmatory factor analysis, parameters were estimated using the generalized least squares (GLS) method (Sagan, 2003). Model evaluation was based on the Hoelter's critical N statistic, the Root Mean Square Error of Approximation (RMSEA), the chi-square to degrees of freedom ratio (χ^2/df), and selected absolute fit indices, including the Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), and the Standardized Root Mean Square Residual (SRMR).

In the first step, the overall model fit was assessed. Subsequently, parameter estimates were calculated, including standardized factor loadings, which in the presented model were positive and statistically significant (Figure 2). Hoelter's critical N represents the largest sample size for which the model with a given CMIN value and degrees of freedom could be accepted. More specifically, at that sample size, there would be no grounds to reject the null hypothesis stating that there is no discrepancy between the data and the model. The calculated value for the model should not be lower than 200, whereas values below 75 indicate a very poor model fit (Kenny, 2015). RMSEA indicates how poorly the model fits the data, taking into account the number of parameters requiring estimation. The closer the value is to 0, the better the theoretical model fits the covariance matrix; acceptable values should not exceed 0.08 (Browne, Cudeck, 1993). Values above 0.08 suggest a serious approximation error with regard to generalizing the results to the population (Zakrzewska, 2004). Further indices included GFI and AGFI. The GFI index can be interpreted analogously to R^2 in multiple regression analysis (Tanaka, Huba, 1989). It is generally assumed that values equal to or greater than 0.90 indicate good fit, and such a model does not require modification (Zakrzewska, 2004).

The final index analyzed was SRMR, which indicates the level of residual error, the smaller the value, the lower the error. Ideally, this coefficient should not exceed 0.08 (Hu, Bentler, 1999). The approximation error for the model indicated satisfactory fit to the empirical data (RMSEA = 0.08). Hoelter's critical N (1983) was lower than the expected 200 ($N = 175$). The χ^2/df ratio was 7.45 ($p < 0.001$), also indicating satisfactory parameter estimation (Bedyńska, Książek, 2012), and the standardized root mean square residual did not exceed the suggested maximum value (SRMR = 0.03). The fit indices (GFI = 0.91; AGFI = 0.87) allowed the four-factor model to be evaluated as satisfactory. The obtained standardized factor loadings ranged from 0.87 to 0.93 ($p < 0.001$); they were positive and high (Figure 2), indicating the homogeneity of the subscales (Sagan, 2003).

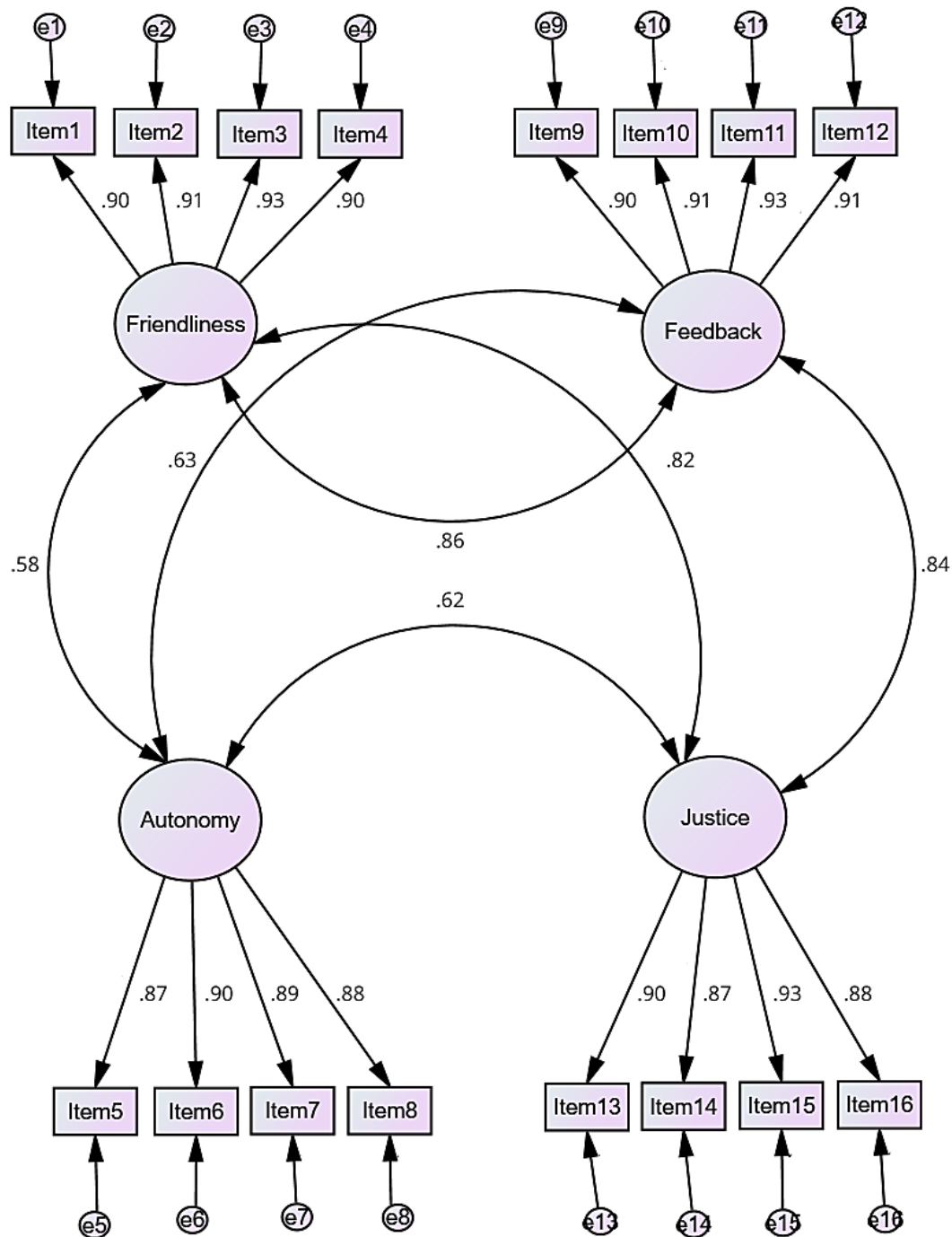


Figure 2. Confirmatory Factor Analysis of the Four-Factor Model for the PLSLQ.

Source: own work.

The results of the confirmatory factor analysis further confirm hypothesis H1 regarding the four-factor structure of the questionnaire. Table 4 presents the correlations between the individual components of the perceived supervisor leadership style. None of the dimensions correlates strongly with any other component, which indicates that we are dealing with four distinct components of the perceived supervisor leadership style.

Table 4.

Correlations Pearson's r coefficient between individual components of the perceived supervisor's management style ($N = 827$)

Variables	M	SD	Friendliness	Autonomy	Feedback	Justice
Friendliness	14,6	5,87	1,00	0,53*	0,77*	0,77*
Autonomy	17,0	5,65	0,53*	1,00	0,51*	0,55*
Feedback	14,2	5,75	0,77*	0,51*	1,00	0,76*
Justice	14,6	5,79	0,77*	0,55*	0,76*	1,00

Note. * $p < 0,05$.

Source: own work.

It can be concluded that The Perceived Supervisor Leadership Style Questionnaire measures four behaviors displayed by a supervisor: friendliness, autonomy, feedback, and justice. Each subscale contains four items. Each of these components is relatively orthogonal. The maximum possible score for each component is 24. The higher the score in each component, the more positively the employee perceives the manager's behavior.

3.4. Validity of the Perceived Supervisor Leadership Style Questionnaire (PSLSQ)

This study aimed to assess the validity of a new questionnaire, the Perceived Supervisor Leadership Style Questionnaire. We examined the validity of the PSLSQ by correlating scores on the PSLSQ with measures of job characteristics (WDQ, Hauk, 2014), Perceived Supervisor Support Scale (Wnuk, 2020), The satisfaction with job scale (Zalewska, 2003), and Big Five personality traits (TIPI-PL) adapted by Sorokowska, Słowińska, Zbieg and Sorokowski (2014).

Study 4. The study involved 100 employees, including 55 women and 45 men, with an average age of 39.62 ($SD = 8.3$), and years of experience ranging from 1 to 44 years ($M = 17.19$, $SD = 8.31$). The r -Person correlation coefficients between PSLSQ and the measures used to verify its construct validity are presented in Table 5.

Table 5.

Correlations Pearson's r coefficient between individual components of the perceived supervisor's management style and selected measures used to verify the theoretical validity ($N = 100$)

Variables	M	SD	Friendliness	Autonomy	Feedback	Justice
Feedback From Job	3,79	0,78	0,09	0,18	0,24*	0,18
Autonomy	3,94	0,93	0,01	0,33*	0,07	0,04
Feedback From Others	3,17	1,08	0,53*	0,43*	0,69*	0,59*
Interdependence	3,02	0,76	-0,08	-0,14	-0,13	-0,01
Interaction Outside Organization	3,01	0,93	0,17	0,23*	0,25*	0,24*
Social Support	3,50	1,15	0,20	0,25*	0,25*	0,26*
Job satisfaction	23,84	5,80	0,29*	0,34*	0,35*	0,35*
Benevolence and integrity	38,21	8,34	0,77*	0,60*	0,66*	0,75*
Abilities as well as competences	27,32	8,86	0,80*	0,60*	0,71*	0,76*
Extraversion	4,71	0,82	0,03	-0,06	0,06	0,01

Cont. table 5.

Agreeableness	5,66	1,08	-0,03	-0,01	0,05	0,05
Conscientiousness	5,93	1,09	-0,04	0,05	-0,01	-0,02
Emotional Stability	4,44	1,60	0,21*	0,26*	0,20*	0,24*
Openness	5,01	1,11	0,02	0,00	0,16	0,06

Note. * $p < 0,05$.

The obtained pattern of correlations provides support for hypotheses H3 and H4, confirming both the convergent and discriminant validity of the PLSQ. Convergent validity assumes that theoretically related constructs should demonstrate moderate or high positive correlations (Cohen, 1988; $r \geq 0.30$ - moderate effect; $r \geq 0.50$ - large effect). Scores on the perceived supervisor leadership style were positively correlated with selected job characteristics, with the greatest number of associations observed for the feedback dimension and the fewest for the friendliness dimension. Each dimension of the perceived supervisor leadership style showed moderate to high positive correlations with two components of the Trust in Supervisor scale: benevolence and integrity and abilities as well as competences, with correlation coefficients ranging from 0.60 to 0.80. Positive correlations were also obtained with job satisfaction scores, although these values ranged from 0.29 to 0.35. The observed relationships are consistent with theoretical assumptions and range from moderate to very high. This indicates good, and in some areas very good, convergent validity of the analyzed scales.

Discriminant validity, in turn, was examined between the dimensions of perceived supervisor leadership style and personality traits. Extraversion, agreeableness, conscientiousness, and openness showed no significant correlations with the climate dimensions (r values close to 0). This indicates that the questionnaire does not measure general personality traits, but rather specific perceptions of the work environment.

An exception was emotional stability, which demonstrated significant positive correlations with all four dimensions ($r = 0.20$ - 0.26). These relationships were weak to moderate in strength, suggesting that this trait facilitates a more positive perception of the work environment, but is not its dominant determinant. Individuals high in emotional stability are generally less likely to interpret situations as threatening, experience lower levels of anxiety and tension, are less prone to negative attributions of others' intentions, demonstrate greater stress resilience, and consequently may more often perceive relationships as benevolent, interpret communication as less critical, perceive supervisors' actions as less unfair, and cope better with the responsibility associated with autonomy.

These findings are consistent with theoretical assumptions (Zawadzki et al., 2007), according to which individuals with higher emotional stability are less likely to make negative attributions and display emotional adjustment and the ability to cope with stress without experiencing excessive tension or fear. At the same time, the moderate strength of the correlations confirms the distinctiveness of the organizational climate construct from dispositional personality traits. In this respect, discriminant validity was confirmed.

4. Conclusions and Discussion

The aim of the present study was to develop and psychometrically validate the Perceived Supervisor Leadership Style Questionnaire (PSLSQ), a tool designed to capture employees' perceptions of their direct supervisor's leadership behaviors. The results of the multi-stage validation procedure provided empirical support for the hypotheses formulated in this study. The assumed four-factor structure of the questionnaire was confirmed through both exploratory and confirmatory factor analyses (H1). The PSLSQ demonstrated high internal consistency and temporal stability (H2). Furthermore, the correlations with theoretically related constructs confirmed convergent validity, while low correlations with personality traits supported discriminant validity (H3 and H4).

The exploratory factor analysis conducted in the first stage of the study revealed a four-factor structure corresponding to the theoretically derived dimensions of leadership behavior: friendliness, autonomy support, feedback, and justice. These dimensions integrate relational and structural aspects of leadership, reflecting both the interpersonal quality of supervisor–employee interactions and the organizational mechanisms through which managerial influence is exercised. The identified factor structure was subsequently confirmed through confirmatory factor analysis, which demonstrated acceptable model fit indices and supported the factorial validity of the proposed measurement model (Hair et al., 2019).

From a theoretical perspective, the identified structure is consistent with broader conceptualizations of leadership that emphasize both relationship-oriented and task-oriented dimensions of managerial behavior (Bass, Bass, 2008; Yukl, 2013). The friendliness dimension reflects the relational component of leadership associated with interpersonal sensitivity, support, and the development of positive social exchange relationships between supervisors and employees. Such behaviors are consistent with theoretical perspectives emphasizing the role of leader–member exchange processes and relational leadership in shaping employee attitudes and motivation (Uhl-Bien, 2006).

In turn, the autonomy dimension captures elements related to empowerment and the delegation of responsibility, which are central to contemporary approaches to leadership that highlight the importance of employee self-regulation and intrinsic motivation (Deci, Ryan, 2000). Leadership behaviors that support autonomy have been shown to promote employee engagement, initiative, and psychological empowerment (Ahearne, Mathieu, Rapp, 2005). The feedback dimension reflects the informational and developmental function of leadership. Constructive feedback from supervisors plays a key role in employee learning, performance improvement, and professional development (London, 2003; Kluger, DeNisi, 1996). At the same time, the justice dimension captures the procedural and distributive fairness of managerial decision-making processes. Research in organizational justice consistently demonstrates that employees' perceptions of fairness are strongly associated with trust in

leadership, job satisfaction, and organizational commitment (Colquitt et al., 2001; Greenberg, 1990). The observed relationships between leadership behaviors and positive employee outcomes are also consistent with a broad body of research indicating that supportive and fair leadership practices contribute to higher levels of employee well-being, work engagement, and job satisfaction (Judge, Piccolo, 2004; Skakon et al., 2010). Leadership behaviors characterized by openness, support, and fairness are particularly important in fostering interpersonal trust between supervisors and employees (Dirks, Ferrin, 2002).

Despite the promising results, several limitations of the present research should be acknowledged. First, the study relied exclusively on self-report data collected from employees, which raises the possibility of common method variance (Podsakoff et al., 2003). Although this approach is appropriate when measuring subjective perceptions of leadership behaviors, future research would benefit from the inclusion of multi-source data, such as supervisor self-assessments, peer evaluations, or objective organizational indicators.

Second, although relatively large samples were used at different stages of the validation process, the participants were drawn primarily from Polish organizational contexts. Consequently, the generalizability of the findings to other cultural and institutional environments remains limited. Leadership perceptions may be influenced by broader cultural norms regarding authority, hierarchy, and interpersonal relationships (House et al., 2004). Therefore, future studies should aim to conduct cross-cultural validations of the PLSLQ, examining whether the proposed factor structure remains stable across different national and organizational contexts.

Third, the present study relied on a cross-sectional research design, which limits the ability to draw causal conclusions regarding the relationships between perceived leadership style and employee outcomes. Longitudinal research designs would allow researchers to examine how perceptions of supervisory behaviors develop over time and how they influence longer-term outcomes such as employee engagement, organizational commitment, and job performance (Antonakis, Bendahan, Jacquart, Lalive, 2010).

Future research should therefore extend the present findings in several directions. First, further studies could focus on standardizing the PLSLQ on larger and more representative samples, which would enable the development of normative data and strengthen the questionnaires applicability in organizational diagnostics. Second, future research should examine the predictive validity of the questionnaire, particularly in relation to key organizational outcomes such as employee engagement, psychological safety, job performance, and turnover intentions (Edmondson, 1999; Bakker, Demerouti, 2008). Third, the PLSLQ could be used in studies examining mediating and moderating mechanisms linking leadership behaviors with employee well-being and organizational effectiveness.

In conclusion, the results of the present study suggest that the Perceived Supervisor Leadership Style Questionnaire represents a theoretically grounded and psychometrically sound questionnaire for assessing employees' perceptions of leadership behaviors. By integrating

relational and structural dimensions of leadership within a single measurement framework, the PSLSQ contributes to the growing body of research emphasizing the importance of employees' subjective perceptions of managerial practices. Further research is recommended to expand the empirical evidence supporting the questionnaire and to explore its potential applications in diverse organizational and cultural contexts.

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Appendix 1

Polish version PSLSQ

Kwestionariusz Spostrzeganego Stylu Kierowania Przełożonego (KSSKP)

Proszę, przeczytaj uważnie podane niżej stwierdzenia opisujące pewne zachowania, które może przejawiać Twój bezpośredni przełożony. Zaznacz, w jakim stopniu zgadzasz się z każdym z tych stwierdzeń. Proszę ustosunkuj się do wszystkich zdań, nawet jeżeli nie jesteś pewny odpowiedzi. Nie ma tu dobrych, ani złych odpowiedzi, najważniejsze jest Twoje zdanie, dotyczące tego jak postrzegasz zachowania swojego bezpośredniego przełożonego.

Odpowiadając wykorzystaj poniższą skalę:

Od 1 - prawie nigdy, do 6 - bardzo często (bardzo często oznacza tak często, jak tylko jest to możliwe)

Mój bezpośredni przełożony:						
1. Reaguje na potrzeby pracowników	1	2	3	4	5	6
2. Wyzwała pozytywne nastawienie w pracownikach	1	2	3	4	5	6
3. Słucha swoich pracowników	1	2	3	4	5	6
4. Okazuje szczerze zainteresowanie osobą i jej rolą w organizacji	1	2	3	4	5	6
5. Umożliwia samodzielne planowanie pracy	1	2	3	4	5	6
6. Umożliwia samodzielną organizację czasu pracy	1	2	3	4	5	6
7. Pozwala pracownikowi na swobodę wyboru strategii wykonywania danego zadania	1	2	3	4	5	6
8. Pozwala na niezależność w tym, jak pracownik wykonuje swoją pracę	1	2	3	4	5	6
9. Informuje pracowników na temat jakości wykonania danego zadania	1	2	3	4	5	6
10. Informuje o postępach w realizacji celów	1	2	3	4	5	6
11. Przekazuje informację zwrotną, która jest jasna i obiektywna	1	2	3	4	5	6
12. Informuje o spełnieniu przez pracownika stawianych mu wymagań, osiągniętych wyników i sposobu realizacji zadań	1	2	3	4	5	6
13. Sprawiedliwie wyraża uznanie	1	2	3	4	5	6
14. Przestrzega zasad dotyczących nagradzania i promowania pracowników	1	2	3	4	5	6
15. Sprawiedliwie ocenia wysiłek pracowników w wykonywanej pracy	1	2	3	4	5	6
16. Opiera się na rzetelnych, znanych kryteriach oceny zadania	1	2	3	4	5	6

Klucz (numery twierdzeń wchodzących w skład poszczególnych komponentów):

Życzliwość – 1,2,3,4

Autonomia – 5,6,7,8

Informacja zwrotna – 9,10,11,12

Sprawiedliwość – 13,14,15,16

Appendix 2

English version PSLSQ (not used for psychometric validation)

The Perceived Supervisor Leadership Style Questionnaire (PSLSQ)

Please carefully read the statements below describing certain behaviors your direct supervisor may exhibit. Indicate the extent to which you agree with each statement. Please respond to each statement, even if you are unsure. There are no right or wrong answers; the most important thing is your opinion on how you perceive your direct supervisor's behavior.

Please indicate the extent to which you engage in the following behaviours using the following scale: 1 = hardly Ever, to 6 = very often (very often means as often as possible)

My direct supervisor:						
1. Responds to employees' needs.	1	2	3	4	5	6
2. Fosters a positive attitude among employees.	1	2	3	4	5	6
3. Listens to employees.	1	2	3	4	5	6
4. Shows genuine interest in the employee and their role in the organization.	1	2	3	4	5	6
5. Enables employees to plan their work independently.	1	2	3	4	5	6
6. Allows employees to organize their working time independently.	1	2	3	4	5	6
7. Allows employees freedom to choose strategies for completing tasks.	1	2	3	4	5	6
8. Allows independence in how employees perform their work.	1	2	3	4	5	6
9. Informs employees about the quality of task performance	1	2	3	4	5	6
10. Provides information on progress toward goal achievement.	1	2	3	4	5	6
11. Gives feedback that is clear and objective.	1	2	3	4	5	6
12. Informs employees whether they meet expectations, about their results, and how they carry out their tasks.	1	2	3	4	5	6
13. Expresses recognition in a fair manner.	1	2	3	4	5	6
14. Adheres to established rules for rewarding and promoting employees.	1	2	3	4	5	6
15. Evaluates employees' work effort justice.	1	2	3	4	5	6
16. Bases task evaluation on reliable and transparent criteria.	1	2	3	4	5	6

Note (numbers of the statements included in the individual components):

Friendliness – 1,2,3,4

Autonomy – 5,6,7,8

Feedback – 9,10,11,12

Justice – 13,14,15,16

THE IMPACT OF ECONOMIC SECURITY DIFFERENTIATION ON QUALITY OF LIFE IN EUROPEAN UNION MEMBER STATES

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Purpose: The aim of this article is to assess the variation in economic security and quality of life across European Union (EU) Member States and to identify the interdependencies between these phenomena. The study includes an analysis of income, household consumption expenditure, the risk of poverty, income inequality, and subjective assessments of quality of life, as well as an assessment of changes and the degree of convergence among EU Member States over the period 2013–2023.

Design/methodology/approach: The article adopts a theoretical and empirical approach. The analysis is based on Eurostat data from the EU Statistics on Income and Living Conditions (EU-SILC), covering 27 EU Member States. From an initial set of 44 indicators, 8 indicators related to economic security and 3 indicators referring to quality of life were selected, with incomplete data excluded. Descriptive statistics, variability analysis, the Shapiro-Wilk test, correlation analysis, and multiple regression were applied to assess the impact of economic variables on subjective quality of life.

Findings: The study revealed pronounced differences among EU Member States in terms of economic security and quality of life, with a noticeable convergence trend observed in recent years. Higher income levels, lower income inequality, and a lower risk of poverty are strongly associated with better self-reported life satisfaction. A high quality of life is positively correlated with income and household consumption expenditure, and negatively correlated with financial difficulties and income inequality. The most favourable outcomes are observed in Western European countries, whereas the highest adverse indicators are recorded in Bulgaria and South-Eastern European countries. Multiple regression analysis confirmed the statistical significance of selected economic variables for quality of life, while also indicating the importance of non-material factors.

Research limitations/implications: The findings are constrained by data availability, which necessitated a reduction in the number of indicators. The study addresses only selected determinants of quality of life; therefore, future research should focus on social, health-related, environmental, and regional factors, and incorporate additional statistical methods.

Practical implications: The results may support the design of socio-economic policies. They highlight the need to strengthen households' financial stability, reduce income inequality, and improve households' resilience to unexpected expenditures.

Social implications: The study emphasises the importance of economic security for societal well-being and points to the need for measures aimed at reducing regional disparities.

The findings may be useful for public institutions responsible for cohesion policy and quality of life in the European Union.

Originality/value: The article provides an up-to-date assessment of economic security and quality of life in the European Union, based on the most recent data, and combines the analysis of objective economic indicators with subjective well-being assessments, offering valuable insights for policymakers and researchers.

Keywords: economic security, quality of life, income, income inequality, convergence, EU Member States.

Category of the paper: research paper.

Introduction

Security is an issue that is widely analysed in the literature due to the role it plays in social life as an essential element of individual human needs (Fehler, 2012, p. 7; Misiuk, 2018) and as a fundamental human right (Gierszewski, 2013). The subject of security is always the individual, while its object consists of phenomena and processes related to human existence (Kitler, 2011, pp. 22-23). One of the fundamental types of security is economic security (Gębska, 2017; Kosowski, Kułakowska, 2022; Majka, 2015, p. 48). Economic security affects quality of life by determining the satisfaction of basic needs, access to education, healthcare provision, and the ability to invest in the future. It constitutes the foundation of well-being and individual satisfaction (Ficoń, 2020, p. 84). However, despite its importance for social policy and state strategic decision-making, this issue has not been addressed in the literature as frequently as it deserves. The analysis of the variation in economic security and its relationship with quality of life is essential for undertaking rational public actions. In view of the above, the aim of this article is to assess the variation in economic security (ES) and the quality of life of the population (QoL) in the European Union Member States and to identify the interdependencies between these phenomena. Within the main research objective, three specific objectives were formulated:

- to analyse the level, variation, and degree of change and convergence of economic security in EU Member States,
- to analyse the level, variation, and degree of change and convergence of the quality of life of EU residents,
- to identify the relationship between economic security and quality of life in EU Member States.

At the outset of the study, a hypothesis was formulated assuming that the level of economic security in the European Union Member States is becoming more equal and affects the quality of life of the population, and that important determinants of life satisfaction include such indicators as income and consumption levels, the risk of poverty, income inequality, and difficulties in meeting unexpected financial expenditures. The article adopts a theoretical

and empirical approach. In order to achieve the research objective and verify the hypothesis, a literature review was conducted, a study based on indicators derived from Eurostat (EU-SILC) was carried out, and the results and conclusions were presented.

Literature review

The term “security” is widely used, and the need for security is one of the most important human necessities (Czechowska et al., 2020, p. 111). Socio-economic and political realities require security to be treated as a paramount human need (of a collective), understood as the “absence of something that is necessary to preserve life, development, and the maintenance of a social role” (Stachowiak, 2012, p. 38). According to R. Zięba, it denotes the certainty of existence and survival, resulting not only from the absence of threats but also from the activity of the subject (Zięba, 2012, p. 8). Security is sometimes understood as a process, a basic need, and a value and goal of existence (Pokruszyński, 2010, p. 9). It is an indivisible category (Fehler, 2012, p. 9); however, for research purposes, various typologies are distinguished. These include, among others, international, national, political, military, economic, social, cultural, and environmental security (Leszczyński, 2017; Wiśniewski, 2011, pp. 11-13). According to the spatial criterion, local, subregional, and regional security can be distinguished (Szczepański, 2023). Security is also treated as a public good, characterised by non-rivalry and provided by the state (Czechowska et al., 2022). Its absence or the subjective perception of its absence causes anxiety and mobilises individuals to neutralise threats (Zięba, 2012, p. 9).

Economic security is analysed interdisciplinarily, in the context of countries, regions, and regional arrangements (Jaźwiński, 2019), from both macro- and micro-level perspectives. It constitutes the foundation of socio-economic development and economic growth of states and regions, as well as an important area of socio-economic policy (Raczkowski, 2012, p. 81; Stachowiak, 2012, p. 45). At the macro level, it denotes economic stability and the maintenance of development indicators, as well as balance in relation to other economies (Księżopolski, 2011). At the micro level, it refers to the solvency of households and enterprises (Raczkowski et al., 2013, p. 35). The objective is the creation, fair distribution, and consumption of goods, which builds societal well-being (Leszczyński, 2017). At the individual level, economic security is based on the satisfaction of basic needs, while at the societal level it is closely linked to social security, the objective of which is the certainty of existence (Stachowiak, Dziurny, 2018). The literature identifies various aspects of economic security, including healthcare costs among low-income groups (Butler, 2006; Rizal et al., 2022), the importance of financial education for older people (Wierzbicka, 2019), perceptions of family and employment security (Kosowski, Kułakowska, 2022), as well as the quality of life of low-income individuals (Puciato et al., 2023).

Quality of life is a multidimensional concept and is widely used in both scientific and everyday language. The literature offers numerous concepts of quality of life, defined from philosophical, psychological, sociological, economic, pedagogical, and medical perspectives (Gaweł-Luty, 2022). The essence and conceptual scope of quality of life are broad, ranging from its identification with material well-being to assessments of personal satisfaction and happiness resulting from consumption, health, the natural environment, or social position. Thus, quality of life refers to the degree of satisfaction of an individual (or society) with the overall conditions of their existence (Bywalec, 2010, p. 42). Quality of life has been examined by many authors (Barlybaev et al., 2021; Gutkowska, Murawska, 2010; Koochi et al., 2017; Lalić et al., 2024; Micelli, Giliberto, 2023; Murawska, 2012; Petelewicz, Drabowicz, 2016; Rizal et al., 2022). These studies include, among others, assessments of personal satisfaction (Micelli, Giliberto, 2023). The measurement of quality of life involves both objective factors – living conditions – and subjective factors – individual criteria of evaluation (Gaweł-Luty, Lemańczyk, 2022; Panek, 2015).

An individual's quality of life is influenced by the material goods they possess, which are crucial because they enable the attainment of psychological well-being and higher-order needs. However, Amartya Sen points out that the ability to use goods in order to live a dignified life is more important than their mere possession, and that a high quality of life is reflected in an individual's capability to achieve valued functionings (Sen, 1973). Living conditions should therefore be assessed from the perspective of their significance for the individual, rather than as values in themselves (Petelewicz, Drabowicz, 2016). Quality of life is linked to the concept of life satisfaction, often identified with happiness and well-being. This implies acceptance of living conditions and the fulfilment of individual needs (Oladipo et al., 2013). Thus, quality of life constitutes an assessment of both the objective and subjective condition of an individual within a local context (WHO, 2012).

An important body monitoring the social situation and quality of life in EU countries is Eurostat (Eurostat, 2025). The data support public policies in diagnosing problems and evaluating interventions. Data comparability enables the analysis of trends and the impact of macroeconomic phenomena. European treaties emphasise the importance of quality of life and well-being: the Treaty of Rome (1992) introduced the objective of the "improvement of citizens' quality of life", while the Treaty of Lisbon introduced the concept of well-being. The concept of sustainable development has also influenced the development of social statistics (EC, 2025a). The implementation of these principles (EC, 2025a; EC, 1993; OECD, 2013) led to the development of a set of quality-of-life indicators. The "8+1" model comprises eight resource domains (including material living conditions, health, education, leisure time, economic security, rights, the living environment, and the natural environment), as well as an additional overall subjective assessment of well-being (EC, 2025b).

In summary, security is a fundamental human need, a public good, and a subjective perception of the absence of threats. The multidimensional nature of this good reflects its importance in a risk society, in which economic security occupies a special place, playing a key role both at the macro level – where it signifies economic stability – and at the micro level – where it determines the solvency of market actors and affects the quality of life of the population.

Research methodology and research process

The data source consisted of datasets from the European Statistical Office, in particular the Statistics on Income and Living Conditions (EU-SILC). The information collected within EU-SILC refers to households and their members. The achieved sample size surveyed in the EU in 2023 amounted to 293 thousand households and 558.7 thousand individuals aged 16 and over (Eurostat, 2025). The data covered 27 European Union Member States and the period 2013–2023. At the initial stage of the study, 27 indicators describing the economic security of the population (ES) (referred to as independent variables X) and 17 indicators describing the quality of life of the population (QoL) (referred to as dependent variables Y) were collected. Subsequently, indicators with missing data were eliminated, and ultimately 8 ES indicators and 3 QoL indicators were included in further analyses. Variables X01–X03 were classified as stimulants (S), while variables X04–X08 were classified as destimulants (D) of the population's quality of life (Table 1).

Table 1.

Indicators included in the analysis of economic security (ES) and quality of life (QoL)

Symbol	Variable description	DOI	Data years	S/D
Economic security of the population (ES) – independent variables				
X01	Mean equivalised net income in PPS	https://doi.org/10.2908/ILC_DI03	2015–2023	S
X02	Median equivalised net income in PPS	https://doi.org/10.2908/ILC_DI03	2015–2023	S
X03	Gross domestic product (GDP) per capita at market prices – individual consumption in PPS	https://doi.org/10.2908/NAMA_10_PC	2013–2023	S
X04	Households making ends meet with difficulty – %	https://doi.org/10.2908/ILC_MDES09	2015–2023	D
X05	Households making ends meet with great difficulty – %	https://doi.org/10.2908/ILC_MDES09	2015–2023	D
X06	At-risk-of-poverty rate – % (threshold: 50% of median equivalised income)	https://doi.org/10.2908/ILC_LI02	2015–2023	D
X07	Inability to face unexpected financial expenses – %	https://doi.org/10.2908/ILC_MDES04	2015–2023	D
X08	Gini coefficient of equivalised disposable income – % (scale 0–100)	https://doi.org/10.2908/TESSI190	2014–2023	D

Cont. table 1.

Subjective assessment of quality of life – life satisfaction (QoL) – dependent variables				
Y01 QoL_H	Overall life satisfaction – high (%)	https://doi.org/10.2908/ILC_PW05	2013,2018, 2021–2023	-
Y02 QoL_M	Overall life satisfaction – medium (%)	https://doi.org/10.2908/ILC_PW05	2013,2018, 2021–2023	-
Y03 QoL_L	Overall life satisfaction – low (%)	https://doi.org/10.2908/ILC_PW05	2013,2018, 2021–2023	-

Notes: S – stimulant; D – destimulant.

Source: authors' own elaboration based on Eurostat (2025).

The indicators were subjected to further detailed analysis, and descriptive statistics were calculated. Among others, coefficients of variation (V_s), range measures (R), coefficients of skewness (S), and kurtosis (K) were computed. The normality of the variables' distributions was examined using the Shapiro–Wilk (S–W) test. Differences in the values of the analysed indicators were also calculated for the periods 2015–2023 (ES) and 2013–2023 (QoL) in order to determine increases or decreases in their values. In addition, correlation and regression analyses were conducted between the independent variables X (ES) and the dependent variables Y (QoL) to verify the relationships between them.

Results

1.1. PROBLEMS OF ECONOMIC SECURITY OF THE POPULATION

Economic security is reflected by objective indicators such as population income, the level of individual consumption, the risk of poverty, and income inequality. Population income can be measured and analysed in national currency, euro, or PPS (i.e. in terms of purchasing power parity). According to data for 2023, the mean equivalised net income measured in purchasing power standards (X01) in EU Member States amounted to 21.3 thousand PPS per capita per year. The median net income (X02) was lower in 2023 and amounted to 18.7 thousand PPS per capita. The lowest population income levels (both mean and median) were recorded in Slovakia, while the highest were observed in Luxembourg. Actual individual consumption (X03), which is one of the measures of gross domestic product (GDP), amounted to 24.3 thousand PPS per capita; the lowest level was recorded in Bulgaria, while the highest was again observed in Luxembourg. The at-risk-of-poverty rate (X06) amounted to 14.1%, with the lowest value in Belgium (7.5%) and the highest in Bulgaria (22.9%). A considerable amount of information on the fairness of income distribution, which subsequently translates into a higher sense of economic security, is provided by the Gini coefficient (X08), which in 2023 amounted to 29.5%. The lowest income inequality was observed in Slovakia (21.6%), while the highest was recorded in Bulgaria (37.2%).

Important indicators reflecting economic security also include subjective measures, namely respondents' direct declarations. In the EU-SILC survey on living conditions, one of the

questions addressed to respondents concerned the assessment of their financial situation in terms of making ends meet. It turns out that in 2023, the proportion of respondents in the EU declaring that they made ends meet with difficulty (X04) amounted to 12.4%, while those declaring that they did so with some difficulty (X05) accounted for 28.3%. Such declarations were most frequently reported by residents of Greece and Lithuania, and least frequently by residents of Luxembourg and Germany. One of the indicators reflecting the population's sense of economic security is the proportion of people who are unable to cope with unexpected financial expenses (X07). In the EU, more than 30% of respondents declared such difficulties. In 2023, the highest proportions of individuals experiencing problems with unexpected expenses were recorded in Bulgaria (46.7%), Romania (46.4%), Latvia (44.8%), and Greece (44.3%). The most favourable situation was observed in Netherlands (15.9%), Malta (15.9%), and Czechia (19.7%) (Table 2).

Table 2.

Descriptive statistics of variables characterising the economic security of the population (ES) in EU Member States in 2023

Variable	$\bar{x}_j$	x_{min}	Country x_{min}	x_{max}	Country x_{max}	R	V_s	A	K	SW-W
X01	21278.2	10777.0	SK	39914.0	LU	29137.0	32.1	0.57	0.54	0.95(ND)
X02	18759.7	10670.0	SK	34777.0	LU	24107.0	32.4	0.57	0.23	0.94(ND)
X03	24353.4	16382.2	BG	39336.9	LU	22954.7	21.8	0.79	0.68	0.93(ND)
X04	12.4	3.9	LU	30.3	GR	26.4	47.3	1.18	2.08	0.93(ND)
X05	28.3	12.1	DE	48.0	LT	35.9	37.2	0.13	-1.05	0.96(ND)
X06	14.1	7.5	BE	22.9	BG	15.4	32.3	0.33	-1.02	0.95(ND)
X07	30.6	15.9	NL	46.7	BG	30.8	30.2	0.28	-0.95	0.95(ND)
X08	29.5	21.6	SK	37.2	BG	15.6	12.5	-0.10	-0.04	0.99(ND)

Notes: S – stimulant; D – destimulant; $\bar{x}_i$ – mean for the EU (27); x_{min} – minimum value of the variable; x_{max} – maximum value of the variable; V_s – coefficient of variation; R – range (max–min); A – skewness; K – kurtosis; S–W – Shapiro–Wilk test result; ND – normal distribution; SK – Slovakia; BG – Bulgaria; LU – Luxembourg; DE – Germany; BE – Belgium; NL – Netherlands; GR – Greece; LT – Lithuania.

Source: authors' own calculations based on Eurostat (2025).

Poland was among the leading countries with the fewest problems related to covering current and unexpected financial obligations, following the previously mentioned Netherlands, Malta, and Czechia. Such problems were reported less frequently also by residents of Belgium, Sweden, Slovenia, Austria, Denmark, and Luxembourg. In the majority of EU Member States, the proportion of people experiencing financial difficulties decreased compared with 2015 (negative orange bars). The largest improvement was recorded in Hungary (a decrease of approximately 40%), as well as in Cyprus and Slovenia. An increase in financial difficulties occurred only in Germany, Sweden, Austria, and Luxembourg, where the orange bars are positive (Figure 1).

Although financial resilience of households is improving across the EU as a whole, inequalities remain substantial – countries of Central and Eastern Europe continue to perform worse than Western European countries. The improvement in the situation may indicate more effective social policy and rising income levels; however, challenges persist, particularly in the poorest EU Member States.

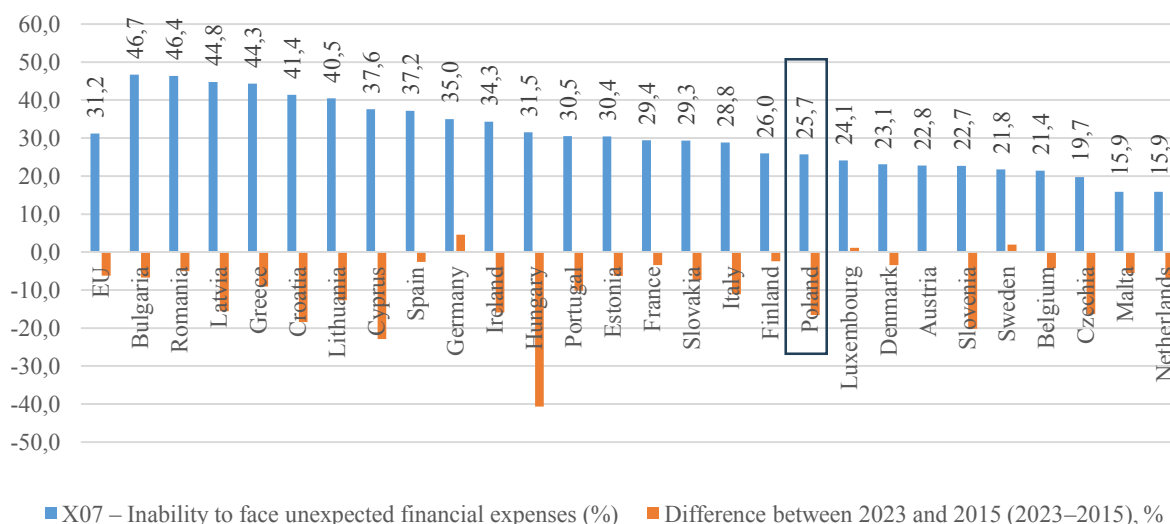
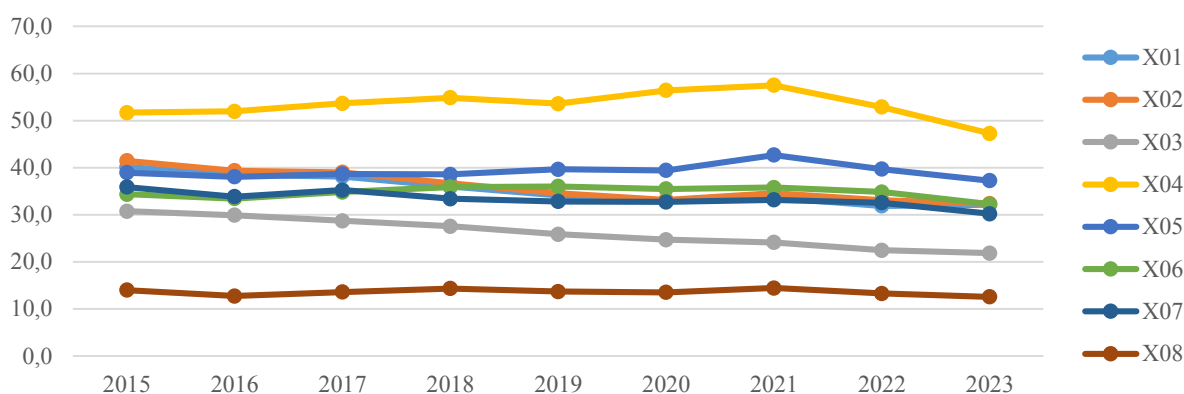


Figure 1. Inability to face unexpected financial expenses in EU Member States in 2023.

Source: authors' own calculations based on Eurostat (2025).

Based on the coefficient of variation (V_s), it can be stated that the highest degree of variation among EU Member States in the period 2015-2023 was observed for indicator X04 (“households making ends meet with difficulty”), whose values fluctuated around 50-58%, with a clear decline in the years 2022-2023. Indicators X01 and X02 (mean and median equivalised net income) exhibited moderate and stable levels of variation, at approximately $V_s = 35$ -43%. In contrast, variable X03 (GDP per capita – actual individual consumption) is characterised by the lowest level of variation. A decline from about 30% to 22% was observed, which may indicate a convergence of EU Member States in terms of consumption levels. Indicators X06 (risk of poverty) and X07 (inability to face unexpected financial expenses) remain at a moderate level of variability, with a slight downward trend. By contrast, the Gini coefficient (X08) shows the lowest and most stable values of the coefficient of variation (12-14%) (Figure 2).



Notes: explanations of the independent variables X01-X08 are provided in Table 1.

Figure 2. Changes in the variation of the economic security of the population (ES) in EU Member States based on the coefficient of variation V_s (%).

Source: authors' own calculations based on Eurostat (2025).

In summary, the level of economic security continues to differ among EU Member States, although these differences have been gradually decreasing, particularly in recent years (2022-2023). This may indicate a slow convergence of economic conditions among EU Member States with respect to income, poverty, and financial difficulties. The greatest degree of variation is observed in subjective assessments of material conditions, which may result both from actual differences and from diverse cultural norms and expectations of residents. The smallest differences are observed in consumption levels and income inequality. This can be attributed to the effective implementation of EU equalisation policies and the strengthening of socio-economic integration within the European Union.

1.2. LEVEL AND VARIATION OF THE QUALITY OF LIFE OF THE POPULATION

Quality of life constitutes a key factor in the assessment of the social and economic development of regions, while the level of satisfaction and well-being, in turn, affects the physical and mental health of individuals. It is a category that goes beyond the framework of classical economics and is difficult to measure and interpret unambiguously. For example, it is possible to live at a high cultural or material standard and nevertheless be dissatisfied with life. Conversely, individuals with low income or health problems may feel happy with the life they have. Therefore, it is important that categories such as economic development, standard of living, well-being, and the level of economic security, which are generally measured using objective indicators, are analysed jointly with the assessment of quality of life, which is a subjective category.

In 2023, in the EU, 23.4% of surveyed respondents assessed their life satisfaction as high (Y01 QoL_H). The lowest level of high life satisfaction was recorded in Bulgaria (8.8%), while the highest was observed in Austria (33.0%). The subjective assessment of quality of life as medium (Y02 QoL_M) exhibited the highest stability among the analysed variables.

The proportion of respondents declaring a medium quality of life amounted to 60.3%, with the lowest value recorded in Bulgaria (46.8%) and the highest in Italy (73.4%). By contrast, the data concerning negative aspects of quality of life (Y03 QoL_L) show very high variability. This indicates that while most countries recorded low values of this indicator, in some countries (e.g. Bulgaria) extremely unfavourable conditions were observed. The distribution of this variable deviates from normality, indicating substantial disparities in the level of negative assessments. As many as 16.3% of the total population surveyed in the EU assessed their life satisfaction as low in 2023; notably, in Bulgaria as many as 44.4% of respondents declared low satisfaction, compared with only 6.5% in Belgium. In summary, the data indicate a relatively even situation with regard to the subjective perception of quality of life, while the largest cross-country differences occur in the negative factors reducing it. Bulgaria records the lowest levels of well-being, whereas Austria and Italy achieve the highest values in terms of high and medium quality of life (Table 3).

Table 3.

Descriptive statistics of variables characterising high, medium, and low quality of life of the population (QoL) in EU Member States in 2023

Variable	$\bar{x}_j$	x_{min}	Country x_{min}	x_{max}	Country x_{max}	R	V_s	A	K	SW-W
Y01 QoL_H	23.4	8.8	BG	33.0	AT	24.2	24.0	-0.38	0.53	0.97(ND)
Y02 QoL_M	60.3	46.8	BG	73.4	IT	26.6	9.2	0.26	1.23	0.96(ND)
Y03 QoL_L	16.3	6.5	BE	44.4	BG	37.9	46.4	1.91	6.54	0.84

Notes: $\bar{x}_i$ – mean for the EU (27); x_{min} – minimum value of the variable; x_{max} – maximum value of the variable; V_s – coefficient of variation (%); R – range (max–min); A – skewness; K – kurtosis; S–W – Shapiro–Wilk test result; ND – normal distribution; BG – Bulgaria; BE – Belgium; AT – Austria; IT – Italy.

Source: authors' own calculations based on Eurostat (2025).

In the period 2013–2023, quality of life (QoL) in the EU and in Poland showed a gradual improvement, particularly evident in the decline in the proportion of people assessing it as low (Y03 QoL_L). In the EU, the share of such individuals decreased from 23.9% in 2013 to 16.3% in 2023, while in Poland the decline was even more pronounced – from 19.9% to 10.6%. At the same time, the proportion of residents assessing their quality of life as medium (Y02 QoL_M) increased, both in the EU (from 54.5% to 60.3%) and in Poland (from 50.7% to 61.5%). In the category of “high quality of life” (Y01 QoL_H), some fluctuations are observed. In the EU, this indicator oscillated around 22–24%, whereas in Poland it was higher and more dynamic, reaching a maximum of 34.6% in 2018 and then declining to 27.9% in 2023. Overall, the data indicate a significant improvement in quality of life in Poland over the decade, approaching or even exceeding the levels recorded in the EU (Figure 3).

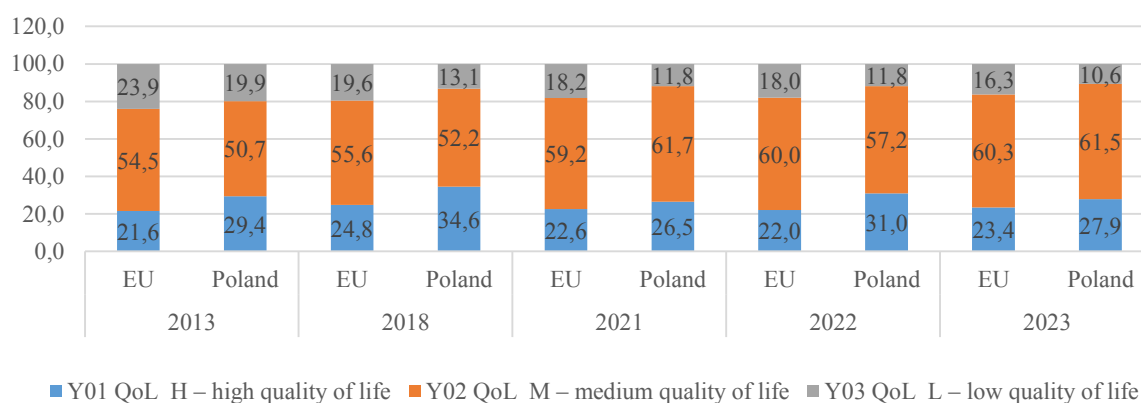


Figure 3. Assessment of quality of life (QoL) by residents of the EU as a whole and Poland in the period 2013-2023 (%).

Source: authors' own calculations based on Eurostat (2025).

Data on the coefficient of variation (V_s) of quality of life in EU Member States over the period 2013-2023 show a clear downward trend, particularly for the assessment of high quality of life (Y01 QoL_H), where variability decreased from 42.5% in 2013 to 24.0% in 2023. This indicates that differences among EU Member States in this respect have been significantly reduced, which may point to a progressing convergence of living conditions. The coefficient of variation for the assessment of medium quality of life (Y02 QoL_M) also declined systematically, reaching its lowest level of 9.2% in 2023. By contrast, for low quality of life, fluctuations were smaller; however, a decline is also observed here, from 53.8% to 46.4% (Figure 4).

The declining variability of life satisfaction in EU Member States indicates progressing socio-economic cohesion and may confirm the effectiveness of policies supporting less developed regions. However, the risk of “downward convergence” should also be taken into account, whereby statistical improvement results from a deterioration in quality of life in more developed countries. The equalisation of indicators does not always imply a real convergence of well-being levels; therefore, continuous monitoring is necessary, along with support for qualitative development rather than merely reducing numerical disparities.

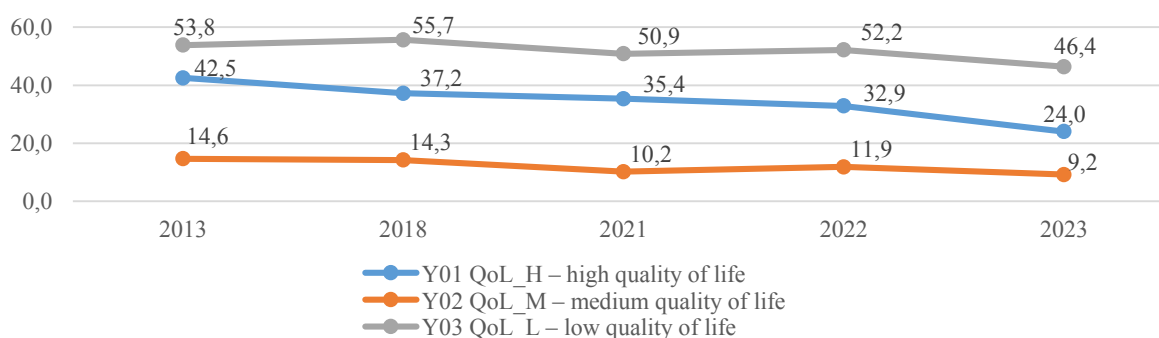


Figure 4. Variation in the quality of life of the population (QoL) in EU Member States in the period 2013-2023, based on the coefficient of variation V_s (%).

Source: authors' own calculations based on Eurostat (2025).

In 2023, a high quality of life (Y01 QoL_H) in EU Member States was declared by 21.7% of all surveyed respondents. A slight increase in high quality-of-life assessments was observed – by only 0.5 percentage points compared with 2013. The highest values of this indicator were recorded in Austria (33.0%), Denmark (32.2%), and Slovenia and Finland (31.6% each). It should be noted, however, that some of these countries recorded a decline in quality-of-life assessments (e.g. Denmark: –10.8 p.p., Finland: –7.0 p.p., Austria: –4.1 p.p.). By contrast, the largest increases were observed in Slovenia (+11.7 p.p.), Romania (+8.7 p.p.), Hungary (+10.1 p.p.), and Cyprus (+10.7 p.p.), which may indicate positive changes in the perception of quality of life in these countries. Poland ranked above the EU average (27.9%); however, compared with 2013, a slight decline was recorded (–1.5 p.p.). Attention should also be drawn to Central and Eastern European countries that improved their positions – among others Czechia, Estonia, Lithuania, and Latvia – which demonstrates the progressing convergence in quality of life between the “old” and the “new” EU (Figure 5).

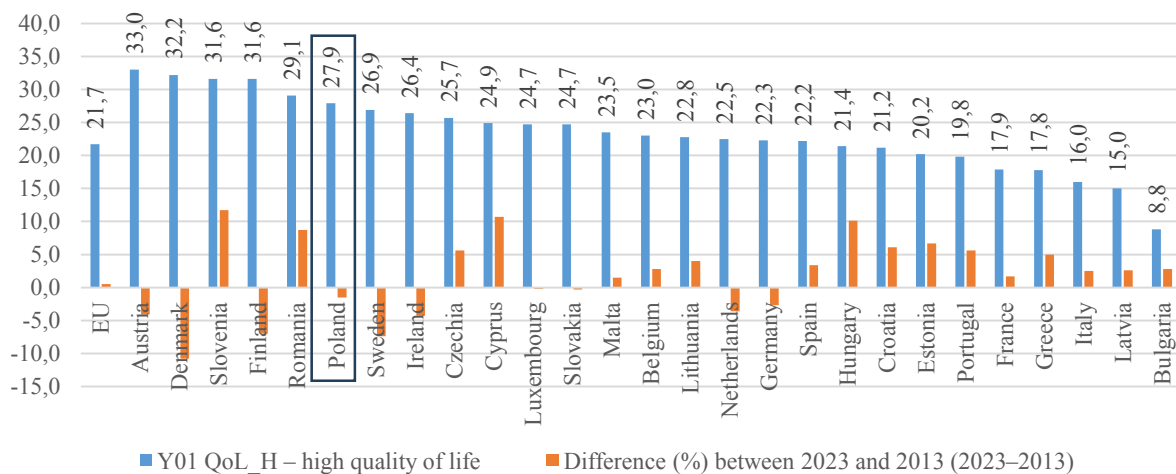


Figure 5. Ranking of EU Member States characterised by a high quality of life (Y01 QoL_H) in 2023 and changes in respondents' opinions over the period 2013-2023.

Source: authors' own calculations based on Eurostat (2025).

In Central and Eastern European countries, the proportion of individuals assessing their quality of life as high has increased, which indicates an improvement in living conditions and socio-economic circumstances. In many Western European countries, the indicators have remained at a high level, confirming their stability. However, a decline in life satisfaction in countries that previously recorded the highest values (including Denmark, Finland, Austria, Sweden, and Ireland) is a cause for concern, as it may reflect rising expectations or growing dissatisfaction. The lack of a clear increase in the EU average nevertheless suggests that progress has been uneven. An improvement in the “new” EU Member States constitutes a positive signal for cohesion policy; however, deteriorating sentiments in some Western European countries may generate tensions. Therefore, policymakers should not only support less developed regions but also ensure the maintenance of well-being in the most developed countries.

1.3. ANALYSIS OF THE RELATIONSHIP BETWEEN ECONOMIC SECURITY (ES) AND QUALITY OF LIFE (QOL)

Based on the conducted analysis, it was demonstrated that a high quality of life (Y01 QoL_H) is significantly positively correlated with income, confirming that higher income levels are conducive to better assessments of quality of life. At the same time, strong negative correlations were observed between high quality of life and indicators reflecting a difficult economic situation, such as the risk of poverty (X06), difficulties in covering unexpected financial expenses (X07), and income inequality (X08). In the case of low quality of life (Y03 QoL_L), opposite relationships are observed – low quality of life is significantly positively associated with poverty, income inequality, and financial difficulties, and negatively associated with income levels. By contrast, medium quality of life (Y02 QoL_M) does not exhibit statistically significant relationships with the analysed economic variables (Table 4).

Table 4.

Relationships between independent variables describing economic security of the population (ES) and dependent variables reflecting the assessment of quality of life (QoL)

Variables	Correlation coefficients							
	X01	X02	X03	X04	X05	X06	X07	X08
Y01 QoL_H	0.35	0.41*	0.39*	-0.52*	-0.33	-0.63*	-0.49*	-0.61*
Y01 QoL_M	0.12	0.15	0.18	-0.15	-0.11	-0.13	-0.23	-0.16
Y01 QoL_L	-0.35	-0.41*	-0.42*	0.49*	0.33	0.56*	0.53*	0.57*

Notes: correlation coefficients marked with an asterisk (*) are statistically significant at $p < 0.05$; $N = 27$ (cases with missing data were excluded); Explanations of variables ES and QoL are provided in Table 1.

Source: authors' own calculations based on Eurostat (2025).

In addition, a multiple regression analysis was conducted between the independent ES variables (X01-X08) and the dependent variable Y01 (Y01 QoL_H), representing a high quality of life. The summary statistics indicate that the regression model achieved a moderate strength of association ($R = 0.73$). The coefficient of determination R^2 equals 0.53, which means that approximately 53% of the variability in the assessment of high quality of life can be explained by the economic security variables included in the model. However, after accounting for the number of predictors and the sample size, the adjusted R^2 decreases to 0.32, indicating that only 32% of the variance in the dependent variable is actually explained by the model. The F-statistic $F(8,18) = 2.56$ with a p-value of 0.05 indicates that the model as a whole is statistically significant at the borderline level; therefore, it can be assumed that a relationship exists between at least one independent variable and quality of life. In summary, the model explains part of the variation in the assessment of quality of life, but it also leaves considerable room for other factors that were not included in this study (Table 5).

Table 5.

Summary statistics of the multiple regression analysis between independent variables describing the economic security of the population (ES) (X01-X08) and the dependent variable Y01 QoL_H – high quality of life

Statistic	Multiple R	Multiple R ²	Adjusted R ²	F(8,18)	p-value	Standard error of the estimate
Value	0.73	0.53	0.32	2.56	0.05	4.63

Source: authors' own calculations based on Eurostat (2025).

The comparison of economic security and quality of life allows for a more comprehensive understanding of the real living conditions of societies and facilitates more accurate formulation of socio-economic policy. It reveals situations in which favourable material indicators are not accompanied by a high quality of life, pointing to hidden problems such as inequality, lack of stability, or high living costs. Combining objective and subjective data helps to better identify areas of exclusion and instability and to design support programmes that address not only material needs but also psychological and social ones. Such an approach supports the development of more balanced strategies for development and poverty reduction.

1.4. POLICY AND PRACTICAL IMPLICATIONS

The obtained results indicate the significant role of economic security in shaping the quality of life of residents in the European Union countries, which has direct implications for socio-economic policy. In particular, public actions should focus on strengthening the financial stability of households by reducing poverty, decreasing income inequalities, and increasing the economic resilience of the population to unexpected expenses. Such policies may include, among others, the development of income support instruments, improving access to stable employment, and implementing measures aimed at enhancing the financial security of households.

The results of the study also indicate the need to further strengthen socio-economic cohesion between EU countries and regions. The persistent differences in the level of economic security and quality of life justify the continuation of cohesion policy measures aimed at supporting the development of less economically developed economies and reducing development disparities. At the same time, the process of designing public policies should take into account both objective economic indicators and subjective assessments of quality of life, which allows for a better diagnosis of social needs and the creation of more comprehensive development strategies.

Conclusions

The study revealed considerable variation in economic security across the EU – highest in the Netherlands, Belgium, Luxembourg, Austria, and Finland, and lowest in Bulgaria, Greece, Romania, Latvia, and Lithuania. In the years 2022–2023, a reduction in this variation was observed, indicating a gradual convergence of living conditions. Quality of life also improved, as evidenced by a declining share of individuals assessing it as low, with Poland ranking above the EU average. Convergence is particularly visible in Central and Eastern Europe; however, in several highly developed countries (including Denmark, Austria, and Finland), life satisfaction declined, which may reflect rising expectations or the impact of global crises. The largest disparities continue to concern the negative aspects of quality of life. The analysis of the relationship between the economic security of the population and quality of life in EU countries confirmed the stated hypothesis. Higher levels of income and consumption, lower income inequality, and a reduced risk of poverty significantly contribute to better assessments of quality of life, whereas indicators reflecting a difficult economic situation – such as poverty risk, high income inequality, and difficulties in meeting unexpected expenses – are strongly associated with low quality of life. The findings indicate that economic security has a significant, though not exclusive, impact on quality of life, and that combining material and perceived perspectives allows for a more comprehensive understanding of the complexity of living conditions and provides valuable guidance for designing more accurate and comprehensive socio-economic policies. The results underscore the need to reduce inequalities and strengthen citizens' financial stability, as well as the importance of an integrated socio-economic policy that combines objective conditions with subjective perceptions in order to more effectively counteract exclusion. From a scientific perspective, they also point to the need for further research into the role of non-financial factors in shaping quality of life.

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CONDITIONS AND CHALLENGES OF MANAGING DEVELOPMENT INVESTMENTS IN POLAND IN THE FACE OF CONTEMPORARY CHANGES IN THE ECONOMIC ENVIRONMENT

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Purpose: To assess the conditions and mechanisms of development investment management in Poland in the context of changes in the economic environment. The aim of the study covered the theoretical principles of investment management as well as the practical aspects of assessing the directions of public spending in conditions of uncertainty and volatility.

Design/methodology/approach: The study used critical analysis of the literature on the subject, comparative analysis and time series analysis using selected descriptive statistical methods in the field of empirical and statistical data in a generic and territorial system according to selected categories of public sector entities.

Findings: The importance of public investment was highlighted and the methodological conditions for distinguishing development expenditure were identified. Through the perspective of the classification of development expenditure, the possibilities for improving strategic management methods to strengthen the effects of socio-economic development were assessed. The directions and intensity of spatial differences in investment potential in regions in Poland were determined, considering changes in the economic environment.

Research limitations/implications: The results are limited by the availability of empirical data in public statistics. Due to the currently observed factors of socio-economic instability, it is advisable to resume data updates and further analyses.

Practical implications: The practical dimension of the analysis refers to possible applications in the preparation of diagnoses and socio-economic development plans at various levels of public administration.

Social implications: The results of the research may provide information for public sector entities to support public investment programming processes in order to achieve socio-economic cohesion, reduce social disparities and development potential.

Originality/value: The paper presents the results of analyses concerning the improvement of strategic management methods in the area of public investment in response to changing crisis phenomena affecting the national economy and the capacity of selected components of the economy to undertake investment expenditure. The territorial approach used provides up-to-date knowledge that can be used in further detailed scientific research and in the decision-making process concerning investment policy at national and regional level.

Keywords: public management, investment, regional development, public sector.

Category of the paper: research paper.

1. Introduction

Contemporary investment process management in Poland takes place in a dynamically changing economic environment and crisis conditions. The continuing unfavourable changes in investment activity in the economy, affecting both the public sector and private sector investments, generate the need to give appropriate priority to the management of development investments in Poland in the current short-term as well as in the long-term strategic period. Development investments, understood as activities aimed at long-term growth of socio-economic potential, are an important element of the development strategies of the state and local government units.

The aim of this paper is to assess the conditions and mechanisms of development investment management in Poland in the context of changes in the economic environment. The subject of the study covered both the theoretical foundations of investment management and the practical aspects of assessing the directions of public spending in conditions of uncertainty and volatility. The analysis is based on the use of various research methods, including a review of the literature on the subject, strategic documents, selected studies and public statistics (e.g. GUS, AMECO), time series analysis using selected descriptive statistics methods, and comparative analysis.

The time horizon presented in the paper covers the period from 2015 to 2024. This period was chosen as it reflects the dynamics of the changes occurring in the economic environment and the deterioration of the public finance sector due to the economic consequences of the Covid-19 pandemic, the military conflict in Ukraine, and the growing threat of spreading hybrid warfare.

2. Conditions for managing investment processes and development investments against the backdrop of challenges and changes to the economic environment in Poland: a literature review

An investment project can be defined as the comprehensive material scope of a tangible investment (development objective), which is planned for implementation at a specific time and in a specific place for a specific purpose. According to this definition, some researchers consider the concept of an investment project to be a document or study that forms the basis for the implementation of an investment (Borowiecki, 1995; Brzozowska, 2003). Therefore, a project is a process-based representation of an investment, defining a set of activities related to the commencement of the investment and then operating the project until its closure. A permanent element of the project is the documentation and procedures that precede the commencement of

the investment and facilitate the decision to implement or reject the project (Rogowski, 2013; Kawa, Wydymus, 1998).

In classical terms, investment management comprises three basic phases, i.e. project preparation, implementation and control of results. Each of these phases requires the use of appropriate analytical, financial and organisational tools. Particular importance is attached to risk analysis and the assessment of the economic and social effectiveness of investments (Olszowy, Sepioło, 2023). In the literature on the subject, development investments are defined as long-term projects aimed at improving the quality of life, increasing competitiveness and promoting the sustainable development of regions and countries (Mieleszko, 2021).

The economic significance of the public sector stems largely from its role as an important driver of socio-economic development. The scope of competences and responsibilities of public sector entities extends to many areas of investment activity, supporting the creation of favourable conditions for development in the short and long term (McCartney, 2015). The activities of public sector entities and organisational units, both governmental and local government, should be directed towards achieving the overarching strategic goals of the entire socio-economic system, and in this context, the issue of investment activity management and its effectiveness in this sector should be examined (Miłaszewicz, 2014; Jarosiński, Opalka 2016). In view of the factors mentioned above that shape the level of instability of economic conditions, the importance of a strategic approach to public investment is increasing, and it is justified to undertake a quantitative analysis of public expenditure at the level of government, regional and local administration, which could confirm the importance of developing new approaches for better management of public resources.

In Poland, investment process management is strongly linked to regional policy and European Union structural funds. Instruments such as the National Recovery Plan and EU cohesion policy operational programmes form the basis for financing many infrastructure, social and environmental projects. At the same time, changing macroeconomic conditions, such as inflation, exchange rate volatility, volatility in the prices of strategically important raw materials and geopolitical tensions, influence investment decisions and require a flexible approach to management (Jarosiński, 2025). Contemporary approaches to development investment management also consider aspects of participation, sustainable development and innovation. The role of stakeholders in the decision-making process, both public institutions and local communities, is increasingly emphasised (Lipiński et al., 2025). Investment management is becoming not only a technical process, but also a political and social activity. In this context, it is worth emphasising once again that the concept of development investments should be defined in close connection with activities that are aimed at long-term growth of socio-economic potential.

The economic activity of public sector entities should contribute to improving the welfare of society, but the conditions governing the functioning of this sector are complex and extend beyond strictly economic issues. The macroeconomic and macrosocial level concerns the

management of the entire economy and the effects created by the public sector as a whole (Kleer, 2005). Investment process management refers to planning, financing and implementation, which requires the use of specific measures of expenditure and results achieved. In the public sector, the effects of the various tasks carried out have both a quantitative and qualitative dimension, which often makes it difficult to measure them directly and sometimes causes problems of immeasurability in terms of numbers (Sawant, 2010; Satoła, 2017). Therefore, it is important to have the competence to select the appropriate evaluation measures and correctly interpret the results obtained.

From the perspective of the government and local government sector, when planning budget expenditure for development purposes, it is important to construct and implement budgets in a way that optimises the effects achieved through the expenditure of funds in terms of the tasks that should be performed for the state, society and the economy. An information system that ensures precise monitoring of the programming, planning and implementation of these expenditures can be considered the basis for optimal budgeting of development expenditures. Such a system should also enable comprehensive identification of the effects, where they occur, identification of the beneficiaries of development expenditure, monitoring and empirical data for the purpose of assessing the effectiveness of the use of funds allocated from the budgets of government and local government institutions for development purposes (GUS, 2020).

Recognizing the need to improve the process of implementing development activities by public sector entities at various levels of management, Poland has attempted to create and implement a system for monitoring development expenditure that could support management processes. The proposed system made it possible to observe the variation in the amount of development expenditure incurred by the government and local government sector as a whole, as well as by individual institutional sub-sectors. The theoretical basis for identifying and separating expenditure for development purposes was the methodological approach proposed in the study by M. Bitner and J. Sierak 'Classification of development expenditure and its application to the budget expenditure of local government units' carried out as part of the activities of the Ministry of Investment and Development – currently the Ministry of Funds and Regional Policy (MFIPR). In accordance with the adopted methodology, development expenditure was defined as '... funds spent as part of the state's development policy by government and local government institutions for entities not belonging to this sector, leading to positive socio-economic changes, in particular an increase in competitiveness, productivity, and enhanced social and economic cohesion' (Bitner, Sierak, 2017).

The practical dimension of the concept of monitoring development expenditure was implemented in a research project carried out by the Central Statistical Office entitled 'Development of a system for monitoring development expenditure, including calculations of development expenditure for the government and local government sector broken down by institutional sub-sectors'. The aim of the project was to create an integrated IT system for monitoring development expenditure and to develop a calculation methodology for the

government and local government sector. It was assumed that the implementation of the development expenditure monitoring system would serve to better target public funds spent on the national development (GUS, 2020).

The research work focused on providing access to an innovative classification of statistical data describing the development expenditure of the government and local government sector broken down by institutional sub-sectors. The formula for the availability of data organised in a systematic manner can constitute an information resource supporting public resource management processes and, consequently, facilitating development activities undertaken by various entities at different levels of management. It also constitutes a comprehensive solution, limiting the dispersion of information and promoting tools for improving the efficiency of public spending, including European funds (GUS, 2020).

The general assumption adopted in the Classification of Development Expenditure (CDE) concept is to demonstrate that the impact of the redistribution of budgetary funds by government and local government institutions on maintaining and stimulating social and economic development in accordance with the objectives of development policy is achieved through the support of specific public tasks. The determination of the level of development expenditure is interpreted as a measure of its importance or effectiveness in relation to the development policy pursued, the type or area of activity financed from public funds, broken down by economic category. The expected practical effect of introducing the system is to improve the planning of public expenditure allocated to the country's development within the framework of individual regional strategies, as well as its allocation in areas such as transport, infrastructure, health care and education (Bitner, Sierak, 2017).

The economic environment is a key context for investment decisions. In Poland, as in other developing countries, the volatility of macroeconomic, regulatory and institutional conditions affects the effectiveness and direction of development investments. In recent years, significant changes in the structure of the economy have been observed, which determine new approaches to investment management (Opalka, 2024). The Polish economy has undergone a number of significant changes, from political transformation and integration with the European Union to the challenges and crises associated with the Covid-19 pandemic and the war in Ukraine. Since 2004, as a member of the European Union, Poland has been subject to the influence of EU policies, including the European Green Deal, the digitalisation strategy and innovation policy. Global trends such as decarbonisation, automation and demographic change present both opportunities and threats for development investments. In addition, geopolitical tensions, changes in supply chains and growing international competition require investment managers to take a strategic approach and be adaptable. In this context, scenario analysis and the assessment of projects' resilience to changes in the environment are becoming increasingly important. Rising inflation, exchange rate volatility and increasing energy costs affect investment calculations and require greater flexibility in project planning.

The regulatory environment in Poland is dynamic and subject to frequent changes, which may constitute a barrier for investors. Changes in tax law, administrative procedures and public procurement rules affect investment risk. At the same time, instruments supporting investment are being implemented, such as tax relief, European funds and government programmes. The structure of investment demand is also changing due to the growing importance of the service sector, the digitalisation of the economy and the development of information technologies, with projects related to digital infrastructure, green transformation and social innovation playing an increasingly important role. An important element of the institutional environment are regional development strategies and planning documents at the national level, including the National Development Concept 2050, the National Regional Development Strategy 2030 and the National Urban Policy 2030. Their updating and the possibility of maintaining the consistency of local investment plans with the above documents are crucial for effective project management (Opalka, 2025a).

Despite differences between regions, which are often the result of long-standing economic and demographic phenomena and thus shape the autonomy of regional development conditions, the fundamental research and planning problem remains the financing of investments. In terms of the state's economic system, the main source of financing for public sector investments should be own funds collected and spent within the budgets of the relevant entities (Dworakowska, 2015). The structure of public sector entity budgets has been adopted as an important instrument for identifying factors determining investment opportunities, due to the direct dependence of budget revenue sources on the state of the economy in various territorial contexts. This situation is the result of previously established development processes, often with a regional or even local dimension, and also determines the possibilities of obtaining external funding under programmes financed or co-financed by EU funds. Among the above conditions, the phenomenon of financial barriers is becoming increasingly common, affecting the ability to obtain resources for the proper implementation of investments (Kollatz-Ahnen, Roick, 2018).

Based on the results of previous studies, it can be assumed that Poland has experienced a persistent shortage of budgetary funds that could be used by public sector entities to finance development tasks (Cenkier, 2016; Opalka, 2020). Using the observations contained in the above-mentioned studies concerning investment needs and budgetary funds allocated to investments by the above-mentioned entities, it can be concluded that in the public sector, both at the national and regional levels, there are many difficulties in implementing statutory tasks.

This was also confirmed by research conducted by M. Bitner and J. Sierak (2022), which showed high dynamics of changes in the basic financial indicators examined in the area of budgetary management of local government units. It was observed that in the period 2018-2020, there were unfavourable changes, which intensified especially during the Covid-19 pandemic. Simulations of future cash flows carried out as part of the above research, in four scenarios

extending to 2029, clearly show that in many local government units, maintaining the previously achieved level of investment will only be possible if there is a significant reduction of current expenditure growth (Bitner, Sierak, 2022).

Referring to practical conditions in Poland, it can also be noted that a typical phenomenon in times of crisis is the emergence of multidirectional changes in the public sector concerning investment financing, with the effects of crisis factors appearing in investment budgets with some delay, which may require the completion of investments that have already been started, even under crisis conditions. It is also important at this point to address the methodological consideration of incorporating autocorrelation phenomena into the analysis of time series relating to public investment and development expenditure. Autocorrelation, which is related to two distinct dimensions (temporal and spatial), is a key tool in the analysis of public investment expenditure, as it allows relationships that are missed by classical linear models to be captured.

Examining autocorrelation in the temporal dimension provides an assessment of whether public investments, particularly those implemented by local government units, demonstrate durability, cyclicity or decision-making inertia. Positive first-order autocorrelation ($ACF(1)$) indicates e.g. a strong correlation between current and previous expenditure, reflecting the continuation of multi-year projects and stable investment policy. In Poland, electoral cyclicity is noticeable, with an increase in expenditure in the years preceding local government elections, while fluctuations resulting from the absorption of EU funds are also a significant factor.

Spatial autocorrelation, on the other hand, enables clusters of municipalities with similar investment or development expenditure levels to be identified, and allows it to be assessed whether expenditure is concentrated in specific areas or spread to neighbouring units. As Kopczewska (2017) notes, these relationships are described by a spatial weight matrix W , which is most often based on the criterion of a shared border. The spatial lag, which is calculated as the average in neighbouring areas weighted by the W matrix, is then compared with the value in the examined region. The presence of positive spatial autocorrelation indicates clustering of phenomena and a lack of spatial independence, which is important when analysing the diffusion of development processes, migration and agglomeration effects (Smętkowski, 2011). The diverse endowment of municipalities with fixed assets generates complex economic processes that cannot be analysed without considering neighbourhood effects.

The financial autonomy of local government units, together with the principle of subsidiarity, means that investment decisions are made locally and are not subject to simple macroeconomic mechanisms (Kopczewska, 2017). Investment determinants stem from the financial capabilities of municipalities, their access to external financing, and the assessment of development needs and the effects of previous actions. These processes are most often modelled using panel methods, including dynamic models with time and space lags (Rios et al., 2017). Spatial effects resulting from spatial autocorrelation can be controlled by incorporating spatial lags into the models for the dependent variable, explanatory variables, and error terms (Elhorst,

2010). The cumulative nature of fixed assets and the multi-year lags in the impact of investments pose a challenge, requiring an appropriate understanding of their sustainability and complementarity. In practice, however, models often operate on nominal annual expenditure, taking into account only a few time lags. This highlights the complexity and multidimensionality of local investment analysis (Fleming, Measham, 2014).

The results of the empirical study presented in this paper indicate that investment expenditure in the public sector in Poland remained at a fairly high level, although its share in total investment expenditure in the Polish national economy gradually diminished. Until 2017, the analysed indicator of the share of public sector investment expenditure gradually decreased, and from 2018 onwards, the share of this expenditure began to increase again. The highest share in recent years was achieved in 2020 (36.9%), followed by a decline in subsequent years, although in 2023 the indicator returned to a higher level of 37.8%. In 2024, the level of investment expenditure in the national economy and in municipalities and provinces declined once again.

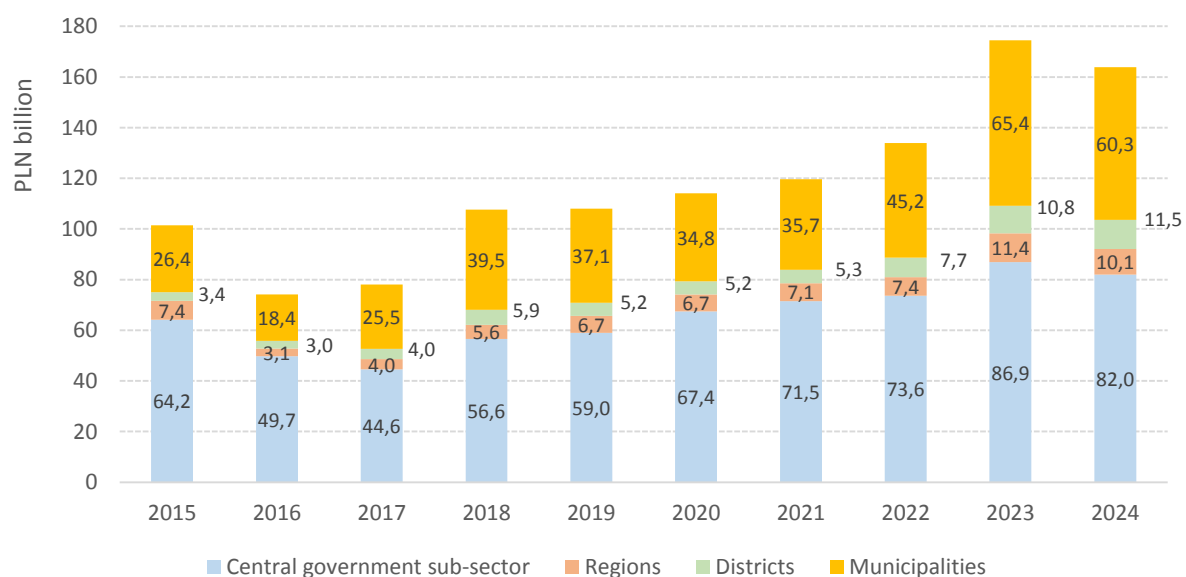


Figure 1. Investment expenditure in selected groups of public sector entities in Poland in 2015-2024 (in PLN billion).

Source: own study based on Local Data Bank of the Central Statistical Office and Macroeconomic Data Bank of the Central Statistical Office data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 2.02.2026.

According to the results of the analysis presented in Figure 1, in the case of the local government sub-sector, the largest share of investment expenditure was accounted for by expenditure incurred by local government units at the local level, including expenditure incurred by municipalities. This is consistent with the adopted division of competences, in which municipalities are responsible for a wide range of public tasks, including those that require specific investment expenditure. However, the government sub-sector plays a significant role, and the coordinated investment policy of both sub-sectors has an impact on socio-economic development.

The results of previous studies (Opalka, 2025b) indicated that the commitment to meeting social needs is permanent, even in times of economic crisis. This requires adapting such management methods in the public sector at the national level, as well as in the regional and local economy, including the search for solutions to improve the management of development expenditure, which should contribute to improving the efficiency of the use of funds for investments, that are even more limited in conditions of economic instability.

3. Development expenditure management using CDE in the context of supporting the quality of planning and implementation of public sector investment projects – research results and discussion

The role and operating principles of the public sector in a society-based market economy determine the importance of a long-term approach to economic development processes in terms of identifying public needs and ensuring that these needs are met on a sustainable basis. A distinctive feature of the public sector is the significant expansion of the structure of strategic objectives, which consequently determines the arrangement of intermediate and detailed objectives, which are usually identified and precisely defined in the strategic planning process. The identification of objectives is further related to the possibility of determining the scope of economic and social tasks, as well as defining development projects. This justifies the need to examine the effects of the projects undertaken, including the risks and benefits associated with their interrelationships, and emphasises the legitimacy of using strategic analysis tools and creating customised strategic project management mechanisms by public sector entities.

The implementation of project management in an economic context can generate benefits mainly related to improvements in the operational tools of public sector entities in terms of strengthening their strategic planning competencies, strategic analysis tools, as well as methods for evaluating projects in financial and qualitative terms. The ability to adapt methods developed in the private sector strengthens the competence of public entities and provides opportunities to focus on economic effects, apply methods of effective project parameterisation, including risk assessment and the effective use of public resources. In view of emerging or growing crisis phenomena in the economy, associated with a reduction in budget revenues, project management can be an important platform for establishing and maintaining cooperation between public sector entities in the form of partnerships with private entities, including organisational cooperation and co-financing of projects, in particular infrastructure investments aimed at supporting development and socio-economic cohesion.

The development expenditure methodology analysed in this paper falls under the concept of development potential management, focusing primarily on the financial resources of state and local government budgets to ensure optimal allocation and the best possible development

outcomes. The key question is which areas of expenditure can be considered appropriate, i.e. those that stimulate the generation of economic or social results corresponding to the objectives of a given development programme or public policy. As an example, reference can be made here to the results of research conducted on empirical data from OECD countries by O. Barbiero and R. Cournède (2013), which indicate that GDP changes in the long term are most strongly influenced by increases in expenditure on education, health care and transport infrastructure. In their analyses, the authors refer to a functional classification system that divides expenditure into productive and unproductive, in line with the concept presented by R. Barro (1990).

Research conducted in Poland by A. Moździerz showed that between 2002 and 2015, healthcare expenditure did not fluctuate significantly, while education expenditure decreased. The author of the above-mentioned study identified increasing expenditure on transport infrastructure as the main driver of potential GDP growth in Poland. The conclusions of the study pointed to a growing overall trend in expenditure on development between 2005 and 2011, which was mainly based on an increase in transport infrastructure expenditure, whose share in total expenditure rose from 4.6% in 2004 to 9.7% in 2011, and which was assessed as a positive phenomenon. However, this situation changed in 2011-2013, when expenditure on transport infrastructure was significantly reduced and potential GDP fell from 4.1% to 2.9%. The reduction in expenditure on basic research to 0.2% of GDP in 2009-2013, as well as the persistently low level of expenditure on research and development during this period, not exceeding 0.3% of GDP, were considered as factors unfavourable to the growth of the economy's potential. The highest volume of pro-development funds was spent on the implementation of the state's functions in the field of education and health care (Moździerz, 2016).

Referring to the presented research results, this paper analyses changes in development expenditure in selected categories included in the CDE classification. This classification can be used as a methodological tool to support the identification, specification and definition of the subject areas of statistical indicators used to measure public sector development expenditure, as well as to measure the economic and organisational effects achieved by public sector organisational units and entities outside this sector.

The CDE concept distinguishes three main levels of expenditure classification. Expenditures classified according to 'Groups' reflect the criterion of importance for development processes, where, based on the chapters of the budget classification, it is possible to classify expenditures into CDE groups according to common characteristics. The second level of classification includes 'Economic Categories', according to which the economic criterion of the type of expenditure is determined, based on the budget classification paragraphs, enabling classification into CDE economic categories. At this level of classification, 'Investments' are additionally distinguished as a specific form of development expenditure. This category includes expenditure on construction investments and the purchase of fixed assets

with an initial value exceeding the value specified in the budget classification, as well as subsidies for financing or co-financing investments carried out by entities outside the government and local government sector. The third level of classification is ‘Tasks’, reflecting the function criterion in development expenditure, where the allocation of expenditure to a specific task is based on the chapters of the budget classification (GUS, 2020).

In the theoretical assumptions, the Classification of Development Expenditure mainly refers to expenditure incurred from national budget funds. The above development expenditure is included in the expenditure implemented in terms of the budgetary economy of the government and local government sector, broken down into the sub-sector of government institutions, local government institutions and social security funds. Table 1 presents the results of the study relating to the scope of changes in development expenditure incurred from national funds, examined in general terms and in the form of ‘investments’, in accordance with the methodology for their identification presented above.

Table 1.

Development expenditure from national funds in 2015-2022

Specification	2015	2016	2017	2018	2019	2020	2021	2022
Total development expenditure from domestic funds (PLN billion)	209.0	214.9	231.3	244.9	267.0	284.1	325.2	366.3
Rate of change in total development expenditure from domestic funds (%)	-	2.8	7.6	5.9	9.0	6.4	14.5	12.6
Development expenditure from domestic funds in the form of investments (PLN billion)	33.3	31.8	35.5	45.0	43.3	46.5	51.2	68.2
Rate of change in development expenditure from domestic funds in the form of investments (%)	-	-4.5	11.8	26.5	-3.7	7.6	10.0	33.1
Share of development expenditure from domestic funds in the form of investments in total development expenditure from domestic funds (%)	15.9	14.8	15.4	18.4	16.2	16.4	15.7	18.6

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 12.11.2025.

The data presented indicate an acceleration in the growth rate of total development expenditure in 2015–2022. The change in relation to previous years amounted to as much as 14.5% in 2021 and 12.6% in 2022. In the case of investment development expenditure, the rates of change varied greatly, with declines even recorded in 2016 (-4.5%) and 2019 (-3.7%). A significant improvement in the rate of change occurred from 2020, and in 2022, the value of the indicator under study increased to 33.1% compared to the previous year.

The analysis also highlights regional differences in selected indicators. Figures 3 and 4 present a graphical interpretation of the indicator of total development expenditure and investment development expenditure per capita by region for 2019 and 2022.

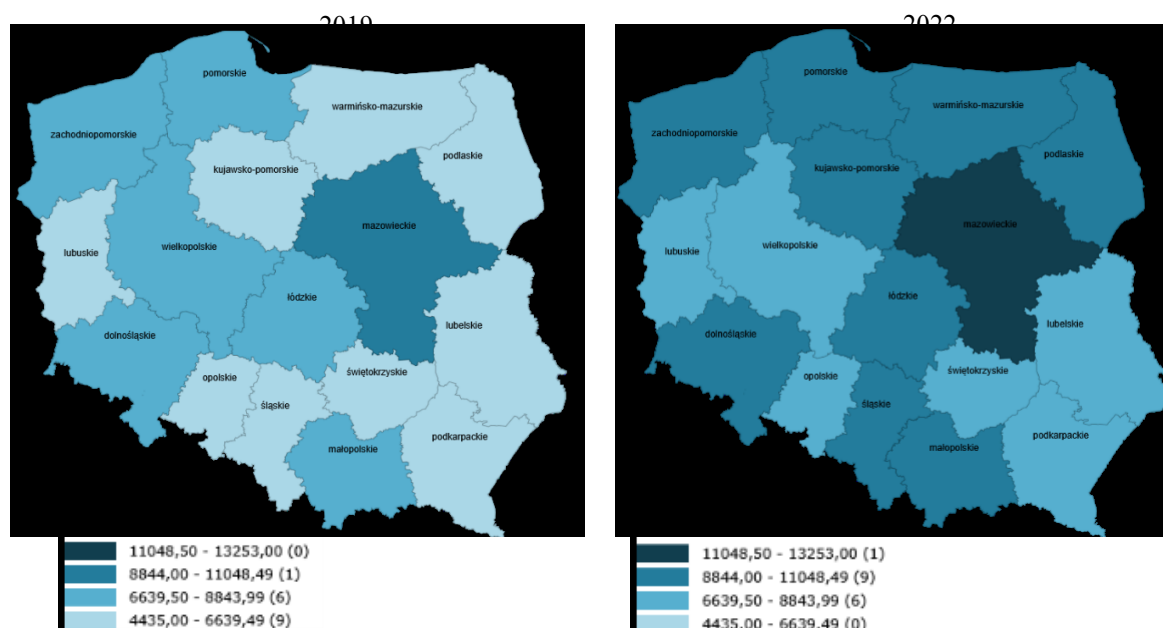


Figure 3. Total development expenditure from national funds per capita by region in Poland (PLN).

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 12.11.2025.

Between the two periods analysed, there was a significant increase in the level of total development expenditure per capita, particularly noticeable in the Mazowieckie region and in the central and northern regions. There was also a marked increase in the number of regions where the indicator reached relatively high values. In 2022, nine regions recorded values exceeding PLN 8830, whereas in 2019 only the Mazowieckie region had values in this range.

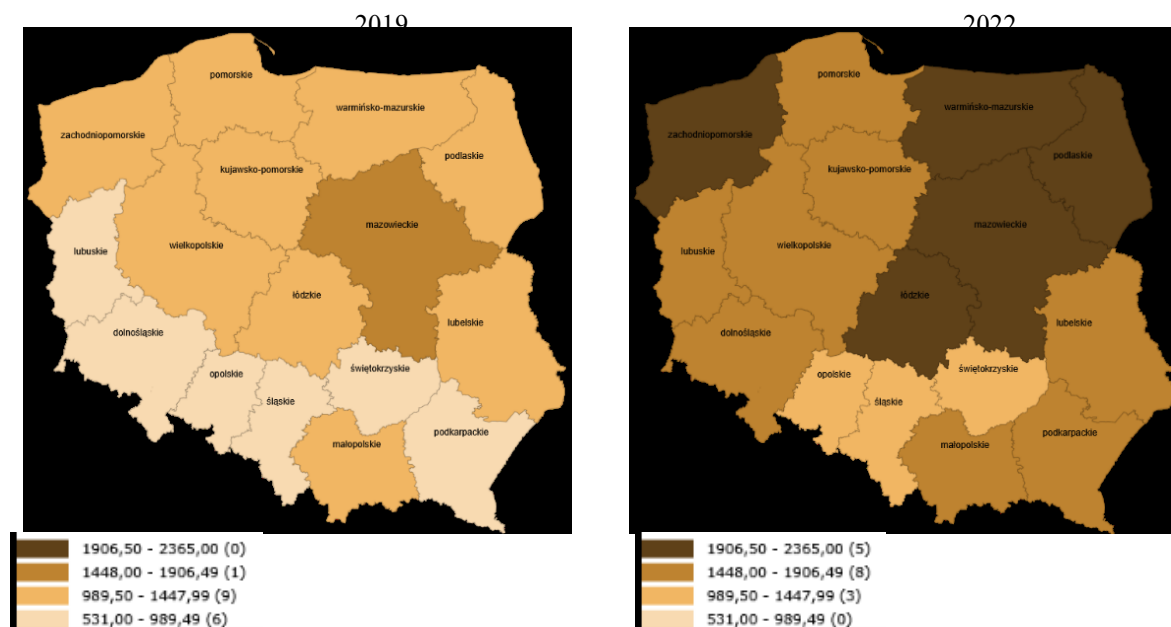


Figure 4. Development expenditure from national funds in the form of investments per capita by region in Poland (PLN).

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 12.11.2025.

The development expenditure indicator in the form of investments per capita in 2019 was highest in the regions in the central and northern parts of the country. This phenomenon intensified in 2022, with a higher concentration of high values of the indicator in the regions of Łódź, Mazovia, Warmia-Masuria, Podlasie and West Pomerania. A distinctly unfavourable situation in terms of the indicator value persisted in the Opole and Świętokrzyskie regions, but also in the Silesian region.

In 2015-2022, there was a significant increase in development expenditure on a nationwide scale, from PLN 209 billion to PLN 366.3 billion. The largest volume of expenditure was realised in group III, 'Economic and social base conditioning the implementation of development policy', where expenditure reached PLN 189.3 billion in 2022. The second group with a high level of expenditure was 'Physical, human and social capital key to development processes (II)', where PLN 135.7 billion was spent in 2022.

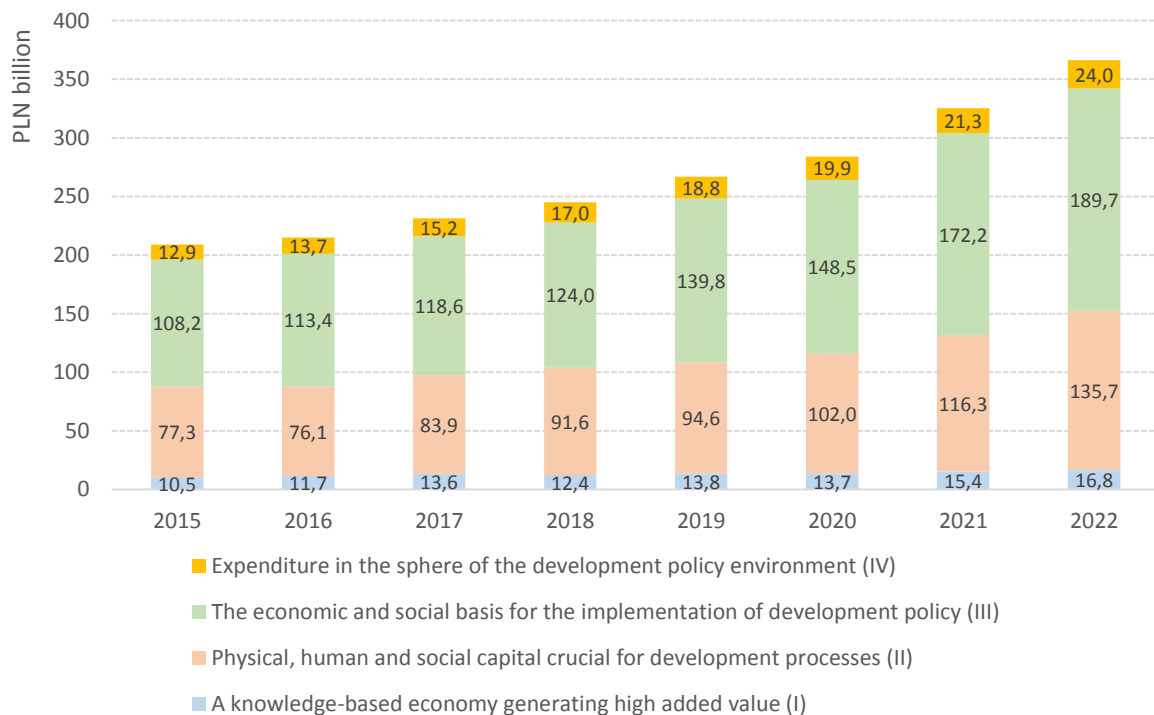


Figure 5. Development expenditure from national funds by group in 2015-2022 (PLN billion).

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 3.11.2025.

Despite the overall upward trend observed in each of the four expenditure groups, the rates of change in the period 2015–2022 varied significantly. As shown by the calculations presented in Figure 5, the most stable growth was recorded in group IV, 'Expenditure in the area of development policy environment', with an average annual rate of change for this group of 9.27%. The greatest volatility was observed in the expenditure group 'High value-added knowledge-based economy (I)', where significant fluctuations in the rate and direction of change were particularly evident in 2017-2020, with an average annual rate of change of 6.99%.

The years 2021-2022 were a clear period of stabilisation in all the groups studied, with relatively high growth rates compared to the previous year.

The analysis conducted in the sub-sector structure indicated the leading role of the local government institutions sub-sector in the implementation of total development expenditure. As shown in Table 2, the volume of development expenditure incurred by the above-mentioned group increased in the analysed period from PLN 130.1 billion to PLN 235.3 billion, which represented a change of 179.9%. An increasing trend was also observed in the central government sub-sector, where the change between 2015 and 2022 reached 177.6%. In contrast, development expenditure by entities in the social security funds sub-sector showed a year-on-year decline in some periods and a significantly lower overall level of expenditure compared to the other two sub-sectors.

Table 2.

Development expenditure from national funds in 2015-2022

Specification	2015	2016	2017	2018	2019	2020	2021	2022
Central government sub-sector	64.3	64.7	71.8	75.5	83.0	86.3	102.5	114.8
Local government sub-sector	130.1	135.0	143.3	153.3	170.2	182.0	207.1	235.3
Social security funds sub-sector	14.6	15.2	16.3	16.1	13.8	15.8	15.6	16.1

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 3.11.2025.

The results of the analysis indicate minor changes in the structure of total development expenditure by sub-sector. In 2015-2022, over 60% of development expenditure was incurred at the level of local government institutions, and this share gradually increased, reaching 64.2% in 2022. A similar increase in the share indicator was recorded in the case of the government institutions sub-sector, with the value of the above-mentioned indicator slightly exceeding 30% throughout the entire period under review. At the same time, the share of the social security funds sub-sector decreased, where, with a significantly lower volume of expenditure, this share fell from around 7% at the beginning of the period analysed to just 4.4% in 2022.

Recognising the significant role of development expenditure implemented by local government units, particularly municipalities, a scenario analysis of changes in expenditure levels within the local government subsector was undertaken. This allows for the estimation of further changes in periods for which statistical data are no longer published. Table 3 shows the expenditure recorded, as well as the expenditure projected for 2023-2024, calculated using the average annual rate of change in development expenditure between 2016 and 2022.

The comparative scenario was based on rate-of-change indicators relative to the previous year, calculated for total budget expenditure incurred by municipalities, districts and regional governments between 2016 and 2024. This reflects expenditure dynamics across the entire local government institution subsector in Poland. As emphasised in this paper, development expenditure goes beyond investment expenditure in budget classification terms, encompassing a broader scope of financing tasks that influence development processes in the economy. Socio-economic instability often leads to an increase in current, emergency budget expenditure,

reflecting emerging threats or the need for public intervention. Therefore, the rate of change in total budget expenditure can be used to forecast changes in the value of development expenditure, reflecting the actual potential for local government units to engage public financial resources. The base point for the included forecast was the level of development expenditure achieved in 2015; then, the expenditure estimates for subsequent years were calculated by multiplying the expenditure values by the relevant rate of change indicator for each year.

Table 3.

Scenario analysis with a forecast of total development expenditure from domestic funds in the local government subsector in 2015-2024

Specification	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total development expenditure incurred (in PLN billions)	130.1	135.0	143.3	153.3	170.2	182.0	207.1	235.3	256.3*	279.1*
Rate of change in total development expenditure (%)	-	3.8	6.1	7.0	11.0	6.9	13.8	13.7	8.9**	8.9**
Rate of change in total budget expenditure (%)	-	4.9	11.7	12.7	8.0	6.8	5.6	12.0	8.8	12.3
Development expenditure scenario according to the rate of change in total budget expenditure (in PLN billions)	130.1	136.5*	152.4*	171.8*	185.6*	198.2*	209.3*	234.4*	255.0*	286.3*

* - forecasted values

** - average annual rate of change in development expenditures in the period 2016-2022.

Source: own study based on Local Data Bank of the Central Statistical data. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 19.03.2026.

The results obtained indicate that, assuming the adopted scenario, total development expenditure in the local government sector would have been significantly higher and exhibited a faster growth rate until 2020. From 2021 onwards, development expenditure increased faster than total budget expenditure. However, the collection and publication of development expenditure data in statistical form was suspended from 2023 onwards. According to the method adopted for the 2023-2024 forecast, based on the average annual rate of change, the expected level of development expenditure in 2024 would have been lower than the corresponding value obtained using the annual rate of change of total budget expenditure.

The use of the CDE classification at the central level of state administration by entities with competences in shaping development and allocating financial resources can significantly improve the rationality and effectiveness of budgetary resource distribution. At the same time, determining the priorities for expenditure on various objectives, dividing them into optional and mandatory development objectives and 'non-development' objectives remain current and important decision-making issues. As indicated by the observations contained in the submitted

paper, this shapes the scope and quality of the implementation of public tasks and development programmes financed through the budgets of government and local government units, and at the same time contributes to the maintenance and growth of the existing social and economic potential in a particular territory.

4. Summary

The continued socio-economic instability in Poland is creating barriers to financing investments in the national economy. In practice, this means that there are more frequent cases of aversion to investing in the private enterprise sector, as well as a change in attitude towards public investment, especially in highly capital-intensive projects. Despite the crisis phenomena observed earlier and the current economic instability, entities classified as part of the public sector at the central, regional and local levels have carried out a significant range of investment activities. Thus, despite political and economic turbulence, these entities have strengthened their role as important participants in economic processes, sharing responsibility for stabilising development processes and improving the living conditions and economic activity of local communities.

The European Union's cohesion policy is implemented in accordance with the principles of strategic planning and through the implementation of programmes covering the financing of development expenditure from public, government and local government budgetary funds. However, given the complex structure of public objectives, there is a need to improve the management of development investments, which requires a strategic approach and flexibility in government and local government institutions. Key challenges are identified at the strategic planning level, covering the most important stages identified in strategic management methodologies, i.e. prioritisation of objectives, coordination of multiple projects, and optimisation of resource use. The current situation and forecasts for further development also indicate a continuing strong need to develop the competences of administrative staff and beneficiaries and to continuously improve management tools.

In developed economies that are open and knowledge-based, development expenditure determines a country's economic and social potential in the medium and long term, as well as the level of efficiency and competitiveness of the economy. Development expenditure incurred by the government and local government sector, which is meso- and macroeconomic in nature, is particularly significant. Based on the analysis, it can be assessed that the use of the Classification of Development Expenditure in Poland is in line with the favourable conditions contributing to economic and organisational effects, the final beneficiaries of which are society and economic entities outside the public sector. The possibilities for the practical application of the CDE as a universal methodological tool using statistical indicators for planning, measuring

and evaluating public expenditure aimed at achieving the above-mentioned effects should also be assessed positively. The presented results of the empirical study based on the use of the CDE system made it possible to assess the differences in selected aspects of the allocation of total development expenditure for Poland and in the territorial breakdown of regions.

The results of the study also lead to the conclusion that achieving the best possible long-term resource management results involves the need to implement appropriate management processes not only strictly for investments, but also for development expenditure, taking into account current conditions and future financial possibilities. Effective management contributes to long-term social and economic benefits, which reflects the concept of development expenditure as a tool of national development policy.

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ENVIRONMENTAL AWARENESS OF YOUNG CONSUMERS: THE GAP BETWEEN ATTITUDES AND BEHAVIOUR WITH THE PERCEPTION OF ENVIRONMENTALLY ORIENTED COMPANIES

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Purpose: The purpose of this paper is to examine the level of environmental awareness among young consumers and to identify the gap between their pro-environmental attitudes and actual consumption behavior. The study also explores whether perceptions of environmentally oriented products extend to broader evaluations of companies, including their overall corporate image.

Design/methodology/approach: The study adopts a quantitative research design based on a structured questionnaire administered to a convenience sample of 172 young consumers in Croatia. The survey measures environmental awareness, attitudes towards eco-labelled products, purchasing frequency, perceived barriers and motivators of sustainable consumption, and includes open-ended questions for qualitative insights. Data are analyzed using descriptive statistics, while qualitative responses are used to support interpretation. The paper is positioned within the theoretical framework of sustainable consumption and sustainable business models.

Findings: The results reveal a pronounced attitude–behavior gap. Although respondents express positive attitudes towards environmental protection, eco-labelled products are mostly purchased only occasionally. Product quality and perceived health benefits are the main motivators of sustainable consumption, while higher prices, limited availability, and low trust in eco-certifications represent key barriers. Trust in environmental labels is moderate, with a large share of neutral responses. Qualitative findings indicate that environmentally responsible companies are perceived as more socially desirable, suggesting that eco-branding influences broader corporate image beyond consumption.

Research limitations/implications The study is limited by convenience sampling, a single-country context, and reliance on self-reported data. Future research should use larger and cross-national samples, apply inferential methods, and directly examine links between environmental awareness, green branding, and employer attractiveness.

Practical implications: Companies should reduce price and availability barriers, improve transparency of eco-labels, and align sustainability communication with verified practices. Eco-branding may strengthen corporate reputation among young consumers when supported by credible sustainability actions.

Originality/value: The paper contributes empirical evidence on the environmental attitude–behavior gap among young consumers and extends existing research by linking sustainable consumption patterns with perceptions of corporate environmental orientation.

Keywords: environmental awareness; young consumers; sustainable consumption; eco-branding; corporate image.

Category of the paper: Research paper.

1. Introduction

Issues of sustainable development and environmental protection have gained increasing importance in economic and business discourse over recent decades. Faced with climate change, the depletion of natural resources, and growing regulatory pressures, companies are increasingly oriented towards developing business models that integrate environmental, social, and economic dimensions of sustainability (World Commission on Environment and Development, 1987; Bansal, 2005). In this context, consumer behavior is recognized as one of the key factors shaping market trends and driving changes in corporate business strategies (Geissdoerfer et al., 2018).

Particular attention in the literature is devoted to young consumers, who are often perceived as a more environmentally aware group with greater sensitivity to issues of sustainable consumption. Research indicates that young people express positive attitudes towards environmental protection and support sustainable products and practices (Kokkinen, 2013). However, despite a high level of declared environmental awareness, numerous studies point to the existence of a significant gap between consumers' attitudes and their actual behavior, especially in the context of purchasing environmentally friendly products (Hassan et al., 2010; Perron et al., 2006).

Environmental awareness encompasses knowledge, attitudes, and perceptions of personal responsibility for environmental conditions, as well as the willingness to adapt consumption decisions accordingly (Kokkinen, 2013). Nevertheless, empirical findings show that positive attitudes do not necessarily translate into sustainable behavior, as consumer decisions are often constrained by economic and market factors, such as higher prices of environmentally friendly products, limited availability, and a lack of trust in the credibility of environmental certifications (Geissdoerfer et al., 2018).

Understanding the gap between environmental attitudes and actual behavior among young consumers is particularly important for the development of sustainable business models. Companies seeking to integrate sustainability into their operations face the challenge of aligning

environmental objectives with real consumer behavior and the purchasing power of target groups (Bocken, 2020). Therefore, analyzing the behavioral patterns of young consumers can provide valuable insights into the barriers and motivators of sustainable consumption and contribute to more effective business and market strategies.

Based on the above, the aim of this paper is to analyze the environmental awareness of young consumers and to examine the existence of a gap between their attitudes and actual consumer behavior, with particular emphasis on the factors that hinder the transformation of environmental awareness into concrete purchasing decisions.

2. Literature Review

The concept of sustainable development represents a fundamental framework for understanding contemporary economic and business changes related to environmental protection. According to the definition provided in the Brundtland Report, sustainable development refers to meeting the needs of the present generation without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). This concept has been further elaborated through the integration of environmental, economic, and social dimensions of sustainability, which together form the basis for the development of long-term sustainable business models (Bansal, 2005; Strežov et al., 2017).

In the business context, sustainable business models are increasingly viewed as a response to growing environmental challenges and shifts in consumer preferences. Authors emphasize that integrating sustainability into business models enables the reduction of negative environmental impacts, more efficient resource use, and the achievement of long-term competitive advantage (Geissdoerfer et al., 2018; Bocken, 2020). Particular attention is given to circular business models, which contribute to waste reduction and more rational resource use through recycling, reuse, and extending product life cycles (Bocken, 2020).

A central role in the development of sustainable business models is played by consumer environmental awareness. Environmental awareness is defined as a combination of knowledge, attitudes, and capabilities that guide consumers towards behaviors with a lower negative impact on the environment (Kokkinen, 2013). Research suggests that higher levels of environmental awareness positively influence consumer attitudes towards sustainable products and practices, but not necessarily their actual behavior (Hassan et al., 2010).

Special attention in the literature is devoted to young consumers, who are often identified as a group with heightened sensitivity to sustainability issues. Although young people generally demonstrate a high level of awareness regarding the importance of environmental protection, empirical findings confirm the existence of a gap between their declared attitudes and actual

purchasing decisions (Hassan et al., 2010; Perron et al., 2006). This gap is most commonly explained by economic and market constraints, such as higher prices of environmentally friendly products, limited availability, and a lack of trust in the credibility of environmental labels and certifications.

The literature also emphasizes that awareness alone is insufficient to change behavior without adequate institutional, market, and organizational support. Perron et al. (2006) highlight that continuous education, transparency, and trust are key prerequisites for transforming environmental awareness into sustainable behavior, while Geissdoerfer et al. (2018) warn of the need to align business strategies with consumers' real purchasing capabilities.

Based on the reviewed literature, it can be concluded that although the environmental awareness of young consumers represents an important potential for the development of sustainable business models, its actual market impact depends on the ability of companies and institutions to remove barriers that prevent the consistent application of sustainable consumption decisions. This relationship between awareness and behavior constitutes the central research issue of this paper.

3. Methodology

The empirical research was conducted with the aim of examining the environmental awareness of young consumers and analyzing the gap between their attitudes and actual consumer behavior. A quantitative research approach was applied using a questionnaire survey method.

Data were collected through a structured questionnaire covering questions related to the level of environmental awareness, attitudes towards environmentally friendly products, the frequency of their purchase, and perceptions of barriers and motivators of sustainable consumption. The questionnaire included closed-ended questions and statements measured using a Likert scale, enabling a standardized analysis of respondents' attitudes.

The research sample consisted of young consumers in the Republic of Croatia, with a total of 172 respondents participating in the study (in 2025). A convenience sampling method was used, and data collection was conducted anonymously and voluntarily, in accordance with ethical research principles.

Data analysis was performed using descriptive statistics, including frequencies, percentages, and basic measures of central tendency. The results enabled the identification of dominant attitudes, behavioral patterns, and key barriers contributing to the gap between environmental awareness and actual consumer behavior among young consumers.

The methodological approach used in this study provides insight into the perceptions and behavior of young consumers; however, it also has certain limitations related to the size and structure of the sample and the use of self-reported measures, which should be considered when interpreting the results.

4. Results

The research results are based on the analysis of responses from 172 young respondents in the Republic of Croatia. The analysis focuses on examining the level of environmental awareness, consumer habits related to environmentally friendly products, and perceptions of barriers and motivators of sustainable consumption.

The results indicate that the majority of respondents occasionally purchase products with environmental labels, with 56.4% reporting occasional purchases. A smaller proportion of respondents stated that they rarely purchase environmentally friendly products (25.6%), while 4.7% reported that they do not purchase such products at all. Regular purchases of environmentally friendly products were reported by a relatively small share of respondents, indicating limited frequency of sustainable consumption among young consumers.

As the main motivators for purchasing environmentally friendly products, respondents most frequently highlighted product quality and healthier ingredients (71.5%). Concern for the environment was cited as a motivator by 26.7% of respondents, while other reasons were mentioned to a much lesser extent. These findings indicate that young consumers' motivation for purchasing environmentally friendly products is more strongly linked to personal benefits than to purely environmental considerations.

On the other hand, the results clearly identify barriers limiting more frequent purchases of environmentally friendly products. The most commonly cited barrier was the higher price of environmentally friendly products, indicated by 64.5% of respondents. A lack of trust in environmental certifications and labels was reported by 32.6% of respondents, while 27.3% pointed to insufficient availability of environmentally friendly products on the market. These findings point to the existence of structural and market-related constraints in the application of sustainable consumption.

The analysis of trust in environmental labels shows a moderate level of confidence among respondents. Approximately 39% stated that they generally trust environmental labels, while 40.7% expressed a neutral position. A smaller proportion of respondents expressed distrust towards environmental certifications, indicating an uneven perception of their credibility.

The results also show that respondents perceive their own influence on companies' business strategies as limited but not negligible. More than half of respondents (52.3%) believe that their consumer choices partially influence companies' business decisions, while 19.8% believe they have a significant influence. At the same time, a smaller proportion consider their influence on business strategies to be insignificant.

Regarding willingness to change consumption habits, the majority of respondents express a certain degree of readiness. Partial willingness to change habits for environmental protection was reported by 66.9% of respondents, while 26.7% indicated full willingness to change. A smaller proportion of respondents expressed no willingness to change their consumption behavior.

Finally, the results indicate perceptions of future trends in environmental awareness. The majority of respondents (66.3%) believe that consumer environmental awareness will increase in the future, albeit at a slower pace, while nearly half of respondents perceive the level of environmental awareness in the Republic of Croatia as lower compared to other countries.

In the final section of the questionnaire, a smaller number of respondents provided additional comments and suggestions related to the research topic. Although most participants did not offer additional comments, the collected responses provide valuable qualitative insights into the attitudes of young consumers.

Beyond the above, qualitative responses point to broader implications of companies' environmental orientation. Respondents implicitly associate corporate environmental responsibility with social desirability, perceiving environmentally responsible companies more positively. These attitudes suggest that environmentally friendly products and sustainable business practices not only shape consumer purchasing decisions but also influence the overall perception of companies as socially responsible organizations.

In this context, the results of the open-ended questions point to a potential relationship between environmental product branding and a company's broader image, including its attractiveness to young people as future employers. Although this study does not directly examine employer perceptions, the obtained responses open space for future research to more systematically analyze the relationship between young consumers' environmental awareness, consumer attitudes, and perceptions of companies in their role as employers.

5. Discussion

The obtained results confirm findings from previous research indicating a relatively high level of environmental awareness among young consumers, accompanied by a limited frequency of actual sustainable consumption behavior. Although most respondents occasionally purchase products with environmental labels, regular purchasing remains uncommon, pointing

to a pronounced gap between attitudes and behavior. This pattern is consistent with literature emphasizing that environmental awareness, while a necessary prerequisite, is not sufficient on its own to drive changes in consumer decision-making (Kokkinen, 2013; Hassan et al., 2010).

The results further indicate that motivators of sustainable consumption among young consumers are more frequently linked to personal benefits, such as perceived higher product quality and health advantages, rather than purely altruistic or environmental motives. These findings confirm that the environmental aspect of products is often evaluated through individual benefits, while concern for the environment plays a secondary role in purchasing decisions. At the same time, identified barriers—high prices, lack of trust in certifications, and limited availability—confirm the existence of market and structural constraints that hinder consistent sustainable consumption, in line with research on barriers to the implementation of sustainable business models (Geissdoerfer et al., 2018; Bocken, 2020).

A particularly interesting finding relates to young consumers' perception of their own influence on corporate business strategies. Although respondents generally do not perceive themselves as having strong individual influence, the majority believe that their consumer choices partially shape corporate behavior. Such perceptions suggest an awareness of collective market power, which represents an important prerequisite for long-term changes in business practices and sustainability strategies.

Qualitative insights obtained from open-ended questions further extend the interpretation of quantitative results. Respondents implicitly associate companies' environmental orientation with their social desirability, evaluating environmentally responsible companies more positively. These attitudes indicate that environmentally friendly products and sustainable business practices do not operate solely at the level of market supply but also shape the broader image of companies as socially responsible organizations.

These findings are consistent with recent research demonstrating that sustainability and corporate social responsibility significantly influence perceived organizational attractiveness, particularly among young people entering the labor market. Presley, Presley, and Blum (2018) empirically show that companies applying sustainable business principles, including environmental practices, are perceived as more attractive employers and increase young people's willingness to accept job offers. Similarly, Rzemieniak and Wawer (2021) demonstrate that sustainability measures integrated into employer branding positively influence the motivation of Generation Z candidates to apply for jobs, with certain gender-related differences in perception.

Furthermore, Carballo-Penela et al. (2023) highlight that communicating a company's commitment to sustainability during recruitment processes increases perceived organizational attractiveness, with factors such as organizational prestige and cultural context playing an important role. These findings are further supported by Thang et al. (2023), who show that among Generation Z, attitudes towards corporate social responsibility influence job pursuit intentions through the perceived attractiveness of the employer.

In this context, the results of the present study suggest that environmental product branding may have effects that extend beyond consumption and reflect on the overall perception of companies. For young consumers, who also represent the future workforce, sustainability and environmental responsibility may become important elements in evaluating the social acceptability and desirability of companies. Although this study does not directly examine employer perceptions, qualitative responses indicate a potential link between young consumers' environmental awareness, their perception of products, and the broader corporate image, including attractiveness as future employers.

These findings open avenues for future research to more systematically connect young consumers' environmental awareness with concepts of green branding, organizational image, and employer attractiveness. They further confirm that sustainability is not merely a market or marketing tool but may become an integral part of a company's overall value proposition in the eyes of younger generations.

6. Conclusion

The aim of this paper was to analyze the level of environmental awareness among young consumers and to examine the gap between their attitudes and actual consumer behavior. The research results confirm that young consumers in the Republic of Croatia exhibit a relatively high level of environmental awareness and positive attitudes towards sustainable consumption; however, this awareness is only partially reflected in their actual market decisions. The limited frequency of purchasing environmentally friendly products points to the existence of a gap between attitudes and behavior, primarily conditioned by economic and market-related factors.

The study shows that young consumers' motivation to purchase environmentally friendly products more often stems from perceptions of quality and personal benefits than from exclusively environmental reasons, while high prices, lack of trust in certifications, and limited product availability represent key barriers to sustainable consumption. These findings confirm that environmental awareness, although a necessary prerequisite, is not sufficient to ensure consistent changes in consumer behavior without adequate institutional and market support.

A particular contribution of this study lies in the qualitative insights pointing to broader implications of companies' environmental orientation. Young consumers implicitly associate corporate environmental responsibility with social desirability, perceiving environmentally oriented companies more positively not only as producers but also as socially responsible organizations. These attitudes suggest that environmental product branding may shape a company's broader image and potentially influence its attractiveness to young people as future employers.

Although this research does not directly examine companies in their role as employers, the obtained results open space for future studies to more systematically analyze the relationship between young consumers' environmental awareness, consumer attitudes, and perceptions of companies as socially responsible and desirable organizations. This confirms that sustainability goes beyond its role as a market tool and may become an important element of long-term corporate reputation and overall value proposition in the eyes of younger generations.

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THE LEVEL OF INNOVATION IN ENTERPRISES IN THE KUYAVIAN-POMERANIAN REGION

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Purpose: The aim of the article is to determine the level of innovation in enterprises in the Kuyavian-Pomeranian region.

Design/methodology/approach: The research comprised an analysis of specialist literature on innovation and the transfer of knowledge and technology from research institutions to the economy, along with a representative questionnaire survey of enterprises in the Kuyavian-Pomeranian region.

Findings: The article emphasizes the types, significance, and level of innovations developed and implemented by the researched entities. It identifies the types of innovations, their sources of financing, whether they were developed independently or in collaboration, and the degree of novelty of the changes introduced in 2023-2024.

Research limitations/implications: Future research should undoubtedly continue to examine enterprises and employees, monitoring changes in cooperation between scientific institutions and business and identifying both positive practices and barriers in the innovation creation process.

Practical implications: Effective innovation management may generate measurable benefits for enterprises and other organizations, not only in terms of improved competitiveness and market position, but also through the strengthening of cooperation with scientific and research institutions. This is relevant not only for rapidly developing industries characterized by dynamic change, but also for other sectors. It concerns both large entities, considered centers of innovation creation, as well as micro, small, and medium-sized enterprises, which dominate the economy in terms of number and potential.

Social implications: Theoretical and practical aspects of innovation and cooperation between enterprises and scientific and research institutions (including universities).

Originality/value: The research findings have both theoretical and practical value, particularly with regard to data collected during the implementation of the project – Doskonalenie procesu transferu i komercjalizacji rozwiązań innowacyjnych między nauką a gospodarką, “Nauka dla Społeczeństwa II” (Improving the Process of Transfer and Commercialization of Innovative Solutions between Science and the Economy, ‘Science for Society II’), part of which is presented in this article.

Keywords: innovation, enterprise, university, knowledge and technology transfer.

Category of the paper: General review.

1. Introduction

Academic and scientific research institutions are becoming increasingly important in the transfer of knowledge and technology to enterprises. This is related to the pressure from the business environment to implement innovations in all areas of their operations.

This article was prepared as part of a project carried out by Bydgoszcz University of Science and Technology entitled ‘Doskonalenie procesu transferu i komercjalizacji rozwiązań innowacyjnych między nauką a gospodarką, “Nauka dla Społeczeństwa II”’ (Improving the Process of Transfer and Commercialization of Innovative Solutions Between Science and the Economy, under the program ‘Science for Society II’). The publication was co-financed from the state budget within the program of the Minister of Education and Science entitled Science for Society II, project no. NdS-II/SP/0235/2024/01. The amount of funding was PLN 1,000.00, and the total value of the project was PLN 626,941.33.

The project aimed to identify and redesign the processes of cooperation between Bydgoszcz University of Science and Technology and its socio-economic environment. To achieve this aim, several specific goals were defined: identifying the factors influencing the growth of activity and competitiveness of the science sector in innovation development and external collaboration; increasing the number of enterprises operating on innovative solutions generated through university-industry cooperation; stimulating the development of pro-innovative solutions in enterprises through collaboration with Bydgoszcz University of Science and Technology; and conducting benchmarking to identify good practices in innovation transfer and commercialization. Implementation of these objectives required tasks involving an in-depth analysis of secondary sources, including the literature, statistical databases, and published results of scientific research on innovation, technology transfer, commercialization, and university–business cooperation, as well as the conduct of original empirical research based on primary sources of information created for the purposes of the project, using both quantitative and qualitative methods.

The results of the quantitative study of enterprises from the Kuyavian-Pomeranian region relating to innovation processes and cooperation with scientific institutions, including Bydgoszcz University of Science and Technology, will be disseminated in monographs and academic journal articles. This article presents the project assumptions and selected findings from the empirical research.

2. Concept and typology of innovations

Progress, improved quality of life, and new opportunities for meeting societal needs are the outcomes of scientific advancement and the support of innovation processes. In this context, the project Improving the Processes of Transfer and Commercialization of Innovative Solutions Between Science and the Economy ('Science for Society II'), carried out at Bydgoszcz University of Science and Technology between 2024 and 2026, addresses the key challenge of enhancing the development potential of social and business organizations and, consequently, of consumers, who benefit from higher-quality products and services. Changes resulting from the Fourth Industrial Revolution (Industry 4.0) have prompted many operating enterprises to seek new paths of development. The integration of new technologies and knowledge-based solutions into the production process requires an innovative approach to problem-solving and the creation of conditions that foster creativity. In order to remain competitive in a rapidly changing environment, companies must continuously develop new products, services, and business models. Contemporary development trends indicate that enterprises built on two pillars: knowledge and innovation, achieve competitive advantages. This in turn provides sustainable enterprise development (Podgórska, 2022). Innovation can be understood as the ability to search for and create new solutions, adapt them to specific conditions, implement them in practice, and subsequently disseminate them (Perry-Smith, Mannucci, 2017). Innovation processes vary across different types of institutions, including scientific, economic, political, or cultural organizations. Innovations result from interactive processes of generation, diffusion, and application of knowledge. Innovations in science and technology are of particular importance, as they not only improve products and services but also contribute to the development and preservation of human life. For these reasons, innovations related to sustainable development are becoming increasingly significant.

The literature provides a range of approaches to defining innovativeness. Numerous studies emphasize the distinction between the concepts of innovation and innovativeness. Table 1 presents selected definitions.

Table 1.
Definitions of innovation and innovativeness

Concept	Author/authors	Definition
Innovations	Donatella Cavagnoli	It is the process of creatively applying knowledge and converting both the internal and externally acquired knowledge into new products, services, or processes.
	Joe Tidd, John R. Bessant	It is a process in which an identified opportunity is transformed into a new idea, which subsequently finds broad practical application.
	Agnieszka Sopińska, Piotr Wachowiak	Innovations are the outcome or process of introducing new or substantially improved solutions to the market.

Cont. table 1.

Innovativeness	Robert Majkut	At its core, innovativeness involves the selective search and application of innovations within the competitive rivalry among enterprises to expand their market share.
	Jill E. Perry-Smith, Pier Vittorio Mannucci	The ability to search for and generate new solutions, adapt them to specific conditions, implement them in practice, and ultimately disseminate them.
	Małgorzata Golińska-Pieszyńska	The ability to continuously search for, implement, and promote innovations.

Source: own study, based on: Cavagnoli, 2011; Golińska-Pieszyńska, 2015; Majkut, 2021; Perry-Smith, Mannucci, 2017; Sopińska, Wachowiak, 2016; Tidd, Bessant, 2018.

The multiple interpretations of the concepts of innovation and innovativeness indicate the complex nature of this subject. Innovations are understood as various types of novelties, both in products and services. In contemporary enterprises, the ability to introduce innovations plays a significant role, constituting an important factor of competitiveness and enables them to outperform market rivals. Innovativeness encompasses the creation of an organizational culture that encourages creativity, risk-taking, and experimentation. It requires organizations to maintain appropriate structures, processes, and resources that support the development of innovation and creativity. While several types of innovations can be distinguished, eco-innovations are gaining increasing importance due to their positive impact on the natural environment. Table 2 presents the types of innovations along with their characteristics.

Table 2.
Types and characteristics of innovations

Type of innovation	Characteristic
Product	They relate to the improvement of an existing product or the introduction of a new one to the market. Often, this includes adding new features that facilitate its use or provide additional advantages to the user.
Organizational	They refer to the introduction of new organizational solutions into an enterprise, concerning business operations, workplaces, or collaboration with external environment. These innovations also relate to all aspects of management, including planning, motivation, decision-making, and control. Organizational innovations result from strategic decisions made by the management of a given enterprise.
Marketing	They relate to changes in marketing strategy aimed at improving the satisfaction of customer needs. These involve a new marketing method that may include changes in product design, packaging, or in the positioning, promotion, or pricing of the product. Marketing innovations are typically part of a new marketing strategy that significantly differs from the methods previously used by the enterprise.
Process	They are associated with the introduction or modification of production, distribution, and service delivery methods.
Technological	They refer to the use of various new technological processes within an enterprise, the main objective of which is to improve or accelerate production and enhance working conditions.

Source: own study based on Oslo Methodology.

Universities and other research institutions hold significant potential for generating innovations. In this context, the transfer of knowledge and technology, as well as the ability to build relationships with the economic environment, are particularly important. The effectiveness of universities' entrepreneurial activities is influenced by multiple factors, including the characteristics of the institution itself (including its management practices)

(Algieri et al., 2013), market and technological uncertainty, national institutional conditions, state and regional policies, and the structure of the regional and global economy (Ambos et al., 2008). Technology transfer centers, together with spin-off enterprises, academic business incubators, and career offices, are considered part of the innovative infrastructure supporting academic entrepreneurship. Academic entrepreneurship refers to the process of creating and managing new ventures based on technology or knowledge developed through academic research. It involves the use of intellectual property and knowledge generated within the academic environment to create commercial opportunities and generate economic value (Poznańska, 2014). Through activities related to technology transfer and the commercialization of research outcomes, academic institutions can facilitate the implementation of innovations by enterprises, public administration, and society at large (Piwowar-Sulej, Kwil, 2018). Research on academic entrepreneurship also highlights additional directions, addressing various aspects of this complex phenomenon (Friedman, 2002; Li, 2009), including its impact on regional development (O'Shea et al., 2004) and its role as a catalyst for innovation (Etzkowitz, Klofsten, 2005). Clarysse et al. (2011) underline the critical relationship between a university's capacity to operate entrepreneurially and the presence of academic staff with suitable entrepreneurial characteristics. Nevertheless, there is still a lack of detailed analyses and frameworks describing the generation of creative ideas, their commercialization, collaboration with enterprises, and individual management of implemented products. Another remaining challenge is evaluating the extent to which various initiatives for the commercialization of academic research are effective and genuinely support enterprise innovation (Ambos et al., 2008). Polish universities actively support academic entrepreneurship through a range of initiatives and programs. Many have established technology transfer offices to assist researchers in commercializing their ideas and inventions (Sopińska, Wachowiak, 2016). Funding for the development of academic entrepreneurship and research on innovation is derived both from public resources at the national and regional levels and through collaboration with enterprises. Studies conducted to date, including research at the Bydgoszcz University of Science and Technology, indicate persistent barriers to maintaining sustainable relationships between the academic and business environments. Despite some progress, Polish research institutions still need to implement more effective strategies to strengthen their position in academic entrepreneurship. A key factor in further developing this area is researchers' experience in securing business partners to finance successive stages of commercializing innovative ideas developed in university laboratories, as well as the support provided by units such as Technology Transfer Centers. In Poland, most research projects are concentrated in engineering and technical disciplines, consistent with international statistics showing that around 50% of research and development expenditures are allocated to these fields. Natural sciences occupy the next position, receiving approximately 23% of funding in recent years. A notable strength of the innovative ideas undertaken by researchers at the analyzed institution was their high degree of uniqueness. Makiela (2017) emphasizes that an

entrepreneurial and innovative university requires a new management model aimed at effective collaboration with national and international partners. Such a university conducts research with commercialization potential, and academic staff, students, and graduates are motivated to take on competitive challenges, with entrepreneurship forming an integral part of the academic culture. Research on academic entrepreneurship indicates that most researchers do not possess all the skills required to act as entrepreneurs. Supporting the innovation process through technology transfer centers and achieving outcomes in the commercialization of research projects is therefore an effective way to address these gaps. Another key research direction, identified by the project team, is analyzing enterprises' demand for innovations and preparing appropriate responses by the university. Disseminating the project results also serves to promote inventiveness and is accompanied by an information campaign outlining the principles and scope of Bydgoszcz University of Science and Technology's cooperation with business environment.

3. Project objective. Selection of research methods.

The project aims to identify and redesign the collaboration processes between Bydgoszcz University of Science and Technology and its socio-economic environment. To achieve this aim, the project has defined the following specific objectives: to determine the factors that enhance activity and competitiveness in the scientific sector; to increase the number of enterprises implementing innovative solutions generated through university–enterprise cooperation; to stimulate the development of pro-innovation solutions in enterprises in partnership with the Bydgoszcz University of Science and Technology; and to conduct benchmarking to identify best practices in innovation transfer and commercialization. To achieve these objectives, the project involved a comprehensive analysis of secondary sources, including literature, statistical databases, and published research on innovation, technology transfer, commercialization, and university-enterprise collaboration, alongside empirical research based on primary data collected specifically for the project through quantitative and qualitative methods. Disseminating the project results also serves to promote inventiveness and is accompanied by an information campaign outlining the principles and scope of Bydgoszcz University of Science and Technology's collaboration with the business environment.

In the first stage of the project, a representative survey was conducted among enterprises in the Kuyavian-Pomeranian region. Two purposively selected samples were used, each meeting minimum size requirements. The first sample comprised small and medium-sized enterprises, while the second included large enterprises. The samples were proportionally stratified according to the number of entities in the manufacturing, service, and trade sectors. Subsequent

stages of the survey involved developing questionnaires for both small and medium-sized and large enterprises, testing the questionnaires, contacting enterprises to collect empirical data, verifying the accuracy of the collected responses, and refining the questionnaires.

In 2023, there were 220,848 business entities registered in the REGON system in the Kuyavian-Pomeranian region, of which 212,822 were micro-enterprises. Given their large number and inherent instability, micro-enterprises were excluded from the planned survey. Experience to date also indicates that micro-entities have a limited role in driving innovation, often acting as followers. Technical, product, and organizational innovations in micro-enterprises were constrained by their small scale and limited financial and human resources. Although these changes were new for the enterprises themselves, they were not novel overall. The quantitative research was carried out using a survey of enterprises in the Kuyavian-Pomeranian region. Two purposively selected samples were defined: the first including small and medium-sized enterprises, and the second including large enterprises, with proportional stratification according to the number of entities in the manufacturing, service, and trade sectors. As of the end of April 2023, 7,817 small and medium-sized enterprises were registered in the region, with an estimated sample size of 367, while 209 large enterprises were registered, with an estimated sample size of 66.

The survey included 433 respondents (Table 3). Over half of the participants were owners of service enterprises (52.7%), while one-third represented manufacturing enterprises (33.7%). Small enterprises constituted the largest share of the sample (60.5%), followed by medium-sized enterprises (24.2%) and large enterprises (15.2%). The majority of surveyed companies had been operating in the market for more than 15 years (81.8%).

Table 3.
Structure of surveyed enterprises

Business sector	% of total	Enterprise size	% of total
manufacturing	33.7%	small (10 to 49 employees)	60.5%
trade	13.6%	medium (50 to 249 employees)	24.2%
services	52.7%	large (250 or more employees)	15.2%
Total	100%	Total	100%

Source: own study.

4. Level of innovation in enterprises in the Kuyavian-Pomeranian region – research results

Table 4 presents the types of innovations introduced by enterprises over the past two years. Product innovations were the most frequently reported, at 48.3%. Process innovations, involving changes in the production of goods or the delivery of services, accounted for 21.7%, while organizational innovations, such as modifications to organizational structure or

management methods, represented 21.2%. Marketing innovations, including new marketing strategies or changes in promotional approaches, were the least common, reported by 14.1% of enterprises.

Table 4.

Types of innovations introduced by enterprises in 2023-2024 (N = 433)

Type of innovation	Percentage
Product (introduction of new products or services)	48.3%
Process (changes in the production of goods or delivery of services)	21.7%
Marketing (new marketing strategies or changes in promotional methods)	14.1%
Organizational (changes in organizational structure or new management methods)	21.2%

Source: own study.

The majority of innovations were developed independently by the enterprises themselves (Table 5). Organizational innovations had the highest rate of internal development (93.5%), followed by product innovations (90.4%), marketing innovations (88.5%), and process innovations (75.5%). Collaboration with other domestic or international partners was most relevant for process innovations (24.5%). None of the innovations were solely developed by other domestic or foreign entities.

Table 5.

Independent development of innovations in enterprises

Type of innovation	Product (N=209)	Process (N=94)	Marketing (N=61)	Organizational (N=92)
Developed independently by the enterprise	90.4%	75.5%	88.5%	93.5%
Developed by the enterprise in collaboration with other domestic or international entities	9.6%	24.5%	11.5%	6.5%

Source: own study.

Table 6 presents the types of financing used by enterprises to support innovation. Internal funds were the most commonly used, accounting for 95.2% of responses. Domestic funding from public institutions was the second most frequent source (11.0%), while foreign non-repayable funds (3.8%) and loans or other financial liabilities from financial institutions (1.4%) were much less commonly used. These results indicate that enterprises primarily relied on self-financing to implement innovations.

Table 6.

Types of financing used by enterprises to support innovation (N=291)

Source of financing	Percentage
Internal (own) funds	95.2%
Domestic funding obtained from public institutions	11.0%
Foreign non-repayable funds	3.8%
Loans, credits, and other financial obligations from financial institutions	1.4%
Other	1.7%

Source: own study.

The majority of innovations were new only for the enterprises themselves, as reported by 81.4% of respondents (Table 7). Innovations new to the national market were reported by 13.4%, and to the European market by 3.4%. Globally novel innovations accounted for 1.0%, while breakthrough innovations, characterized by an exceptional degree of originality, appeared in only 0.7% of cases.

Table 7.

Novelty of changes introduced by enterprises in 2023-2024 (N=291)

Novelty of the innovation	Percentage
New for the enterprise	81.4%
New to the domestic market	13.4%
New to the European market	3.4%
New to the global market	1.0%
Breakthrough innovation	0.7%

Source: own study.

5. Conclusions

The transfer of innovative solutions between science and industry is expected to play an increasingly important role. The intensification and improvement of this process require the active involvement of all actors, including research institutions and commercial enterprises. The volume and pace of innovation implementation call for additional support, particularly in the large sector of small and medium-sized enterprises, which, due to limited resources and operational scale, often lack the infrastructure and human capital needed to conduct research on new solutions.

The percentage-based results of the enterprise survey in the Kuyavian-Pomeranian region indicated that companies strongly recognized the need to implement innovations, although collaboration in this area remained very limited. Product innovations were the most frequently reported type. The vast majority of innovations were developed internally by the enterprises, with independent development reported across nearly all categories, most notably for organizational changes (93.5%), as well as product (90.4%), marketing (88.5%), and process innovations (75.5%). Enterprises predominantly financed innovations from internal resources, which accounted for 95.2% of all responses. Some concern was raised regarding the novelty of the implemented changes, as the majority of innovations were new only to the enterprise itself (81.4%), and far less frequently new to the national (13.4%) or European (3.4%) market. These findings indicate a relatively low level of originality, reflecting a high degree of imitation necessary for maintaining market position.

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AREAS AND SCOPES OF ARTIFICIAL INTELLIGENCE AND THE METAVERSE APPLICATION IN BUILDING CUSTOMER EXPERIENCES FOR THE TOURISM AND HOSPITALITY INDUSTRY

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Purpose: In recent years, new technologies have been reshaping the tourism and hospitality sectors, representing a powerful catalyst for new approaches in the industry. These new perspectives are key drivers of market growth and business dynamics, and are a vital source of prosperity for many countries and destinations. This article aims to identify the areas and scopes of AI and Metaverse applications in tourism and hospitality as a part of the customer experience process.

Design/methodology/approach: This paper provides a comprehensive discussion on the potential applications of AI and the Metaverse they pose to the hospitality and tourism industry. The meaning and use of AI and the Metaverse in different travel stages and decision-making processes are also discussed. A literature scoping analysis and bibliometric analysis were conducted using the VOSviewer software to achieve the aim. Two research questions address the identified research gap: (RQ1) How can AI and the Metaverse enhance the customer experience more broadly in the tourism and hospitality industry, and (RQ2) At which stages of tourists' experiences has this new technology been applied? The empirical part of the article presents the exploratory, qualitative research conducted using descriptive research methods and a multiple-case study, which was subjected to comparative analysis.

Findings: In the tourism and hospitality sector, AI and Metaverse applications have become a hot topic in society and, consequently, a theme of scientific research worldwide. We identified the main areas and scopes of application for these technologies as valuable resources that enhance the travel experience at every stage—before, during, and after the trip by offering personalized recommendations and assistance to travelers. AI is already evident in tourism and hospitality at every stage of the customer experience. However, the Metaverse is more applicable before or during the trip. Analyzing the industries adopting these new technologies, we noted that travel portals, hotels, and airlines are the main ones. However, the adoption is still weaker in tourist destinations and their attractions.

Originality/value: The main contribution is the identification of repeatable decision-making areas that hold future potential for Artificial Intelligence and the Metaverse as tools to enhance the customer experience.

Keywords: AI, Metaverse, Customer Experience, Tourism, and Hospitality.

Category of the paper: Viewpoint, Case study.

1. Introduction

Tourism is a highly experience-driven industry, where the quality of customer interactions plays a decisive role in shaping satisfaction, loyalty, and overall competitiveness. Recent technological advancements, particularly Artificial Intelligence (AI) and the Metaverse, are transforming the way destinations, travel agencies, and hospitality organizations engage with their customers. AI enables personalization, predictive analytics, and automation, while the Metaverse introduces immersive, interactive, and persistent virtual environments that allow customers to explore destinations and experiences beyond the limitations of the physical world.

The tourism and hospitality industry faces significant challenges and is undergoing significant transitions. New technologies are reshaping tourism and represent a powerful catalyst for innovation in the sector, which is a key driver of growth, job creation, and business dynamics, and a vital source of prosperity for many local communities (OECD, 2024). The adoption of new technologies will result in substantial changes throughout the hospitality and tourism industry by disrupting how customers search for information, make decisions, and how businesses produce, deliver, and customize services and experiences.

The extent to which AI ultimately impacts and transforms the tourism sector, with its unique characteristics and reliance on in-person, high-touch experiences, remains uncertain; however, it is a growing topic of attention and debate in scientific articles and industry reports. We present this paper to inform this discussion, as there is a need, in the first instance, for destination policymakers and businesses to understand the potential of AI and the Metaverse to enhance innovation in tourism. This includes developing a better understanding of the complex digital environment for tourism and hospitality, and of the key components of AI and the Metaverse's potential to improve the tourist experience.

From a marketing perspective, consumers want more than just the delivery and consumption of products and services. Instead, they seek unique consumption encounters to accompany the products and services that create memorable experiences (Walls et al., 2011). Therefore, the researchers directed long ago that businesses need to shift their focus from a “delivery-focused” service economy to one that emphasizes high-quality products and services and “staged” experiences that create memorable consumer experiences (Pine, Gilmore, 1999). In a hospitality and tourism setting, practically everything a tourist goes through at a destination is an experience, be it behavioral or perceptual, cognitive or emotional, expressed or implied (Oh et al., 2007).

This article aims to identify the areas and scopes of AI and Metaverse applications in tourism and hospitality as a part of the customer experience process, both theoretically and practically. A literature scoping analysis and bibliometric analysis were conducted using the VOSviewer software to achieve this aim. Two research questions related to the identified research gap were developed: (RQ1) How can AI and the Metaverse enhance the customer

experience more broadly in the tourism and hospitality industry, and (RQ2) At which stages of tourists' experiences has this new technology been applied? The empirical part of the article presents the exploratory, qualitative research conducted using descriptive research methods and a multiple-case study, which was subjected to comparative analysis.

The cross-sectional case study and comparison of existing examples of using AI and the Metaverse in Tourism and hospitality as part of the customer decision process provided valuable insights into the challenges of creating and improving the tourist experience. The main contribution is the identification of repeatable decision-making areas that become future potential applications of Artificial Intelligence and the Metaverse as tools to enhance the customer experience. The article concludes by proposing a potential future research agenda.

2. Artificial Intelligence (AI) and Metaverse in Tourism and hospitality - theoretical background

In the technology-driven era, Artificial Intelligence is one of the most innovative inventions that has revolutionized various industries worldwide. Artificial Intelligence (AI) can be referred to as the development of computer systems that can perform tasks and activities that require human intelligence (Russell, Norvig, 2016, p. 4).

Nowadays, Artificial Intelligence (AI) has a transformative impact on economies and societies and pervasive effects across all sectors and industries. The application of AI is already prevalent in many aspects of daily life and can profoundly transform how businesses operate and innovate, and this will have implications for what is an increasingly complex digital environment for tourism (OECD, 2024).

AI refers to a system's ability to learn from external data and automatically apply the learned knowledge to accomplish specific objectives and tasks through adaptation (Haenlein, Kaplan, 2019). AI has four specialized areas: computer vision, natural language processing (NLP), robotic process automation (RPA), and expert systems (Huang et al., 2022). Modern AI applications may combine multiple specialized AI domains to perform tasks that typically require human intelligence (Huang, 2024). Artificial Intelligence is broadly defined as "the study of agents that receive percepts from the environment and perform actions" (Russell, Norvig, 2021, p. 3). AI is a machine-based system that mimics human intelligence to learn, adapt to changing environments, and perform tasks. It is defined as "a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments" (OECD, 2024). AI can reason, recognize patterns, and make predictions or decisions; create images, text, videos, and other content; control smart, connected devices and robots; and engage in basic conversations (OECD, 2022). It is not one technology but

a mix of technologies that operate with other complementary technologies, such as robotics and Internet of Things (IoT), to dramatically augment capacity for image/face recognition, natural (human) language processing, predictive capacity, automation, and, more recently, content generation. AI is data-driven and operates with (intangible) resources such as data, algorithms, and skills, as well as (tangible) assets that make up the AI computing infrastructure (OECD, 2024). The most common AI applications include: a) chatbots and virtual assistants, primarily used for customer service; b) recommendation systems, which analyze customer data to provide personalized suggestions; c) personalization engines, such as machine learning and Natural Language Processing (NLP), which are techniques used to enhance the customer experience (Della Corte, 2025).

In the tourism and hospitality sector, AI manifests in applications such as chatbots, recommendation engines, virtual assistants, and service robots (Ivanov, Webster, 2019). AI-powered personalization has become a hallmark of modern travel platforms, offering real-time suggestions based on customer preferences, purchase histories, and contextual data (Buhalis, Leung, 2018). Many AI-related applications have already been adopted in the tourism sector, with further scope for innovation to support sustainable and inclusive tourism development. Analysis of existing applications and the potential of AI in tourism shows the variety of implemented and planned AI applications in place, with the potential to (OECD, 2024):

- Enhance the visitor experience with more interactive, personalized experiences and seamless travel, while increasing responsiveness to demand with 24/7 and more personalized services.
- Improve accessibility and audience engagement with greater accessibility of content and a diversified offer of culture and recreation services.
- Enhance market intelligence and data use, as well as capacity for market segmentation and customer profiling.
- Optimize visitor flows and traffic management with real-time data and automated decision-making.
- Support price/cost optimization through predictive maintenance, resource use, and procurement.
- Automate internal processes and basic customer services.

A good example of an AI application is the use of robots in the tourism sector, which illustrates the advancement of AI in the tourism industry, providing innovative customer services. These robots not only streamline the check-in and check-out process at hotels and airports but also act as concierges, enhancing guest interaction with immediate responses and personalized assistance (6 Examples of How AI is Used..., 2021).

On the practical front, customers typically do not distinguish the types of AI technologies but rather view AI as one holistic concept in service provision and delivery (Li et al., 2021). For example, recognizing the value of customer insights to improve brand equity, hotel businesses have begun offering intelligent robot concierges powered by AI to serve customers across various hotel areas (e.g., lobby, front desk, luggage storage, room service deliveries, outdoor pools, hotel restaurants). These service robots can provide instant answers to customer questions, assist with check-ins and check-outs, and engage with customers through speech recognition capabilities. Some can even learn and adapt to prior interactions to improve the accuracy of their responses to customers' inquiries and become smarter (Hueng, 2024).

Another important and even spectacular technological solution that is already being used in business is the Metaverse. The Metaverse is defined as “a persistent, immersive, and interconnected three-dimensional virtual environment where users interact with each other and with digital objects in real time” (Dionisio, Burns, Gilbert, 2013; Lee et al., 2021).

In this paper, the Metaverse is defined as the convergence of physical and digital universes, where users can seamlessly transition between them for work, education, training, health, exploring interests, and socializing with others. The metaverse is still largely conceptual and not yet clearly executed. Only in gaming is there already clear evidence of mainstream adoption by gamers (Katz, 2022). Academics from different disciplines work closely together to define, structure, organize, and visualize the future of the Metaverse (Dwivedi et al., 2022, 2023; Koohang et al., 2023).

In tourism, it offers an experiential layer that extends beyond physical boundaries. Virtual reality (VR), augmented reality (AR), and mixed reality (MR) enable tourists to preview destinations, experience cultural heritage virtually, and participate in immersive simulations before committing to physical travel (Guttentag, 2010).

Table 1.

Metaverse hospitality services before, during, and after a physical visit

The moment/stage	The Metaverse hospitality services
BEFORE a physical visit	• Experience hospitality services virtually when real travel is not possible. • Enjoy ambience and atmosphere through realistic gamification. • Information collection and fact-finding before visiting. • Assessment of suitability and fitness of services to needs and requirements.
DURING a physical visit	• Planning of daily itineraries. • Explore local resources for visiting. • Use AR for interpretation and understanding. • Engage with additional knowledge sources to appreciate history or nature.
AFTER a physical visit	• Re-experience places and recharge their memories. • Re-engage with people, places, resources, cultures. • Reconnect with service providers and also fellow customers. • Demonstrate destinations and organization and show them to others. • Plan further trips and exploration.

Source: own elaboration based on Buhalis (2022).

With the support of the Metaverse, people can stay at home or in other places but experience some of the intangible elements of hospitality virtually. These intangible consumer experiences can be accessed at any time and from anywhere. Virtual hospitality experiences can only simulate the real physical experience, and therefore cannot be considered as an attractive replacement. According to Buhalis (2023), Travelers will be using the Metaverse extensively before, during, and after visiting hospitality organizations to undertake a range of functions, as illustrated in Table 1. The use of new technologies in the tourism and hospitality sector, however, cannot be separated from the customer, the tourist. Therefore, a significant research issue currently is the adaptation of technology, but taking into account the context of the customer experience.

3. Customer Experience in Tourism

Tourism offers complex experiences and memories related to a place (Hosany, Sthapit, Björk, 2022). According to Carù and Cova (2003), an experience is "mainly a type of offering to be added to merchandise (or commodities), goods, to give the fourth type of offering which is particularly suited to the needs of the postmodern consumer" (p. 272). As an offering, experience has become closely related to a trip, journey, or even the attraction itself (Volo, 2009). Admittedly, an experience is created when "a company intentionally uses services as the stage and goods as props, to engage individual customers in a way that creates a memorable event" (Pine, Gilmore, 1999, p. 11).

Despite the enthusiastic movement toward the experience economy and its particular relevance to the hospitality and tourism industry (Gilmore, Pine, 2002; Titz, 2007), the literature has demonstrated a wide-ranging and perplexing set of definitions and theoretical meanings (Walls et al., 2011). Tourist Experience is a complex and wide-ranging construct arising from broader interactions with actors, stakeholders, and other tourists (Jaakola et al., 2015; Verhoef et al., 2009; Packer, Ballantyne, 2016; Kandampully et al., 2018; Meyer, Schwager, 2007). In light of the above discussion, many studies refer to the tourism experience as cumulative of each moment experienced by tourists during their journey, i.e., before the experience occurs, during the travel destination, and long after the tourist returns to their home environment. This ongoing process influences tourists' future behavior and expectations of the next trip. Lewis and Chambers (2000) defined consumer experience as - the total outcome to the customer from the combination of the environment, goods, and services purchased. Lashley (2008) discusses tourism experiences from the perspective of creating hospitable relationships between hosts and guests; these experiences engage emotions, which are essential to creating lasting memories. From a consumer's perspective, according to Oh et al. (2007), experiences are enjoyable, engaging, and memorable encounters for those participating in these events.

Andersson (2007) proposed the tourist experience as the moment when tourism consumption and tourism production meet. The tourist experience is still depicted as an obscure and diverse phenomenon, which the individual consumer mainly constitutes (Uriely, 2005).

While most definitions of tourism experience refer to the experience at the destination, the tourism experience encompasses multiple distinct yet interacting stages (Bernaki, Marso, 2023). It begins with the planning and preparation phases (anticipation), continues during the trip when tourists are physically present at the location (on-site), and extends beyond the trip by capturing moments to remember (recollection) and reflecting on the journey (reflection) (Cutler, Carmichael, 2010). In other words, the entire process, from planning to reminiscing, contributes to the overall tourism experience (Godovykh, Tasci, 2020). To illustrate, Tung and Ritchie (2011) define an experience as “an individual’s subjective evaluation and undergoing (i.e., affective, cognitive, and behavioral) of events related to their tourist activities that begin before (i.e., planning and preparation), during (i.e., at the destination), and after the trip (i.e., recollection)” (p. 1369). Thus, different factors influencing tourist behavior can be illuminated during each stage of the experience process (Chen et al., 2014). Still, no prior holistic conceptual model exists in the literature that has examined all the elements that form the tourist experience.

We can agree with Buhalis & Sinarta (2019) that Customer Experience (CX) in tourism is the holistic perception of a customer’s interaction with tourism organizations across multiple touchpoints, encompassing cognitive, emotional, behavioral, sensory, and social responses. To sum up, customer experience in tourism and hospitality is multidimensional and experiential, influenced by pre-trip information search, the service encounter, and post-trip sharing (Walls et al., 2011).

To identify the areas and scope of AI and Metaverse applications in tourism and hospitality within the customer experience process, we employed VOSviewer bibliometric analysis to support the exploration of the literature. These method is commonly used in works on the state of the art in a wide variety of areas. For the purposes of the analysis, techniques such as citation analysis, word co-occurrence analysis, and cluster mapping were used. The data obtained from the Scopus database were subjected to bibliometric analysis. The keywords (presented in Table 2) were used to search for titles, abstracts, and keywords (searches were conducted in September 2025). The electronic database was searched using Boolean operators. Only reviewed records covering documents published in scientific journals and books written in English were analyzed. No publication timeframe was specified, and no limits were applied to the subject areas in which publications were classified.

The co-occurrence analysis, as employed in VOSviewer, focuses on identifying relationships based on the frequency of item co-occurrence within the same context. The co-occurrence maps serve as a valuable starting point to identify prominent relationships between items, such as keywords. These visualizations offer a high-level overview of the

interconnectedness among items, helping this study to identify relevant themes and clusters within the dataset (Bukara, 2023).

Table 2.

The co-occurrence analysis - Keyword analysis

Key words combination	Question/Search String	Number of articles (Scopus TITLE-ABS-KEY)	The co-occurrence analysis of Terms
1. Metaverse, Customer Experience, Hospitality, Tourism Industry	((metaverse OR "social VR") AND ("customer experience*" OR "guest experience*" OR "tourist experience*") AND ("hospitality industr*" OR hotel* OR resort* OR restaurant* OR "tourism industr*" OR tourism OR "travel industr*"))	53	Total keywords: 266 Minimum number of occurrences – 3 Meets the conditions: 26
2. AI, Customer Experience, Hospitality, Tourism Industry	((“artificial intelligence” OR AI) AND (“customer experience*” OR “guest experience*” OR “service experience*”) AND (hospitality OR “hospitality industry*”) AND (tourism* OR “tourism industry*”))	105	Total keywords: 514 Minimum number of occurrences – 5 Meets the conditions: 27

Source: own work based on VOSviewer.

To identify the areas of research on which AI and the Metaverse in tourism and hospitality articles focus, a map of link intensity among the most frequent keywords was developed. The maps are presented in Figures 1 and 2.

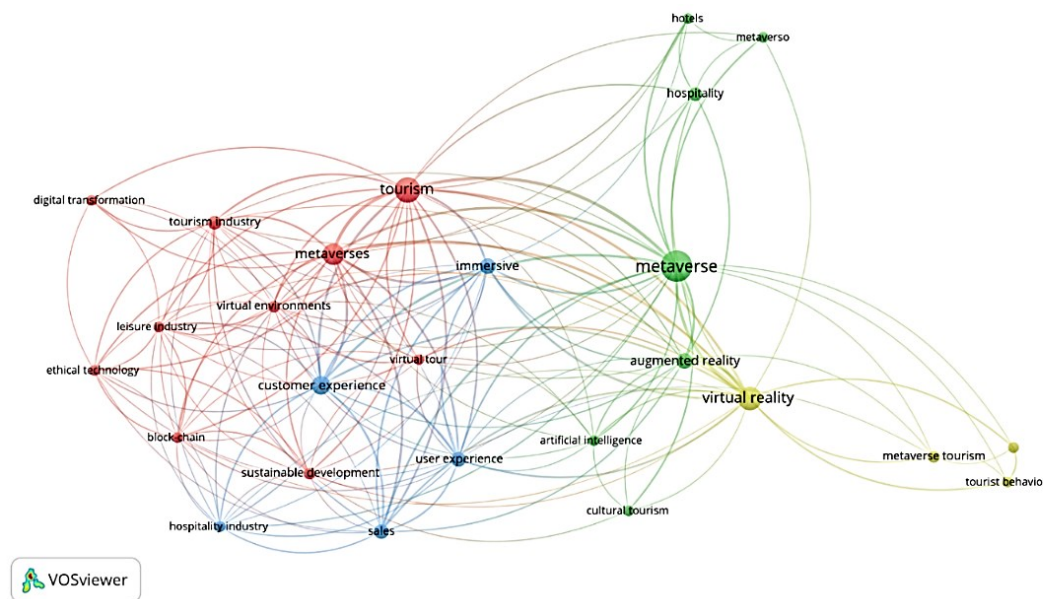


Figure 1. Map of the Intensity of Links between Keywords - combination 1 – clusters recognition.

Source: own work based on VOSviewer.

The network visualization and density visualization features of VOSViewer make it an exceptional tool for mapping scientific knowledge (Bukar et al., 2023). The visualization map of term occurrence depicts the frequency of occurrence of specific key terms, hence called the occurrence metric (Xu et al., 2021). The terms are represented as nodes of varying sizes,

proportional to the terms' recorded frequency. Additionally, the analysis indicates the frequency with which the terms appear in close proximity to one another. According to Bukara (2023), the co-occurrence of terms within a text network substantially affects the construction of text clusters, also known as communities of terms. The term "community of terms" refers to a group of terms that cluster collectively in the text network. Multiple instances of communities can exist on a text network. The VOSviewer's textual clustering method was used to determine the primary cluster prevalent for each text. This strategy aims to produce a number of clusters, each representing a distinct AI and Customer experience or Metaverse and Tourism and hospitality-related topic.

To isolate thematic areas covered in the articles, we visualized the relationships between keywords in the titles and abstracts of the publications. Figure 1 shows that the main research areas (combination 1 related to the metaverse) revolve around four main clusters, represented by the largest circles and marked with different colors: "Tourism" (red cluster – 10 items), "Metaverse" (green cluster – 7 items), "Customer Experience" (blue cluster – 5 items), and "Virtual Reality" (yellow cluster – 4 items). The "Tourism" cluster includes publications focusing on the evolution and use of new technologies in the *tourism* and *leisure industries*, as well as on *digital transformation*, *blockchain technologies*, the *virtual environment*, and the *ethical aspects* of these technologies. The second cluster addresses the use of "Metaverse", *artificial intelligence*, and *augmented reality*. Publications primarily focus on *hotels*, *hospitality*, and *cultural tourism*. The third research area, "Customer/user Experience", focuses on aspects related to the *sales* process and its *immersive* nature, which occurs in the *hospitality industry*. The fourth and final research area concerns "Virtual reality", tourism development, and *tourist behavior*, although it remains poorly defined. It should also be noted that the clusters are not homogeneous; the areas are still weakly connected to each other. The largest circle is the "Metaverse" area (red cluster), but "Customer Experience", the smallest research area, belongs to the blue cluster and is located further away from it. The same situation can be observed for "Tourism", which belongs to the red cluster. This identification indicates a still unexplored area for research in the use of the metaverse as a new technology shaping the tourist experience.

In comparison, Figure 2, which shows the research areas for combination 2 (related to the AI), shows three clusters: "Artificial Intelligence" (red cluster – 9 items), "Tourism" (green cluster – 9 items), and "Sales" (blue cluster – 9 items). The red cluster concerns the connections and use of "Artificial Intelligence" in the *hospitality and tourism industry* in the context of operational *decision making*, i.e., the use of the *Internet of Things*, *robots*, and *technology*. A second cluster, "Tourism", combines *customer experience* with *chatbots*, *machine learning*, and *natural languages* to achieve *customer satisfaction*. The third, blue cluster, focuses on "Sales" and its improvement in the *leisure* and *tourism industry* through *operational efficiencies*, *personnel*, and *technological innovation*. Publications indicate the need to utilize theories regarding *user experience* and *service experience*. The highlighted clusters have the

same number of items, and the dense connections suggest they are more homogeneous than in combination 1.

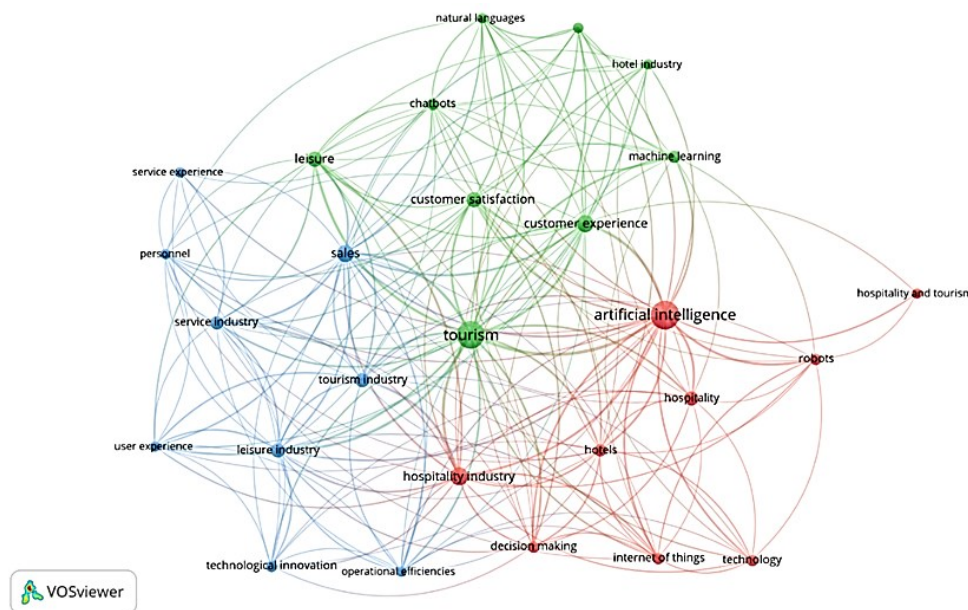


Figure 2. Map of the Intensity of Links between Keywords - combination 2 – clusters recognition.

Source: own work based on VOSviewer.

Although no clear connection between AI-Customer Experience-Tourism industry has been identified, we can see that the distances between the individual dominant areas are significantly smaller. This allows for the interpretation that this area of AI research is already being explored more frequently by researchers, although the context of customer experience still seems untapped.

To identify recent trends in knowledge development, a map (overlay visualization) was created (Figures 3 and 4). Such maps are useful for verifying trends in research, as they make it possible to classify scientific papers using a time scale (Shvindina, 2019).

The overlay visualization for Keyword combination 1 and 2, which is presented in Figures 3 and 4, shows that the individual keywords take on a certain color depending on the year of publication.

According to the timescale assumptions, where dark colors indicate older publications and light colors indicate recent publications, we can conclude that the keyword combinations examined indicate a still young field of knowledge that is in the process of development. This offers significant potential for scientific research. Comparing the previous achievements, we can see a slightly greater maturity of AI research than the metaverse.

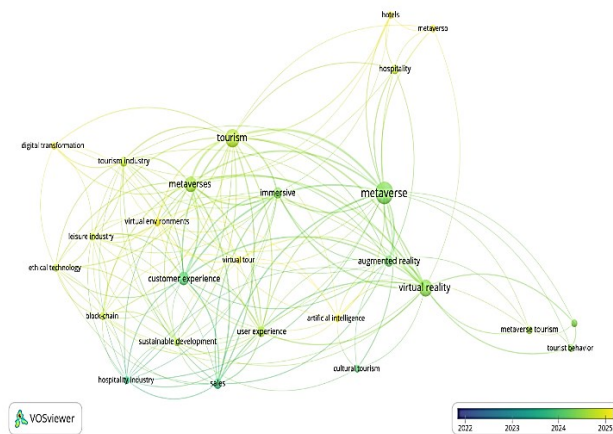


Figure 3. Overlay visualization for Keywords combination 1.

Source: own work based on VOSviewer.

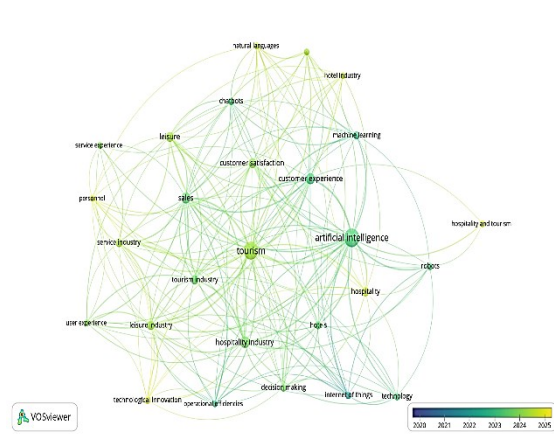


Figure 4. Overlay visualization for Keywords combination 2.

Source: own work based on VOSviewer.

Table 3.
The most cited articles

Key words	No.	Journal	Cited by	Authors/year	Title
Metaverse, Customer Experience, Hospitality, Tourism Industry	1	International Journal of Contemporary Hospitality Management	383	D., Buhalis, Dimitrios; M.S., Lin, Michael S.; D.H., Leung, Daniel Hee/2023	Metaverse as a driver for customer experience and value co-creation: implications for hospitality and tourism management and marketing
	2	International Journal of Geoheritage and Parks	80	D., Wei, Dongying/2022	Gemiverse: The blockchain-based professional certification and tourism platform with its own ecosystem in the metaverse
	3	Journal of Hospitality and Tourism Research	71	F.X., Yang, Fiona Xi; Y., Wang, Ye/2025	Rethinking Metaverse Tourism: A Taxonomy and an Agenda for Future Research
AI, Customer Experience, Hospitality, Tourism Industry	1	Journal of Service Management	774	D., Buhalis, Dimitrios; T.G., Harwood, Tracy Gaynor; V., Bogicevic, Vanja; G., Viglia, Giampaolo; S., Beldona, Srikanth; C.F., Hofacker, Charles Frederick/2019	Technological disruptions in services: lessons from tourism and hospitality
	2	International Journal of Hospitality Management	275	M., Li, Minglong; D., Yin, Dexiang; H., Qiu, Hailian; B., Bai, Billy/2021	A systematic review of AI technology-based service encounters: Implications for hospitality and tourism operations
	3	Journal of Hospitality Marketing and Management	268	D., Gursoy, Dogan; Y., Li, Yu; H., Song, Hakjun	ChatGPT and the hospitality and tourism industry: an overview of current trends and future research directions

Source: own elaboration based on VOSviewer.

This study also examined which articles are most frequently cited, as shown in Table 3. Articles on AI were cited more frequently again. However, given that the topic has only been developing in the last few years, this analysis is only a supporting identification.

The state of the art demonstrates the impact of AI tools and the development of the Metaverse in various fields of tourism and hospitality. Still, there is a relative lack of research exploring the path of AI and Metaverse as part of tourists' decision stages – the research gap. This research context, related to customer experience as a research subject, seems exciting and has excellent scientific potential.

4. The potential of AI and Metaverse in shaping the customer experience

4.1. Research context and research method

The World Economic Forum (2022) acknowledged that tourism is one of the key areas that can benefit from the Metaverse. The Metaverse enables travelers to experience immersion in virtual tourism destinations and organizations before they arrive (Buhalis et al., 2022). Metaverse tours are built on existing virtual tours that use 360-degree or 3D media modality technologies. They allow avatar embodiment as well as psychological and physiological immersion by facilitating synchronous interaction with other agents and objects in a virtual destination (Chen, Yao, 2022; Tsai, 2022). We can also state that AI, particularly its innovation characteristics, will change the way customers seek information about products or services and will have a major impact on various industries, including hospitality and tourism (Zhang, Prebensen, 2024).

The tourists' behavioral aspects, such as customer experience, are vital outcomes resulting from customers' assessments of innovation characteristics and adoption factors, and such evaluations can drive the acceptance and integration of innovative AI technologies and the Metaverse. In this study context, an exploratory research approach was used. The research questions we want to answer are:

- (RQ1) How can AI and the Metaverse enhance the customer experience more broadly in the tourism and hospitality industry?
- (RQ2) At which stages of tourists' experiences has this new technology been applied?

To answer those questions and fulfill the paper's aim, exploratory, qualitative research was conducted. As the method we used, descriptive research and a content analysis based on multiple case studies. We also used comparative analysis of theory and practice. The cross-sectional case study and comparison of existing examples of using AI and Metaverse in Tourism and hospitality as part of the customer decision process provided valuable insights into challenges in creating and improving the tourist experience. We used secondary sources of

information on various activities in the tourism and hospitality sectors. The main task of this empirical comparison was to identify at what stages of consumers' decision-making regarding their experiences before, during, and after a tourist visit, AI and Metaverse solutions are used.

4.2. Results and discussion

The growing reliance on AI and the Metaverse in the tourism sector raises several possibilities about the quality and inclusivity of tourist experiences. The potential applications can increase the experience quality by streamlining the customer journey, using real-time communication systems, or offering personalized offers. The practical examples presented in Table 4 refer to case studies from industries such as hotels, airlines, restaurants, tourist attractions, and travel portals.

Table 4.

The exploration of using AI tools and the Metaverse in Tourism and hospitality for enhancing customer experience – the comparative analysis

		Before visit	During visit	After visit
Artificial Intelligence	Theoretical possibilities of using AI in tourism and hospitality	- Improves the booking experience. - Improves the overall match between traveler preferences and offerings. - Improves risk management and responsiveness. - Increases market reach and personalization, fostering sustainable marketing practices through tailored and efficient customer engagement.	- Improves customer engagement. - Optimizes visitor flows and transport management by reducing congestion and waiting times through automated vehicle routing and seamless connections between sites and hubs, ensuring no delays. - Mass customization ("segment of ONE"), and big data-optimized offerings. - Robots For Face-to-Face Customer Services.	- Improves customer satisfaction. - AI assistants and Intelligent chatbots are deployed in social media sites like Facebook Messenger, Skype, WhatsApp, and Viber to offer users a more personalized booking experience based on their previous experience. - Data Analytics To Identify Valuable Insights. - Sentiment Analysis Through Social Media.
	Practical application - case study examples	Tourism Toronto - use AI to analyze social media activity, booking trends, and spend patterns to develop more effective marketing and tailor offerings. Mindtrip is a collaborative travel planner that uses AI to analyze various sources of inspiration (pictures, social media links) from multiple users and	Destination British Columbia, BC Travel Genius, an AI-powered chatbot that answers questions about destinations, suggests itineraries, and provides information on local attractions. Tokyo Haneda Airport uses AI-powered translation devices to assist travellers through real-time translation.	Expedia uses an AI assistant (Romie) to analyze user preferences and past behaviors to suggest tailored travel options and streamline booking processes. The Dorchester Collection hotel has processed and analyzed customer feedback surveys, customer reviews, and online polls using its AI platform Metis to determine its

		generate customized itineraries and tailored • The travel reservation giants like Booking.com, Skyscanner, and Expedia are utilizing such chatbots in their operations. Usually, customers are prompted to start a conversation with a chatbot by entering details of their intended journey recommendations. • Booking and Microsoft, AI assistant, developed an AI-powered chatbot and virtual assistants to handle routine tasks and customer service, providing instant responses to queries and assisting with booking processes. • SmartGuide, AI-generated guides, use an AI model to generate destination guides adapted to each tourist. • Atout France, Marianne, use generative AI to generate hyperpersonalised travel recommendations and encourage eco-friendly choices.	• Airports (e.g. Paris, Los Angeles, Vancouver, and San Jose) use AI-powered facial recognition systems at checkpoints instead of boarding pass or passport controls. • Barcelona Zoo uses an AI-enhanced Chatbot designed for people with visual, auditory, and cognitive disabilities, or mental health disorders. • A robot at London Heathrow Airport that guides passengers in the terminals. • The Henn-na Hotel in Nagasaki is the world's first hotel fully staffed by multi-lingual robots primarily used for check-in and checkout processing. --Another innovative AI solution is 'Connie,' the robot deployed in the hotel Hilton McLean in Virginia. • Disneyland Parks, Management of crowd flows: Disneyland Parks is harnessing advanced data collection and artificial intelligence to enhance visitor experience and manage crowd flow more effectively. By utilizing data from wristbands issued to hotel guests, along with numerous IoT sensors and cameras throughout the resort, the parks can monitor and analyze real-time visitor movement and identify overcrowded areas. Through the My Disney Experience mobile app, visitors can access up-to-date information on crowd levels and receive guidance on less congested areas to explore.	overall performance. They have discovered through such analysis that there is a lack of loyalty to their hotels. Businesses get the opportunity to devise better solutions that fulfill customer needs by identifying such trends of customers. • Mindtree's PaxPulse is a social Intelligence and Recommendation Platform designed for the airline industry. It uses Mindtree's pre-built classifiers, algorithms, and machine learning frameworks. When a particular passenger posts on social media about his travel partner, its smart algorithms process this sentiment and provide a certain recommendation to resolve passenger concerns. • Analysing traveller surveys in Fukui, Japan: The Fukui Prefecture Tourism Federation uses a data management platform that collects traveller surveys and consumption data, leading to a total of over 50000 cases and 90 facilities. A system has been built in which AI performs analysis according to the region and selected period, and displays the summary of results and suggestions. This supports the development of improvement plans together with local commercial facilities and the Chamber of Commerce and Industry for better management and more consumption.

			• "SmartGuide AI", Digital audio guide application: This initiative utilizes AI-driven technologies to personalize travel recommendations, aiming to optimize tourist distribution and enhance visitor experiences. By analyzing user preferences and interactions, SmartGuide's AI system customizes content, suggesting unique activities and less frequented sites.	
Metaverse	Theoretical possibilities of using the Metaverse in tourism and hospitality	• The metaverse boosts bookings by offering immersive previews of destinations, transport, and accommodation. • Metaverse support trip planning with virtual tours, realistic hotel walkthroughs, and interactive route previews. • The metaverse can facilitate the purchasing decision for travelers. • 5G development can have an answer to multi-sensory experiences. • The metaverse can help inspire tourists and encourage them to book or travel based on personal experience pre-travel.	• The time-travel experiences, smart destination shopping via VR, virtual attendance at trade shows with real-time interaction, and AR-guided tours providing on-demand destination details.	• Post-trip, the real potential of the metaverse lies in the capacity to inspire further travel.
	Practical application - case study examples	• Emirates Airline, Emirates has developed its own VR app, allowing users to explore Airbus A380 and Boeing 777 aircraft interiors. Finally, an interactive 3D seat map lets customers better understand what their seat will be like, and they can even book their preferred seat within that virtual environment. • Travelers can use the metaverse to explore destinations as if they were there themselves.	• Machu Picchu with the Incas, the journey to the lost city. Machu Picchu is a wonderful immersive experience and journey. Tourists will be transported back 450 years to the heart of the ancient Inca Empire in stunning virtual reality. • The BCB Group—a leading crypto banking group—has created a metaverse city that includes representations of some of the most visited destinations in the world, such as the Great	No data

		They can even engage in travel to discover how long it takes to go to the destination or find out the most exciting route to take from one sight to another. • The tourist can stand at the base of Egypt's Great Pyramids, overlook Pompeii ruins, or tour a luxurious hotel room before paying for it. He can do what he likes from the comforts of your own home. It's fully immersive, merging digital and physical realms. The expansion of 5G technology allows for full multisensory experiences. For tourists, it means smelling fresh coffee being brewed in street cafes in Paris, or getting a whiff of freshly baked bread at Italian restaurants.	Wall of China and the Statue of Liberty, the Taj Mahal, the Eiffel Tower, and the Colosseum of Rome. According to BCB, the total cost of flights, transfers, and entry for all these landmarks would come to \$7600—while a virtual trip would cost just over \$2. • Saudi Arabia's Royal Commission for AlUla (RCU) announced that the ancient city of Hegra had entered the metaverse.	

Source: Own elaboration based on literature, websites, and industry reports.

Analysis of the factual material allowed us to present three main conclusions: (1) the use of artificial intelligence is already visible in tourism and hospitality at all stages of the customer experience. However, the Metaverse is more applicable before or during the trip. There is no information on how to apply the Metaverse after the visit. (2) Analyzing the individual stages of the customer experience, the most significant number of examples concern the phase during the visit, which seems obvious. It is also the easiest for service providers due to technological capabilities. (3) Analyzing the industries adopting these new technologies, it should be noted that these include travel portals, hotels, and airlines. However, the adoption is still weaker in tourist destinations and their attractions.

We can also conclude that for travelers, AI tools and Metaverse applications offer personalized recommendations and assistance. These technologies are often seen as valuable resources that enhance the travel experience at every stage—before, during, and after the trip.

5. Conclusions and future research

In an era characterized by escalating service demands, the integration of advanced technologies within the tourism and hospitality industry has surged, profoundly reshaping the dynamics of host-guest interaction (Della Corte, 2025). Traditionally grounded in human-to-human exchanges, these industries have progressively transitioned towards a landscape marked by machine-human engagement (Bowen, Whalen, 2017). This study examined how Artificial Intelligence (AI) and the Metaverse transform customer experiences in tourism. AI applications, ranging from chatbots and recommendation engines to service robots, facilitate personalization and operational efficiency. The Metaverse, through immersive VR and AR environments, provides new forms of cultural engagement, destination marketing, and pre-travel exploration. Together, these technologies reshape how customers perceive, interact with, and evaluate tourism experiences.

Using AI to develop personalized tourist experience interactions will require robust data protection and consumer safeguarding measures. AI applications offer highly personalized travel experiences through customized recommendations and virtual assistant services, analyzing individual preferences to tailor suggestions for each traveler.

Despite promising developments, several future research directions remain. First, there is a need for still longitudinal studies that trace the evolving influence of AI and the Metaverse on customer experience across time. Second, cross-cultural comparisons are necessary, as technology adoption is shaped by cultural and socio-economic factors. Third, ethical and privacy considerations require deeper investigation, particularly regarding customer data use, surveillance, and digital inclusion. Overall, the application of AI and the Metaverse can offer tourism opportunities to enhance customer experiences and address challenges related to ethics, inclusivity, and authenticity. Addressing these dimensions remains a priority for both scholars and practitioners.

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PRODUCT CATEGORY MANAGEMENT ON THE EXAMPLE OF THE LIPTON YELLOW LABEL BRAND

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Purpose: The aim of this article is to identify and assess the role of the Lipton Yellow Label brand in the Polish tea market. The article presents the theoretical foundations of product category management, the role of the anchor brand, and the specific nature of the tea market in Poland. The results of own research are also presented in the final part of the paper.

Design/methodology/approach: The study was conducted by an online questionnaire developed by the Microsoft Forms platform. One hundred and one people participated, 96 of whom declared familiarity with the Lipton Yellow Label product. Only those respondents were included in the detailed analysis. The survey questionnaire included closed-ended single- and multiple-choice questions, as well as a set of statements rated on a five-point Likert scale.

Findings: In a theoretical context, the study demonstrated that effective category management relies on close cooperation between suppliers and retailers, strategic product positioning, and continuous analysis of consumer needs. Thanks to its consistent distribution strategy, iconic packaging, and competitive pricing, the Lipton brand has become an example of effective category management on a global scale. The results of own research indicate clear consumer trends, such as: increasing sensitivity to packaging, health-promoting expectations, and a noticeable segmentation of the market. In response to these trends, the article formulates recommendations for category managers, including optimizing pricing, developing premium offerings, packaging modernization, and educational initiatives to build loyalty to the Lipton brand.

Research limitations/implications: The study's main limitations were the non-random sampling and its focus on a single product (Lipton Yellow Label) within the tea category. Future research should expand the analysis to include comparisons with other anchor brands and incorporate qualitative methods to further explore consumer motivations and attitudes in the tea purchasing process.

Practical implications: The numerous conclusions drawn from the research are presented at the end of the article. They can provide a valuable starting point for category management practitioners, not only in the tea industry but also in other FMCG sectors.

Originality/value: This proprietary study was designed and conducted for the Lipton Yellow Label tea brand. This is the most important brand in the Polish tea market, serving as a benchmark for other brands in this segment. The results are significant for those who manage in practice food product categories.

Keywords: management, product category, Lipton brand, tea market, consumer behavior.

Category of the paper: Research paper.

1. Introduction

The dynamic growth of the tea market in Poland necessitates continuous refinement of product category management strategies and the ways brands communicate with consumers. The growing number of available teas, diverse consumer preferences, and intense competition mean that the mere presence of an attractive product on the market does not guarantee success. A key factor in determining competitive advantage is the ability to create a strong brand, maintain its recognition, and manage the category in a way that optimizes sales and consumer loyalty. This article draws on relevant literature, including industry reports and online sources, regarding brand management. In particular, it presents the results of own research, conducted on a sample of 96 respondents declaring familiarity with the Lipton brand. This research was conducted using a survey questionnaire, which included closed-ended single- and multiple-choice questions, as well as a set of statements rated on a five-point Likert scale.

2. The brand and its role in product category management

The greatest art of marketing is the ability to create, maintain, protect, and improve a brand (Kotler, 2005, p. 410). The process of brand management is a fundamental tool for building a competitive advantage for enterprises. A brand is a fundamental tool for communicating with customers, conveying information about the characteristics of the offer to buyers and guaranteeing the delivery of expected quality. Brand management is a marketing technique that involves introducing, further creating, and coordinating a brand to the market to maximize profits from the sale of its products, as well as all activities aimed at evoking brand associations with a given product among buyers and fostering a positive image (Garczarek-Bąk, 2022, p. 49). One of the most popular definitions of a brand in marketing literature, proposed by the American Marketing Association defines it as a “name, term, sign, symbol, or any other feature that serves to identify the products or services of one seller and distinguish them from those of other sellers (AMA, 2021). The primary function is therefore to positively distinguish a product from its competitors, which will encourage consumers to choose a product sold under a given brand. Although assigning a specific name, logo, or symbol to a product is sufficient to establish its brand (Keller, 2011, p. 20), its actual significance now extends far beyond its identification function. The concept of brand appears in marketing literature in many meanings. The basic ones are summarized in Table 1.

Table 1.
Definitions of the term brand

Source	Definition
Ogilvy (1985, p. 32)	a composite symbol that consists of the intangible sum of a product's features, its name, packaging and price, as well as its history, reputation and the way it is advertised
Kall (2001, p. 12)	a combination of a physical product, brand name, packaging, advertising, distribution activities and pricing that serves to differentiate a marketer's offering from competitive offerings, while providing the consumer with distinctive functional and/or symbolic benefits
Szulce, Janiszewska (2006, p. 50)	a special value, which is a combination of the value of the product, service and a specific promise of the manufacturer
Polański (2008, p. 24)	a product information bank that contains data about the product and its history on the market
Jasińska (2010, p. 24)	a particular product line, product family or product range, as well as the entire product range
Badzińska (2011, p. 145)	the idea around which the community is formed
Staszyńska (2013, p. 31)	guarantee of repeatable quality (in the form of a set of repeatable benefits with every purchase)

Source: (Garczarek-Bąk, 2022, p. 50).

Brand positioning aims to create a lasting "imprint in consumers' memories" so that they can distinguish a given brand from competing brands, which will ultimately allow the brand to occupy an optimal position on the market perception map (Mróz-Gorgoń, Szymański, 2018). The positioning process should begin with market segmentation, which aims to divide the market into internally homogeneous consumer groups characterized by similar characteristics (Bielski, 2006, p. 70). The success of this process depends on the proper identification of preferred brand values, which constitute the benefits desired by the target brand recipient (Zboralski, 2000, p. 267). The essence of positioning, therefore, is to create points of differentiation, constituting brand attributes, that will distinguish the brand's offering from the competition and provide a convincing reason for consumers to choose it. As Keller (2011, p. 130) aptly notes, brand differentiation points have the potential to develop into strong, positive, and unique brand associations only when they meet attractiveness criteria (such as meaning, distinctiveness and credibility) and feasibility criteria (realism, understandability, and durability). Among the types of positioning, the following categories are listed (Entrepreneur's Guide, 2021):

- **Price** positioning – most often the lowest or highest; the most expensive products are associated with the best and most exclusive, while the cheapest ones are usually associated with "good and cheap".
- **Product origin** positioning – the country of origin of a given brand allows for a positive association.
- **Unique attribute** positioning – emphasizing unique, unparalleled features not shared by competitors.

- **Product category** positioning – a state in which a specific product/service becomes an association for the entire category of these products/services (often other products are misleadingly referred to by a given name).
- **Specialization** positioning – focusing on only one area to build the image of a specialist in that field.
- **User** positioning – for example, a well-known personality in an advertisement may suggest certain characteristics.
- **Gender** positioning – targeting a product to a specific audience, such as cosmetics or cigarettes for men.
- positioning **by use** – a given brand is associated with a specific occasion.
- positioning **by purpose** – showing the product in use.
- positioning towards the **competition** – through the prism of the leader.

Category management plays a key role in a company's marketing strategy, enabling retailers and manufacturers to effectively adapt their activities to consumer needs, optimize product ranges, and build long-term customer relationships. This concept was developed in the 1990's, with the intention of helping to organize product offerings based on customer needs. A prerequisite for achieving these goals is close cooperation between supply chain entities (producers and retailers), which involves the integration of business processes (production and sales) based on sales data obtained by the retailer. This data serves as the starting point for the entire concept, indicating which products, in what quantities, and over what timeframe are purchased by consumers (Borusiak, Stefanide, 2017, p. 7). There are many definitions of category management, but AC Nielsen most aptly defines it as "a strategy for managing product groups by channel partners, the goal of which is to maximize sales and profits by meeting customer needs" (ECR, 2007, p. 7). Category management has evolved from a simple process of managing product groups into a sophisticated strategic tool that integrates data analysis, collaboration between channel partners, and dynamic response to changing market trends. Modern category management isn't limited to improving the financial performance of individual categories. It adopts a holistic approach that focuses on providing customers with a comprehensive and coherent offering. By grouping products to meet specific customer needs, companies can build customer loyalty, a key element of marketing strategy. Category management allows for a radical shift in the approach to material flows, yielding significant improvements. The most frequently cited effects of product category management include: price optimization, reduced logistics costs, reduced risk of collaboration in the supply chain, increased profits, and increased company profitability (Kobyłt, 2006). Category management in today's dynamically changing market environment must consider numerous challenges stemming from both global trends and local conditions. Among the key aspects is the growing importance of modern communication channels, the evolution of social media, and adapting advertising to the latest trends. Tools that enable more direct and interactive contact with

consumers require companies to continuously monitor and engage audiences in the digital space, which in turn requires flexibility in product category management. Customers are increasingly engaging in active and open dialogue with sellers of goods and services, becoming active consumers – i.e. partners or so-called prosumers (Dobski, Mikołajczyk, 2023, p. 27). Demographic changes, such as the aging population in developed countries, pose another significant challenge to category management. This has a significant impact on category management strategies. Managers must tailor their offerings to the needs of older consumers, taking into account their preferences and limitations. As an increasingly important market segment, seniors have specific requirements that encompass both product functionality and presentation and accessibility. Above all, companies must consider their preferences for ease of use. Products for older consumers should feature ergonomic, easy-to-open packaging and legible labels with larger font sizes. Product selection must also be tailored to the health needs of this group, which means a greater emphasis on functional foods, dietary supplements, and products friendly to people with allergies and other conditions (Ankiel, 2021). Responding to growing environmental awareness and social expectations related to environmental protection is also a significant challenge for category management. Consumers are increasingly seeking eco-friendly products, forcing companies to implement more sustainable solutions in packaging, production, and distribution. Sustainable marketing involves promoting products or services while minimizing their impact on the environment and society. This requires integrating sustainability principles into every phase of a product's lifecycle, from design and production to distribution and disposal. When implementing sustainable marketing strategies, managers must sometimes prioritize stakeholder value over corporate profit (Mikołajczyk, 2012, p. 7). This means adopting a long-term approach to sustainability, which fosters a positive image and builds trust among customers. Various economic crises further impact consumer behavior, potentially shifting purchasing priorities in favor of lower-priced products with higher utility value. In such conditions, category management must focus on offering solutions tailored to customer budget constraints while maintaining customer loyalty and brand competitiveness. These challenges require companies to continually analyze and optimize category management processes to effectively respond to changing market needs.

3. Factors influencing consumer choices in the tea market

Tea is a beverage derived from evergreen shrubs belonging to the *Camellia* family. It comes in two main botanical varieties: the *Chinese Camellia sinensis* and the *Indian Camellia Assamica* (<https://www.kawa-herbata.com.pl/porada3.html>). Today, tea, alongside water and coffee, is one of the most widely consumed beverages in the world. It is produced in over 30 countries, on almost every continent. However, the most important are Asian countries,

which have specialized in its cultivation and processing for centuries. In 2021, the global tea cultivation area was approximately 4.5 million hectares, and total tea production averages 6.5 million tons per year (<https://www.herbata.info/najwieksi-producenci-herbaty-czyli-kto-rzadzi-herbacianym-swiatem>). Two-thirds of this production is accounted for by two countries: China and India. China accounts for approximately 30% of the global production, while India accounts for 26%. In addition to these two giants, the share of African countries such as Kenya, Malawi, Uganda, Tanzania, Rwanda, and Zimbabwe is also growing. Since 2013, the African continent has produced approximately 700,000 tons of tea annually, representing approximately 13% of the global market (<https://www.herbata.info/najwieksi-producenci-herbaty-czyli-kto-rzadzi-herbacianym-swiatem>). Black tea is the dominant type of tea worldwide, accounting for approximately 80% of total production. Turks are the world's largest tea drinkers. According to FAO (Food and Agriculture Organization of the United Nations), Turks consume almost 4 kg of tea per capita annually. Ireland comes second (approximately 2.19 kg), and the British third (approximately 1.94 kg). Iran, Russia, Morocco, New Zealand, Chile, Egypt, and Poland also consume more than 1 kg of tea per capita per year. It's estimated that one kilogram of tea can brew approximately 400 cups. This is roughly how much the average Pole consumes each year (<https://www.herbata.info/najwieksi-producenci-herbaty-czyli-kto-rzadzi-herbacianym-swiatem/>). An analysis of global tea consumption reveals that there's much more to every cup than just individual taste preferences. Consumer decisions in the tea market are not random. They are shaped by both economic and non-economic factors. Economic factors include all factors directly related to the consumer's financial situation and market conditions. Non-economic factors refer to those elements that do not stem directly from financial circumstances, but from the broadly understood socio-cultural environment (Brzozowska-Woś, 2010, p. 34). It is their interplay that makes tea an everyday, luxury, or occasional choice, and consumer preferences change over time. The most important economic factor determining consumer choice is price. According to the law of demand, lowering the price of tea usually increases its sales, although the strength of this relationship depends on many factors. Tea, as an everyday product, is characterized by relatively low price elasticity – consumers rarely completely abandon a purchase, even if prices increase. The breadth and depth of the assortment available in stores also influences purchasing choices as an economic factor. The wider the selection of teas, the greater the opportunities to tailor purchases to individual preferences. Material characteristics of the product, such as aroma, infusion color, and packaging, are also important. In the case of tea, packaging also serves an informative role – it communicates not only the taste or type of blend but also its origin and quality. Product availability also remains a crucial economic factor. Massive presence in retail outlets builds trust and a sense of certainty about quality, and shapes purchasing habits. Consequently, availability not only facilitates tea purchases but also strengthens its importance in consumers' daily baskets. A brand remains a key element of economic influence on consumers. A trademark evokes associations with a specific standard of quality and image. Consumers are often guided

not only by taste or price but also by a brand's reputation, which influences their loyalty. Tea is a beverage deeply rooted in tradition. In Great Britain and Ireland, it is part of daily rituals, in Arab countries, it is a symbol of hospitality, and in Japan, it is an element of ceremonies with an almost spiritual dimension. Such cultural contexts influence purchasing choices even when substitutes such as coffee or soda are available. These are examples of non-economic factors. The social group to which the consumer belongs also plays a role. Family, friends, and co-workers can shape habits related to the type of tea chosen, the method of brewing it, and the frequency of consumption. The herd effect is making matcha and exotic herb teas fashionable, even if they were previously less popular. The influence of individual habits and customs cannot be ignored either. Long-time black tea drinkers rarely change their preferences, while younger generations are more likely to experiment with new flavors. In this sense, tea is a product with two faces: on the one hand, stable and rooted in tradition, and on the other, susceptible to trends and innovation.

Table 2.

The most important factors determining consumer choices

Economic	Non-economic
Price	Customs and rituals
Variety of assortment	The social group of a given consume
Availability	Habits
Brand	Trends, innovations

Source: own study.

One of the fundamental tasks of marketing is motivating consumers to purchase. To achieve this, it is essential to understand how buyer needs arise and what factors motivate them to act in the market. Marketing communication tools are used to achieve this, not only conveying information but also encouraging purchasing decisions (Wiktor, 2016). In practice, this means building brand recognition, shaping a positive product image, and strengthening consumer loyalty. This is particularly important for new products just entering the market, but also for existing ones. Manufacturers and sellers must ensure that the brand is easily recognizable – through packaging, logos, and appropriate advertising activities. The greater the intensity of these activities, the greater the chances of effectively reaching the customer. This is directly related to brand positioning, which is understood as "the act of designing a company's image in the minds of customers so that they can distinguish the brand from competing brands" (Garczarek-Bąk, 2022, p. 55). Targeting specific factors in marketing strategies can contribute to a brand's significant success. Lipton achieved this with its Yellow Label product, prioritizing broad product availability. This allowed them to create a somewhat unique product that has become a permanent fixture on store shelves. Lipton Yellow Label is a classic black tea considered its flagship product. Its distinctive, intense flavor and deep infusion color have made it a brand symbol and one of the most recognizable tea products in the world. Lipton Yellow Label is a prime example of a strategy aimed at mass consumers by maximizing availability and building a strong visual identity. Lipton Yellow Label's marketing strategy is based on

an intensive distribution model. The product is deliberately placed in the widest possible range of sales channels. It is available not only in supermarkets but also in small local shops, gas stations, kiosks, and food service outlets. This allows this tea to achieve very high numerical distribution (Mikołajczyk, 2022, p. 76). The goal of this intensive distribution strategy is to make Lipton products ubiquitous, accessible to everyone, anytime, anywhere. This widespread availability in retail directly supports the brand's image as a basic, everyday necessity. The packaging and colors of Lipton Yellow Label tea are virtually identical on every continent, allowing consumers to recognize the product even without speaking the local language. Thanks to this strategy, Lipton Yellow Label has become one of the best-selling teas in the world, a clear example of the triumph of mass marketing strategies and the psychological mere-exposure effect, where consumers prefer familiar things (Sharp, 2010).

4. Perceptions of the Lipton Yellow Label brand – results of our own research

The study was conducted using a Microsoft Forms (MF) online survey. Conducting a study using a MF online survey offers several advantages in terms of efficiency, data management, and accessibility. As a tool within the Microsoft 365 ecosystem, it streamlines the research process from creation to analysis. The questionnaire included closed-ended, single-and multiple-choice questions, as well as a set of statements rated on a five-point Likert scale. Respondents could also answer one open-ended question. 101 people completed the survey, 96 of whom declared familiarity with the Lipton Yellow Label brand. Further analysis considered only the responses of 96 people familiar with the Lipton brand. The gender breakdown among respondents was even, with slightly more men (48%) responding. Women constituted 47% of the sample. Some respondents (5%) did not wish to disclose their gender. In terms of age, young people aged 21-27 dominated (54%). The next largest group was those aged 28-39 (24%). Respondents aged 40-60 also constituted a significant group (20%). The smallest group were young people aged 16-20 (3%).

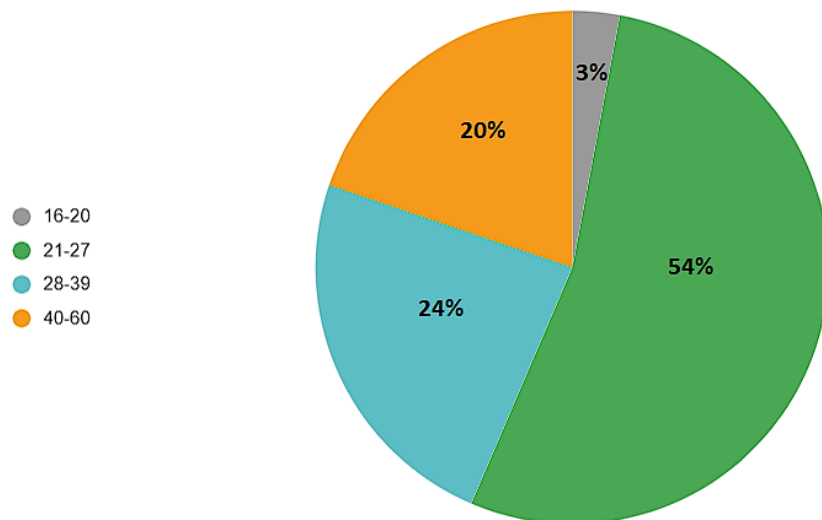


Figure 1. Age of respondents in years (%).

Source: own study based on personal research.

In terms of respondents' education level, higher education with a bachelor's or engineering degree clearly dominated (51%), followed by higher education with a master's degree (33%). The smallest group of respondents had secondary education (16%). In terms of place of residence, the respondents were dominated by cities with populations exceeding 500,000 (50%). One-third of the respondents were residents of medium-sized cities with populations ranging from 150,000 to 500,000. The smallest group of respondents turned out to be residents of small towns with populations of up to 50,000.

The introductory question in the survey questionnaire asked how often respondents consumed tea (Figure 2). Half of the respondents indicated that they consumed the beverage several times a week. The second largest group was those who drank tea daily (31%). Less frequently, i.e., once a week, 14% of respondents declared, and less than 5% of respondents said they drank tea once a month or less frequently. The popularity of tea among respondents allowed for more accurate results in the remaining part of the study.

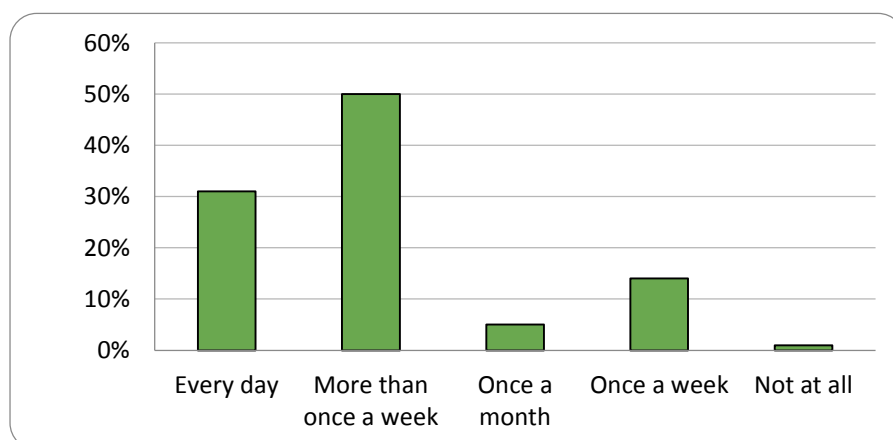


Figure 2. Frequency of tea drinking among respondents (%).

Source: own study based on personal research.

The next question was multiple-choice. It was designed to determine the type of tea most frequently chosen by respondents (Figure 3). Black tea was the clear leader in this section, chosen by a staggering 74% of respondents. Green tea came in second (54%), slightly ahead of herbal infusions (53%). Fruit teas were the next most popular (49%). Yerba mate proved very popular, with 32% of respondents choosing it. Matcha tea was chosen by 22% of respondents, and white tea by 19%. Oolong teas (12%) and iced teas (3%) were the least frequently chosen.

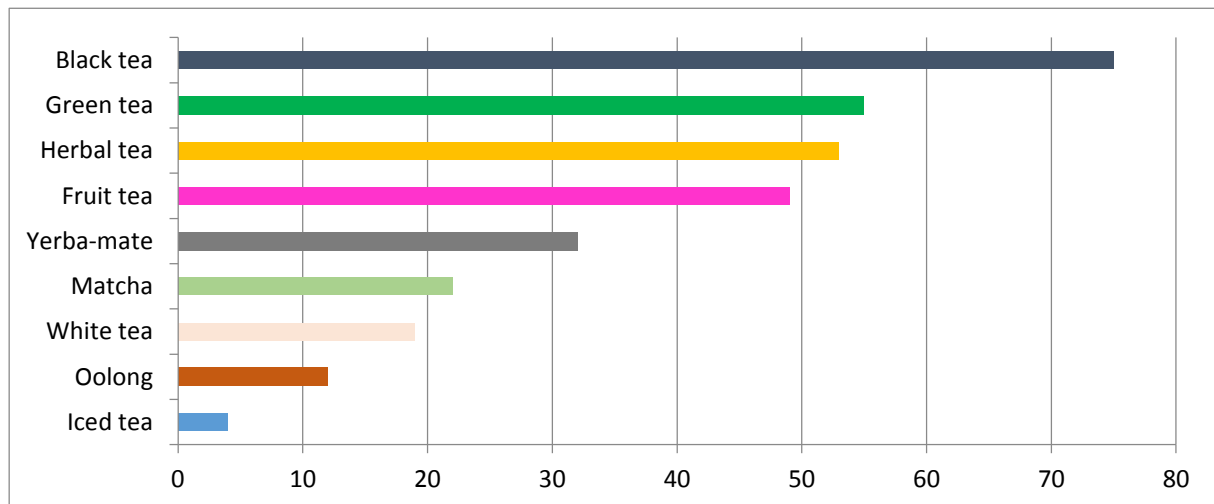


Figure 3. Selection of the type of tea consumed most often by respondents (in %).

Source: own study based on personal research.

The circumstances in which tea is consumed are a crucial element of this ritual. This was also explored in a multiple-choice survey question. Most respondents consume tea when sick or cold (81%). A significant portion of respondents (69%) enjoy relaxing in the evening with their favorite tea. Over 50% of respondents also indicated brewing tea during social gatherings. Respondents agree on drinking tea while working, studying, or watching movies (35%). In the morning, only 30% of respondents choose tea for breakfast, and tea is least frequently consumed while traveling (8%). The results are presented on Figure 4.

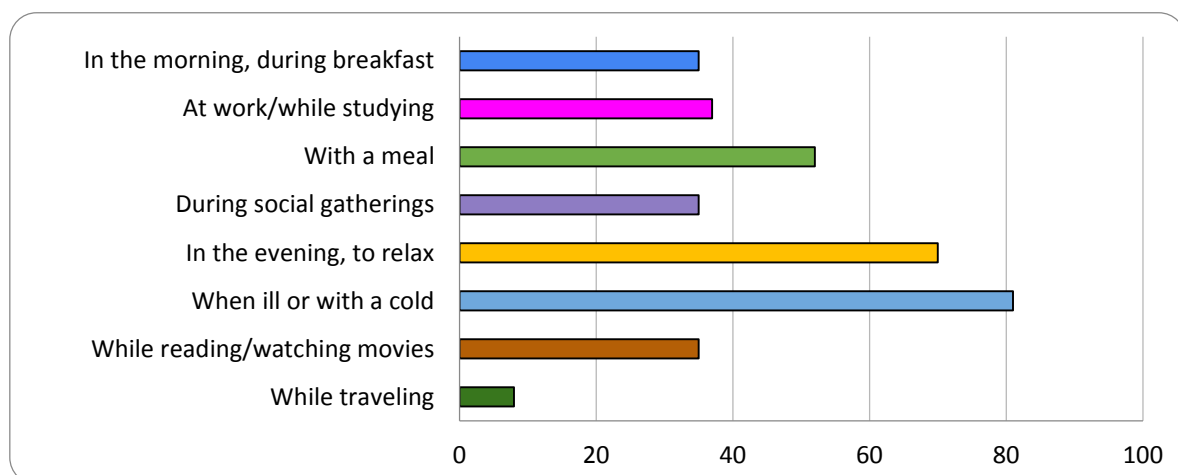


Figure 4. Circumstances of drinking tea among respondents (in %).

Source: own study based on personal research.

The next part of the study examined the key factors in choosing tea (Figure 5). Respondents were asked to rate their considerations when purchasing tea on a five-point scale. Taste and aroma proved to be the most important criteria, with the vast majority of respondents rating them highest. Health properties were similarly highly valued, which may indicate growing consumer awareness of the health-promoting properties of tea. Price is also important, although not the dominant factor. Most respondents considered it important, but not crucial. Store availability was also highly rated, demonstrating that ease of purchase remains an important factor in consumer decisions. Factors such as brewing speed, brand/producer, and recommendations from friends were rated lower. They are considered additional rather than decisive factors. Packaging and product aesthetics do not play a key role for most respondents, although some do pay attention to them. The origin of the tea and quality certificates were given the least importance. This may indicate that for most consumers, issues related to ethics and place of production are secondary to taste and health benefits.

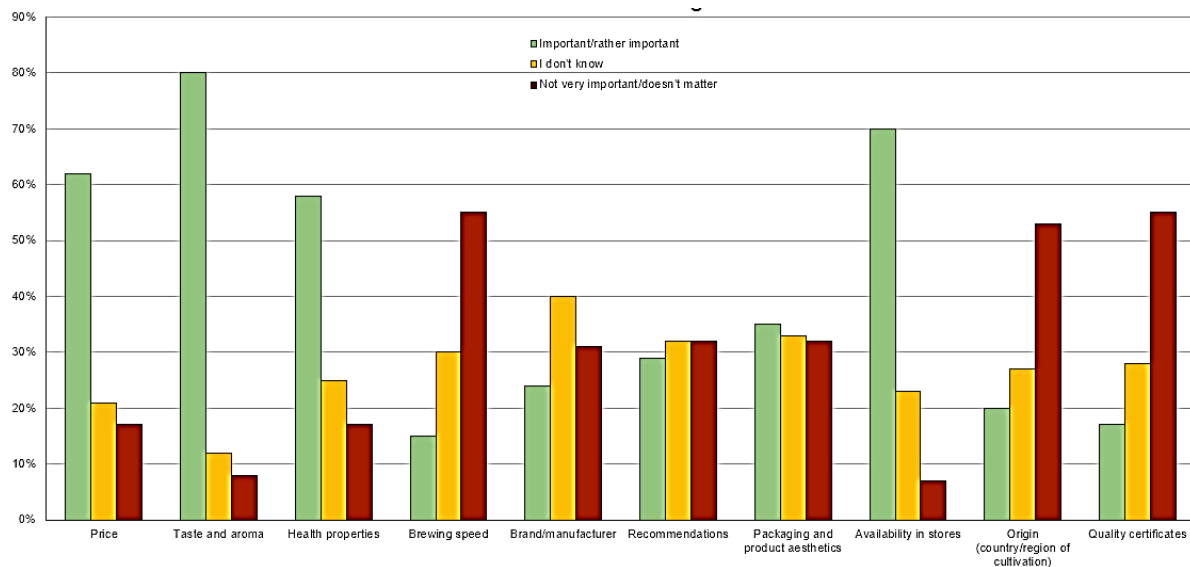


Figure 5. Main factors determining the choice of tea among respondents (in %).

Source: own study based on personal research.

Analysis of the results regarding tea brand recognition reveals significant variations in awareness of individual producers among respondents. Lipton was the most recognizable brand, cited by almost everyone. Saga (88%) came in second, followed by Herbapol (75%). Dilmah (63%) and Loyd (62%) also enjoy high recognition. Brands such as Five o'Clock (52%) and Tetley (45%) achieved average recognition. Sir Adalbert (31%), Big-Active (26%), Richmond (23%), and Ahmad Tea (21%) are slightly less popular (Figure 6).

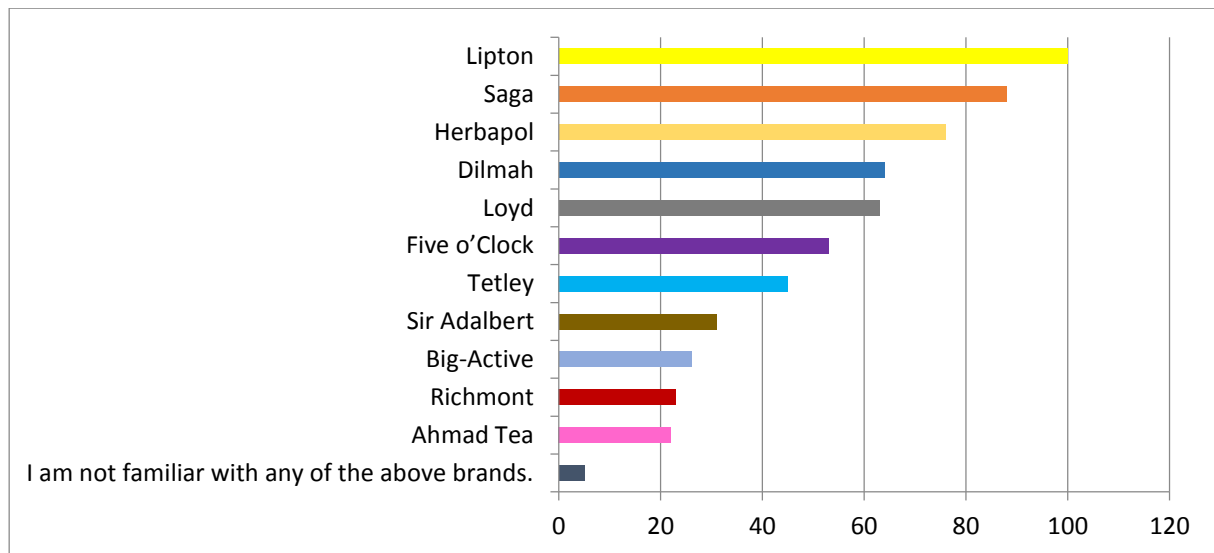


Figure 6. Recognition of selected tea brands (in %).

Source: own study based on personal research.

It's worth noting that only five respondents declared they were unfamiliar with any of the aforementioned brands. This indicates that the tea market is characterized by a high level of consumer awareness and high brand penetration. The high recognition score for the Lipton brand allowed for a 96% positive response rate in the next closed-ended question. This question asked whether the respondent was familiar with the Lipton Yellow Label tea brand Figure 7). Answering "yes" allowed the survey to continue. Selecting "no" led to the metrics questions and the end of the survey. This allowed for the exclusion of respondents unfamiliar with the Lipton brand in later, more specific questions. This positively impacted the survey's credibility. Subsequent questions verified the respondents' perception of the Lipton Yellow Label product. The vast majority (over 75%) correctly identified the product as not a premium brand. Only 18% considered Lipton Yellow Label a high-end product. 5% of respondents were unable to determine whether they were more in favor or against it.

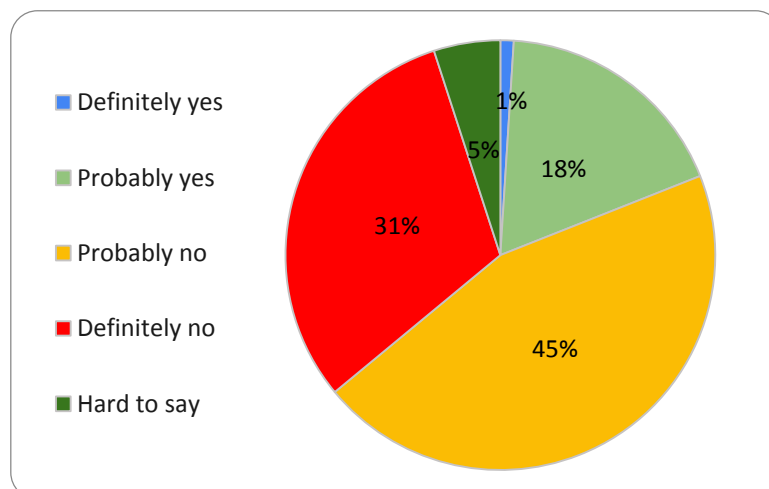


Figure 7. Rating Lipton Yellow Label tea as a premium brand.

Source: own study based on personal research.

In an open-ended question explaining why Lipton Yellow Label tea is or isn't a premium brand, respondents' answers were repetitive and formed several main groups of justifications, including:

- Widespread availability and mass appeal

The most frequently cited reason is that Lipton Yellow Label is "*a mass product, available in every store.*" Many respondents point to its "*too much popularity,*" which, in their opinion, contradicts the exclusivity typical of premium brands. To quote one response: "*It's not a premium brand because it's a mass product, available in almost every supermarket.*"

- Price and market segmentation

Respondents repeatedly emphasized the tea's moderate price – "*it's cheap,*" "*relatively low price,*" and "*optimal price.*" In the opinion of respondents, this positions Lipton Yellow Label in the economy segment, not the premium segment.

- Taste and Quality

Some respondents described the taste as average, unremarkable – "*it tastes quite average,*" "*nothing special,*" "*it doesn't stand out.*" Critical comments were also made, such as "*it's a sawdust chute, not tea*" or "*it tastes like someone poured lawnmower grass into a bag.*" At the same time, a certain group of respondents rated the product positively, citing "*good taste and aroma*" and "*easy brewing,*" though even these respondents didn't consider it premium.

- Packaging and Aesthetics

Several respondents noted that Lipton's packaging was *simple and functional, not exclusive.* The distinctive yellow color evoked mixed feelings – from neutral to negative, as in the response: *because it's a rude yellow.*

- Brand Image

Respondents often emphasized that Lipton reminds them of sweetened beverages rather than high-quality tea. Some also commented that such a large corporation couldn't create premium products on a mass scale. One respondent stated, *Good marketing ≠ premium product.*

The collected responses indicate that the Lipton Yellow Label brand is primarily perceived as an everyday tea, easily accessible and affordable, but lacking any exclusivity. A few opinions point to good quality and taste, but even these do not change the overall impression that the product belongs to the mainstream, not premium, segment.

In the next question (Figure 8), respondents indicated the extent to which they agreed or disagreed with specific statements about the Lipton Yellow Label brand. Responses were to be chosen on a five-point Likert scale (from 1 – I completely disagree, to 5 – I completely agree). The statement that Lipton Yellow Label is "*a readily available product that can be purchased in any store*" received the highest level of support (over 80%). Respondents strongly associate the brand with easy availability and mass appeal. Significantly fewer agreed with the statement that they would miss the product if it were to disappear from the market (over 53%). This indicates that, while Lipton Yellow Label tea is recognizable, it doesn't build strong consumer loyalty. Some respondents positively assess the value for money, though neutral rather than enthusiastic

attitudes prevail. This means the product is accepted as "correct", but doesn't stand out for its added value. Lipton Yellow Label is, to some extent, perceived as an "icon of the tea category". Responses are very even within this category, but there's a slightly stronger indication that consumers consider Lipton Yellow Label tea a benchmark when comparing other brands, regardless of the fact that they don't consider it premium.

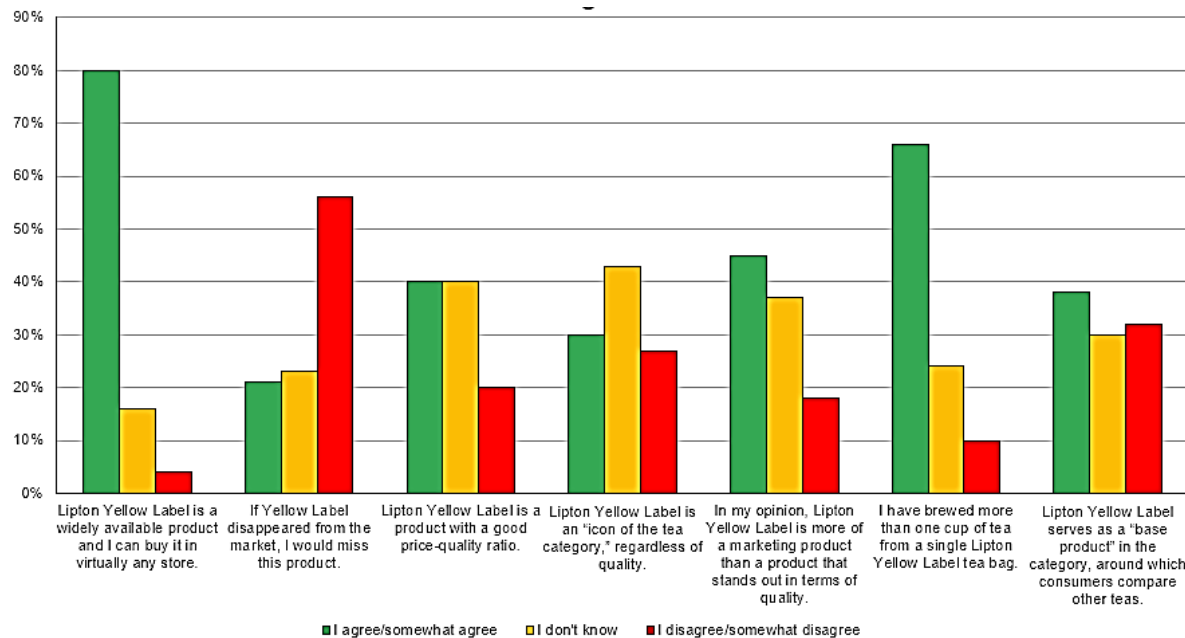


Figure 8. Assessment of compliance with the given statements regarding the Lipton Yellow Label brand (in %).

Source: own study based on personal research.

Many respondents agree that Lipton is more of a marketing product than a quality product (45%). This confirms that the brand's strength stems primarily from recognition, advertising, and mass distribution. When asked about brewing more than one tea bag, responses suggest that over half of consumers have used the product in this way, confirming its intense flavor. Respondents largely agree that Lipton Yellow Label serves as a "base product"—a benchmark for the entire tea category. This underscores its market importance, although it doesn't imply high quality or prestige.

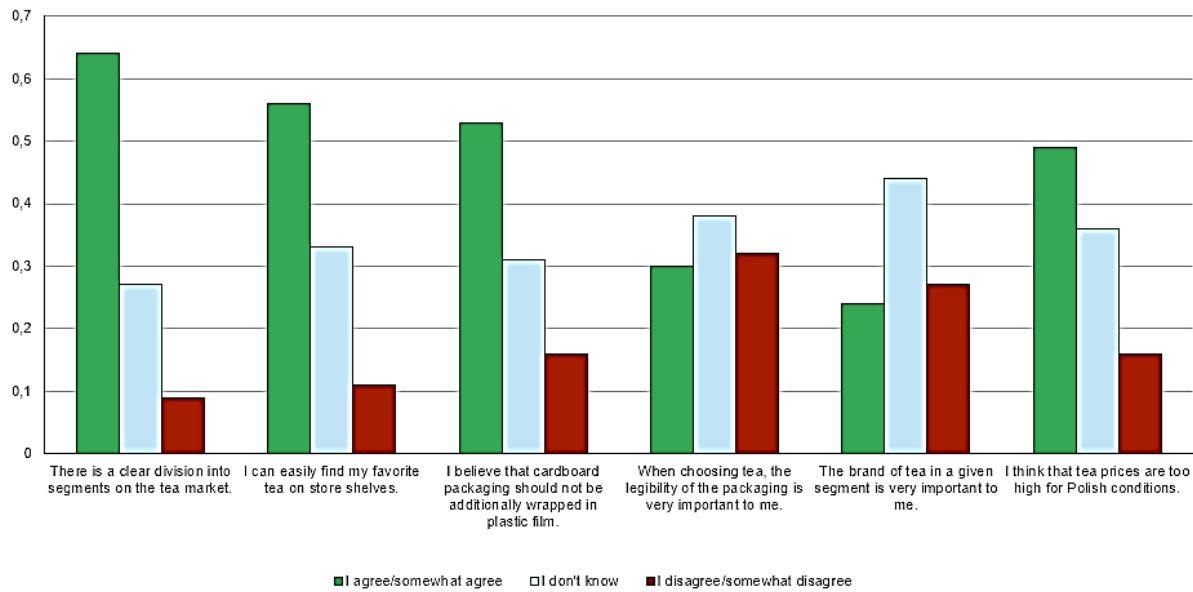


Figure 9. Assessment of compliance with the given statements regarding the tea market in Poland (in %).

Source: own study based on personal research.

The next question was similar to the previous one, but it concerned the tea market in general (Figure 9). Respondents also had to choose answers on a five-point Likert scale (from 1 – I completely disagree to 5 – I completely agree). Over 60% of respondents largely agreed with the statement that the tea market is clearly divided into segments. This indicates that consumers perceive differences in quality and price between individual products. When asked about the availability of their favorite tea, the majority of respondents indicated that they had no difficulty finding their favorite tea on store shelves (60%). This demonstrates the wide distribution and wide variety of brands present in the market. Over half of respondents agreed that cardboard packaging should not be additionally wrapped in plastic. This indicates growing consumer sensitivity to environmental issues and the excessive use of plastic in packaging. 31% of respondents considered packaging clarity important. Therefore, it can be concluded that visual elements such as clear labeling, ingredients, and presentation play an important role in purchasing decisions. When asked about the importance of brand in a given segment, responses were balanced. Some respondents attach great importance to it, while others consider it a secondary factor. This indicates that loyalty to specific producers is moderate. A significant group of respondents believe that tea prices are too high for Polish conditions. This indicates significant consumer price sensitivity and possible barriers to purchasing products from higher segments.

Based on the research, it can be concluded that tea is an important element of everyday consumer habits. Flavor, aroma, availability, and health benefits are key factors in choosing tea. Factors such as brand, packaging, and recommendations from friends play a secondary role. Brand recognition analysis shows that consumers are well-acquainted with the major brands – such as Lipton, Saga, Herbapol, and Dilmah – which serve as benchmarks in the category.

At the same time, Lipton Yellow Label, although highly recognizable, is not perceived as a premium product. Respondents emphasize its mass appeal, easy availability, and moderate price, while also citing its average taste and simple packaging. Many believe that Lipton serves as a basic product with strong marketing appeal, but lacking exclusivity. Consumers generally perceive the tea market as diverse and well-stocked, with increasing emphasis on environmental friendliness, accessibility, and packaging transparency, while also exhibiting a critical approach to pricing.

5. Conclusions and recommendations

Consumer research confirms that tea serves as an everyday product. Most respondents drink it daily or several times a week, with taste, aroma, and health benefits being key selection criteria. The survey also reveals a clear market segmentation and growing consumer sensitivity to packaging (less foil) and the clarity of label information. In the context of category management, Lipton Yellow Label clearly functions as a "core product"—a strong, widely available, and frequently used benchmark in price-quality comparisons. High brand recognition creates an anchor effect on the shelf, but qualitative and open-source research indicates that consumers do not perceive Yellow Label as a premium product. The arguments include mass availability, moderate price, average taste, and simple packaging. This positioning determines its role in the product range. It is more of a penetration product than a luxury product. Based on the conducted research, several operational recommendations can be made, particularly for the category manager for Lipton Yellow Label:

- Maintaining the core product position – Lipton Yellow Label serves as a benchmark in the category – it is widely available, recognizable, and frequently chosen. The recommendation is to maintain a strong presence on store shelves and use appropriate planograms to emphasize its role as a mass-produced and rotating product.
- Pricing and promotional strategy – Due to its lack of premium product perception, Lipton Yellow Label should remain in the economy segment. The key will be the use of attractive promotions and a stable pricing policy, which will maintain its role in everyday purchases and attract consumers to the entire category.
- Development of premium and eco-friendly segments – the research reveals a lack of qualitative differentiators for Yellow Label. The introduction of limited editions to the portfolio will increase the category's value and meet the needs of more demanding customers.
- Packaging and consumer communication – Respondents emphasize the aesthetics and eco-friendliness of the packaging. Reducing the amount of foil, clearer labeling, and more attractive graphics can improve brand image and increase consumer loyalty.

Additionally, communication should emphasize taste and health benefits, which are key factors for customers when choosing Yellow Label.

- Building loyalty through education and marketing – the study results show that consumers do not have a strong emotional connection with Yellow Label. We recommend conducting educational and marketing activities, such as campaigns informing about the production process, the origin of the leaves, and its health benefits. This can strengthen brand relationships with customers and build long-term loyalty.

6. Summary

The aim of this article was to identify and assess the role of Lipton Yellow Label in the tea category. Specifically, the article considered the role of the Lipton brand as Unilever's core product. The survey confirmed that Lipton Yellow Label serves as a benchmark in the tea category, characterized by high brand recognition, widespread availability, and a strong position on store shelves. At the same time, respondents indicated that they do not perceive the Lipton brand as a premium product, which presents an opportunity for the development potential of organic and premium segments. Theoretically, the article demonstrated that effective category management relies on close collaboration between suppliers and retailers, strategic product positioning, and continuous analysis of consumer needs and behavior. Thanks to a consistent distribution strategy, iconic packaging, and competitive pricing, the Lipton brand has become an example of effective category management on a global scale. Our own research results indicate clear consumer trends: growing sensitivity to packaging, health-promoting expectations, and a noticeable segmentation of the market. In response to these trends, recommendations for category managers were formulated, including optimizing pricing policies, developing premium offerings, modernizing packaging, and implementing educational initiatives to build loyalty. The study's main limitations were the non-random sampling and focusing on a single product within the category. Future research should expand the analysis to include comparisons with other anchor brands and incorporate qualitative methods to more deeply explore consumer motivations and attitudes. Regarding the limitations of the research, it should be noted also that the sample size is relatively small. It would also be worthwhile to conduct in-depth qualitative research that could more precisely answer the question of why consumers choose a particular tea brand, by better understanding their quality motivations. Nevertheless, the study's conclusions can provide a valuable starting point for category management practitioners, not only in the tea industry but also in other FMCG sectors.

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ARTIFICIAL INTELLIGENCE IN INDUSTRIAL PROCESSES: OPPORTUNITIES, LIMITATIONS, AND ETHICAL DILEMMAS – A CASE STUDY FROM THE KUJAWSKO-POMORSKIE PROVINCE

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Purpose: The purpose of this article is to analyze the use of artificial intelligence in the packaging ordering process at a confectionery company located in the Kujawsko-Pomorskie Province. The article reflects on the ethical and organizational aspects of implementing intelligent decision support systems in a production environment.

Design/methodology/approach: The article is based on a case study approach, including an analysis of a manufacturing company operating in the food industry. The following methods were used: process analysis, participant observation, interviews with management and procurement staff, analysis of data on order cycles, inventory levels, and delivery timeliness prior to AI implementation.

Findings: The implementation of AI-based solutions in the packaging ordering process brought a number of benefits:

- reduction of order fulfillment time by approx. 18%,
- reduction of packaging inventory by 22%,
- reduction in the number of incorrect deliveries and excess orders,
- improvement in the accuracy of demand forecasts during peak production seasons.

At the same time, barriers and risks were identified, such as: insufficient integration of IT systems, lack of digital skills among employees, and the need to ensure oversight of algorithmic decisions.

Research limitations/implications: The study covers one company and one area of the industrial process (ordering packaging), which limits the possibility of fully generalizing the results.

Practical implications: The article points to practical possibilities for applying AI in the procurement processes of industrial companies. The results can serve as a reference point for production and logistics managers.

Social implications: The implementation of AI requires the development of employees' digital skills, building trust in technology, and taking into account the ethical aspects of decision automation.

Originality/value The article is an example of a rarely analyzed application of artificial intelligence—in the process of ordering packaging in the food industry. It combines technological analysis with ethical and organizational reflection, highlighting the interdisciplinary nature of AI implementations in industry.

Keywords: artificial intelligence, industrial processes, packaging ordering.

Category of the paper: Case studies.

1. Introduction

Contemporary industry is on the verge of a transformation known as Industry 5.0, in which artificial intelligence (AI) plays a key role. Unlike the earlier Industry 4.0 paradigm, which focused on automation and the integration of cyber-physical systems, the new concept emphasizes human-technology collaboration, sustainable development, and corporate social responsibility (Dacko-Pikiewicz, Szczepańska-Woszczyna, Lis, 2023). AI is thus becoming not only a tool for increasing the efficiency of industrial processes, but also a catalyst for organizational, competency, and ethical change.

As Barbara Siuta-Tokarska (Siuta-Tokarska, 2021) points out, the implementation of artificial intelligence in industry is, on the one hand, a huge opportunity to improve the competitiveness of the economy, but on the other hand, it raises a number of social and economic challenges. Automated decision support systems, process robotization, and predictive data analysis models allow for the optimization of supply chains, shortening of production cycles, and reduction of human error. At the same time, questions arise about the limits of machine autonomy, responsibility for decisions made by algorithms, and the security of sensitive data.

The AI Business (Artificial Intelligence, 2025) report shows that the number of AI implementations in the manufacturing, logistics, and construction sectors will grow rapidly in the coming years. These solutions will include demand forecasting, supply planning, quality management, and maintenance. However, the effectiveness of these technologies depends not only on the sophistication of the algorithms, but also on the organizational and cultural readiness of companies.

Piotr Kosiak (Kosiak, 2023), on the other hand, emphasizes that the ethical use of AI requires the creation of transparent rules for the supervision of learning systems and a balance between automation and human control. In the context of industry, this means that mechanisms for auditing algorithmic decisions must be developed and their compliance with the principles of responsible management must be ensured.

The PARP report (Report, 2024) and Andrzej Gontarz's analysis (Gontarz, 2023) show that Polish companies are increasingly using AI in the areas of procurement and logistics.

This article presents a case study of a company from the Kujawsko-Pomorskie Province, operating in the food industry, which has implemented elements of artificial intelligence in its packaging ordering process. The aim of the study is to identify the opportunities, limitations, and ethical dilemmas associated with the implementation of AI in an industrial environment and to assess the impact of this technology on the efficiency and sustainable development of the organization. Automating the packaging ordering process reduces the risk of excess inventory, optimizes costs, and increases flexibility in responding to changing market needs.

2. Theoretical foundations of artificial intelligence applications in industrial processes

Artificial intelligence (AI) is currently one of the key catalysts of industrial transformation, revolutionizing the way production is organized, resources are managed, and operational decisions are made. The literature on the subject indicates that AI technologies—including machine learning, predictive systems, big data analysis, intelligent sensors, and generative language models—enable significant improvements across the entire value chain of a company, affecting the efficiency, quality, and flexibility of manufacturing processes (Brynjolfsson, McAfee, 2014; Baryannis et al., 2019). Their role is particularly important in the context of contemporary challenges, such as the complexity of global supply chains, market instability, pressure to reduce costs, and the need to maintain high quality and continuity of production, which is also crucial for the food and confectionery industry.

The classic approach to Industry 4.0 focused on automation, digitization, and the integration of cyber-physical systems (CPS) (Nawrat, 2020). Artificial intelligence was treated as a technology supporting automation and process prediction. In the Industry 5.0 approach (Dacko-Pikiewicz, Szczepańska-Woszczyńska, Lis, 2025), the emphasis shifts towards human-centeredness, sustainability, and corporate social responsibility.

AI acts as a tool that works with employees, not replacing them, but increasing their decision-making and operational capabilities. Technological transformation cannot be analyzed solely in technological terms—it also represents a cultural and organizational change, which is particularly important in the food industry, where precision, repeatability, and quality control are central elements of the production process, and at the same time, many activities still require manual verification.

In international literature, artificial intelligence is defined as the ability of computer systems to perform tasks that previously required human intelligence, such as pattern recognition, learning, decision-making, and predicting future states of processes (Russell, Norvig, 2021). In industrial practice, AI is used in four key areas:

- Production process optimization (Hao et al., 2020): using predictive algorithms to predict failures, schedule production, and minimize downtime.
- Supply chain management (Baryannis et al., 2019): AI supports demand forecasting, purchasing planning, intelligent inventory management, and transportation optimization.
- Quality control and image analysis (Lee et al., 2018): algorithms using machine vision enable automatic defect detection.
- Decision support systems (DSS): Generative and predictive tools analyze large volumes of data, streamlining decision-making processes, e.g., ordering packaging in the confectionery industry.

Scientific literature consistently emphasizes that despite its enormous technological potential, the implementation of AI faces numerous technical, organizational, and social barriers (Walicka, Czemieli-Grzybowska, 2023). The most frequently cited limitations include low input data quality resulting from a lack of integration between ERP, MES, and warehouse systems (Hazen et al., 2021). Equally problematic is employee resistance to decision automation, resulting from fears of dehumanization of work or loss of control over the process (Sielska, Olszowy, 2024). Insufficient digital skills are a serious barrier to implementation, especially in traditional industries such as the confectionery industry, where many processes still rely on the tacit knowledge of operators (Walicka, Czemieli-Grzybowska, 2023). Ethical challenges, such as responsibility for algorithmic decisions, model transparency, and data security, are another challenge considered when introducing AI.

AI technologies can increase process stability, reduce variability, and improve production repeatability—which is particularly important in industries with highly standardized requirements (Klinkosz, 2023). In practical terms, this means that predictive systems facilitate quality monitoring and non-compliance identification, intelligent demand forecasting models support packaging demand planning, and AI can reduce human error through automated data analysis.

3. Research methodology

The study was conducted in the form of a case study, which enabled the analysis of the application of artificial intelligence in the real operating conditions of a confectionery company in the Kujawsko-Pomorskie Province. Triangulation of research methods was used, including analysis of logistics and production processes, participant observation, semi-structured interviews with management and procurement and packaging employees, as well as analysis of operational data on order fulfillment times, inventory levels, and delivery timeliness before and after AI implementation.

The analysis of the research material was comparative in nature and focused on assessing the effectiveness of the packaging ordering process and identifying the benefits, limitations, and implementation barriers. The methodology adopted allowed for the consideration of both technological and organizational and social aspects related to the implementation of artificial intelligence in an industrial environment.

4. Implementation of AI solutions in the packaging ordering process at company X

Company X, operating in the food industry, was founded in the 18th century in one of the cities of the Kuyavian-Pomeranian Province. It is a leader on the domestic and foreign markets, thanks primarily to its strong, multi-generational brand. The company's logo has remained unchanged since its inception, making its products easily recognizable to a wide range of customers. The products have become a symbol of the region, shaping its history.

The company employs about 500 people, which is a significant number for traditional machines. It stands out on the Polish market thanks to its exclusively domestic capital. The company participates in exports, expanding its reach every year. Export products are sold on a smaller scale, but the company is intensively entering new retail chains, organizing extensive promotional campaigns. The plant sets ambitious goals for its employees related to brand development and building a year-round product range.

In the context of such a complex and multi-element production environment as that of Company X, the role of the packaging cooperator, responsible for maintaining the fluidity of processes and eliminating errors that could disrupt the rhythm of the plant's operations, takes on particular importance. The scope of their responsibilities - including quality control, production data management, and cooperation with the inventory department and packers - reflects the high operational dynamics characteristic of the confectionery industry, where speed of response and precision are key determinants of economic efficiency. It is in this area that the first signs of the implementation of artificial intelligence tools capable of improving the flow of information, supporting decision-making processes, and reducing the risk of human error are becoming apparent. Understanding the specifics of a cooperator's work is therefore an essential context for analyzing the functioning of Company X- a company with a centuries-old history, a strong market position, and constantly growing requirements for quality and production reliability resulting from domestic and foreign expansion.

The packaging cooperator plays a key role in the production area of company X, supporting both quality control and the efficient flow of information between production, warehouse, and purchasing departments. Their primary tasks include monitoring product quality, quickly detecting production errors, and providing packers with the appropriate tools, such as the correct labels, individual packaging, and bulk packaging. The cooperator is also responsible for verifying the correctness of expiration dates and batch numbers, which is particularly important in conditions of frequent changeovers and machine malfunctions.

The cooperator's cooperation with the inventory department includes ongoing inventory control and reporting critical packaging stock levels, which enables quick purchasing decisions. In addition, the employee checks the conformity of packaging deliveries in terms of quantity and quality. The effectiveness of their actions directly affects the economic efficiency of the plant, minimizing the risk of downtime and production losses.

Due to the dispersion of information, the manual nature of many activities, and the high number of potential human errors, the area of packaging cooperator work is an important starting point for the implementation of artificial intelligence-based solutions. Automating data analysis, decision support, and streamlining the packaging ordering process can significantly increase work efficiency and reduce operational risks throughout the entire production and logistics area.

The packaging ordering process at Company X was initially largely manual and relied on the work of a packaging cooperator who, based on the production plan, prepared the demand for packaging materials for subsequent shifts. The need for frequent replenishment of stocks resulted from limited storage space in the production area and high volatility of short-term plans, taking into account machine breakdowns, downtime, and variable staffing.

The process involved a wide range of packaging and auxiliary materials, and manual calculations based on consumption standards were time-consuming and prone to errors, which in extreme cases led to downtime of packaging machines and economic losses.

In response to these limitations, a Microsoft Excel spreadsheet tool was implemented to standardize the process, reduce order preparation time, and minimize errors. The spreadsheet, based on built-in formulas, enabled automatic calculation of demand based on the production plan, material standards, and current inventory levels imported from the SAP system. This solution was positively evaluated by users and became a stable basis for further automation, even though it still required manual data entry.

The next stage was to expand the existing solution with an artificial intelligence module that acts as a decision support system. In line with the Industry 5.0 concept, AI does not replace the packaging cooperator, but supports them by analyzing data faster, identifying risks, and generating order recommendations. The AI module automates demand analysis, compares it with current inventory levels, and reduces errors resulting from manual calculations. The procedure involves feeding data from Excel and SAP, calculating demand, AI analysis and recommendation, and final verification and approval of the order by a human. This approach ensures process consistency, error reduction, and human oversight of algorithmic decisions, which is important both organizationally and ethically in an industrial environment.

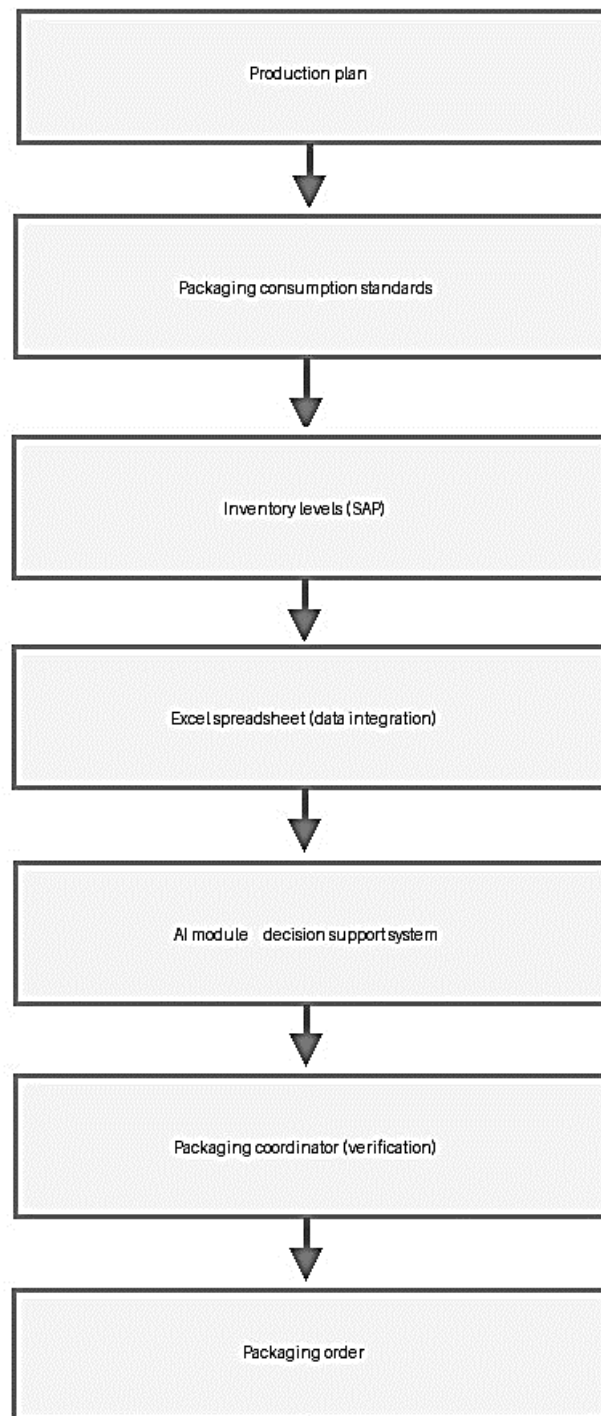


Figure 1. Diagram of the artificial intelligence module of company X.

Source: Own work.

Figure 1 shows a simplified diagram of how the artificial intelligence module works in the packaging ordering process at Company X, a confectionery manufacturer. The input data for the system comes from the production plan, packaging consumption standards, and current inventory levels obtained from the SAP system and integrated into an Excel spreadsheet. The AI module acts as a decision support system, analyzing demand, identifying the risk of stock shortages, and generating order quantity recommendations. A key element of the process

remains the packaging cooperator, who verifies the algorithm's suggestions and makes the final purchasing decision, ensuring that the principle of human supervision over algorithmic decisions is maintained and that the solution is consistent with the idea of Industry 5.0.

5. Summary

The case study showed that the implementation of AI-based solutions in the packaging ordering process at Company X brought measurable organizational and economic benefits. The most significant effects included a reduction in order fulfillment time by approximately 18% and a reduction in packaging inventory by 22%, which directly translated into improved inventory management efficiency. In addition, there was a marked reduction in the number of incorrect deliveries and excess orders, resulting from the automation of analyses and standardization of the decision-making process. AI support also contributed to improving the accuracy of demand forecasts during periods of increased production, which was crucial for ensuring the continuity of packaging processes and operational stability in the confectionery industry.

At the same time, the analysis of company X indicates that technical and competence barriers are a significant limitation to the effective use of artificial intelligence in industrial processes in the confectionery industry. The lack of full integration of IT systems (ERP, warehouse modules, and analytical tools) and the need to manually update key data limit the potential for automation and increase the risk of operational errors, undermining the reliability of AI-generated recommendations. As Hazen (Hazen et al., 2021) points out, outdated input data can lead to significant deviations between planned and actual packaging material consumption, which in an industry with short order fulfillment cycles can result in serious operational disruptions. At the same time, insufficient digital and analytical skills among some employees, as well as an initial lack of trust in algorithmic decisions, slow down the process of technology adaptation and require intensive training and organizational efforts. At company X, this problem manifested itself, among other things, in the need to train packaging operators, warehouse workers, and production managers in interpreting the results generated by the AI module. In the initial phase of implementation, a low level of trust in algorithmic recommendations was also observed. This is confirmed by numerous analyses describing employee resistance to the automation of decision-making processes (cf. Wuest et al., 2020). These results confirm the conclusions of the literature, according to which the effectiveness of AI implementations depends not only on technological maturity, but also on the competence readiness of the organization and the ability to build a data-driven work culture, especially in traditional sectors such as the confectionery industry.

Although the analysis concerns a company in the food industry, the conclusions may also apply to other industrial sectors, such as the automotive, pharmaceutical, and e-commerce industries, where accurate demand forecasting and inventory management play a key role. In sectors with higher automation, the level of system integration tends to be greater, which can accelerate the adoption of AI, but issues of trust in algorithmic decisions and ethical oversight remain universal and cross-sectoral.

Future research should consider quantitative indicators of employee trust in AI systems, measured before and after implementation, e.g., using verified technology acceptance scales (e.g., TAM model extensions). This would allow for a more in-depth analysis of the social implications and a better understanding of the relationship between the level of trust and the effectiveness of algorithmic solutions.

The implementation of AI in a production environment also raises ethical and organizational dilemmas, primarily related to responsibility for algorithmic decisions. In the case analyzed, it was crucial to maintain the principle of human oversight of decisions generated by the AI system, which reduces the risk of errors and strengthens employee trust in the technology. Ensuring the security of production data and the transparency of algorithms also remains a significant challenge.

Based on the research conducted, it can be concluded that artificial intelligence is an effective tool supporting procurement processes in industrial enterprises, provided that it is implemented in a gradual and human-centered manner. Further integration of IT systems, systematic development of employees' digital skills, and formalization of rules for supervising algorithmic decisions are recommended. This approach not only increases operational efficiency but also ensures that AI implementations are consistent with the idea of Industry 5.0 and the principles of responsible and ethical management.

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THE IMPACT OF CULTURAL CONTEXT ON EFFECTIVE SMART CITY MANAGEMENT: AN ANALYSIS OF THE OXFORD ECONOMIC GLOBAL CITIES INDEX

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Purpose: This study seeks to investigate the intricate relationships between the cultural dimensions articulated by Hofstede and the efficacy of smart city management in relation to a city's standing in the global smart cities ranking as determined by the Oxford Economic Global Cities Index 2025.

Design/methodology/approach: Multiple regressions were employed to explore the relationship between the independent variables, cultural dimensions as defined by Hofstede, including power distance, individualism, masculinity, uncertainty avoidance, and long-term orientation, and the dependent variable, which is the value of the Oxford Economic Global Cities Index 2025. The Oxford Economic Global Cities Index was chosen for its timely and thematic significance, as it captures the current outcomes of several key indicators relevant to a city's development. Smart Cities were selected based on their rankings within the Oxford Economic Global Cities Index 2025.

Findings: This study demonstrates that elevated levels of long-term orientation and individualism, coupled with low uncertainty avoidance, positively impact the adoption of smart city solutions. In contrast, the anticipated relationships between power distance and the adoption of smart city solutions, as well as masculinity and the adoption of these solutions alongside effective smart city management, were not substantiated and warrant further examination. The proposed connections between specific dimensions of national culture and effective smart city management are pertinent to the cities featured in the Oxford Economic Global Cities Index 2025.

Research limitations/implications: The primary limitation of this study is the relatively small number of cities included in the analysis. Additionally, there is a lack of a comprehensive metric that encompasses all aspects of the smart city management process. Nevertheless, the research has partially fulfilled its main objective by demonstrating that the proposed relationships between specific dimensions of national culture and the adoption of smart city solutions are valid for the cities featured in the Oxford Economic Global Cities Index 2025. Conversely, the study has also prompted new enquiries regarding the connection between masculinity and power distance, as well as their impact on smart city management, indicating a need for further research.

Originality/value: The existing literature exhibits a notable deficiency in addressing the cultural determinants inherent in the management of smart cities, particularly regarding the organisational and managerial solutions necessary for the transition from traditional urban

frameworks to smart city paradigms. This paper endeavours to critically examine the influence of cultural factors on urban management and development processes. The impetus for this study lies in investigating the relationship between Hofstede's cultural dimensions and the extent of technological adoption within the realm of smart city management, alongside their subsequent impact on a city's standing in global smart city rankings.

Keywords: smart city management, smart city, cultural dimensions, cultural context, the Oxford Economic Global Cities Index.

Category of the paper: research paper.

1. Introduction

The concept of the smart city represents a transformative paradigm in urban planning, emergent from the dynamics of the contemporary digital era. Smart cities, fueled by rapid advancements in information and communication technology (ICT), offer innovative solutions to a myriad of complex urban challenges.

The adoption of smart city technologies is significantly shaped by both national and local cultural dimensions, which influence organisational strategies and citizen engagement practices. A comprehensive understanding of these cultural determinants is crucial for policymakers and city managers, as it allows for the tailoring of interventions aimed at enhancing both adoption rates and equitable outcomes.

National culture has long been considered a contextual factor influencing economic behaviour, including innovation. Scholars have argued that the values of innovation are increasingly recognised as influenced by not only technological infrastructure and economic policy but also deeper cultural values embedded in a society. While traditional innovation studies have emphasised factors such as research and development intensity, education, and market structure, a growing body of research highlights that national culture can significantly shape a country's capacity to innovate (Escandon-Barbosa et al., 2022; Bonetto et al., 2022; López-Cabarcos et al., 2021; Tian et al., 2021).

Culture, defined as a system of beliefs, attitudes, and values (Hofstede, 2001), plays a pivotal role in the manner in which societies respond to contemporary challenges. Geert Hofstede's cultural dimensions theory serves as the predominant framework for conducting cross-cultural analyses of national culture. Hofstede identifies the following cultural dimensions: power distance, uncertainty avoidance, individualism vs. collectivism, masculinity vs. femininity, and long-term vs. short-term orientation. His research underscores the assertion that national culture significantly influences the values and behaviours of a nation's citizens. While a substantial body of literature has explored the relationship between national culture and organisational behaviour, there remains a notable dearth of studies examining the role of national culture within the context of urban resilience.

Consequently, the existing body of knowledge concerning the reflection of national culture in urban resilience planning is limited. This research seeks to address this gap by exploring the implications of cultural factors on urban resilience strategies.

Numerous academic papers endeavour to conceptualise and delineate the fundamental aspects and application domains of smart cities, frequently employing case studies or comparative analyses. However, it is posited that further investigation is warranted to identify successful methodologies for urbanisation and the enhancement of urban areas. Notably, the transition from conventional urban environments to smart cities has not received adequate scholarly attention to the cultural determinants that underpin smart city management, particularly in terms of organisational and managerial solutions (Jourdan, Smith, 2021; Neves, 2025; Avis et al., 2025; Fonesca et al., 2025). Thus, this study aims to elucidate how cultural elements influence urban development and the broader discipline of city management.

The motivation behind this study is to explore the relationship between Hofstede's cultural dimensions and the effective management of smart cities, as well as their influence on a city's standing in the global smart cities ranking. This study seeks to investigate the intricate relationships between the cultural dimensions articulated by Hofstede and the efficacy of smart city management in relation to a city's standing in the global smart cities ranking as determined by the Oxford Economic Global Cities Index 2025.

The structure of the paper is as follows: following this introduction, the next section provides a literature review, which includes a discussion of the research model and the development of hypotheses. The research methodology is elaborated upon in detail. Lastly, the research findings are presented and discussed, the implications examined, and the limitations and avenues for future research identified.

2. Literature review and hypotheses development

The concept of smart cities has undergone a significant evolution, initially characterised by the integration of advanced technologies such as sensors, high-speed internet infrastructure, and big data analytics platforms (Angelidou et al., 2018; Özdoğan et al., 2025; Audretsch et al., 2025). Over time, this paradigm has expanded to encompass a more comprehensive understanding, prioritising the enhancement of overall societal quality of life (Albino et al., 2019; Kinoshita et al., 2025; Palgan, Mont, 2025). The continuous advancement of technological innovations provides new avenues for the management of urban development. In contemporary society, the transformation of urban spaces into smart cities is increasingly recognised as an essential strategy for elevating residents' quality of life. The overarching objective of the smart city framework is to implement modern urban management practices utilising technological instruments (Wang, Zhou, 2022; Intan, Junita, 2025).

As urban areas increasingly digitalise, they are experiencing substantial migration flows from rural regions, as individuals seek improved living conditions and economic opportunities. According to Dastbaz, Naudé, and Manoochehri (2018), the anticipated urban population surge by 2050 is projected to be most pronounced in developing nations, underscoring the critical need for effective management strategies. This necessitates meticulous planning for the requisite infrastructure and services to accommodate the escalating population. Hence, a smart city may be precisely defined as an urban environment that leverages information and communication technology (ICT) to optimise its operational effectiveness (Okafor et al., 2023).

The impact of cultural variables on the adoption of emerging technologies has garnered considerable attention from scholars (Khan, 2022; Blut et al., 2022; Venkatesh, 2022). In particular, research that employs and validates Hofstede's national cultural dimensions illustrates that these constructs hold substantial relevance, with observable variations in national cultures significantly influencing diverse organisational behaviours and outcomes (Bresciani et al., 2021; Tekic, Tekic, 2021; Yeganeh, 2023).

Geert Hofstede, a Dutch sociologist, conceptualises culture as a "collective programming of the mind," which directs how a group interacts with its environment (Hofstede, 1991). His framework is widely recognised as a robust analytical tool for examining technology adoption in smart city governance due to its extensive application in the academic literature. Hofstede's original model encompassed four primary cultural dimensions: power distance, uncertainty avoidance, individualism, and masculinity, with a subsequent fifth dimension, long-term orientation, added later. Each dimension, along with its anticipated relationship to ICT adoption and smart city management, warrants careful consideration (Kole, 2025).

The first dimension identified by Hofstede (1980), power distance, relates to the extent of accepted inequality among individuals within a given culture. Hofstede (2001) articulates power distance as society's acceptance of disproportionate power distribution. Cultures exhibiting low power distance indicate a greater acceptance of hierarchical structures, whereas those with high power distance suggest a societal dissatisfaction with inequalities in power.

Power distance reflects the degree of inequality deemed acceptable within a country and is manifest in organisational hierarchies. Cultures characterised by elevated power distance are often less amenable to novel ideas due to the involvement of decision-making in areas lacking historical precedent and sufficient information (Lee, Peterson, 2000). Conversely, low power distance cultures typically exhibit minimal inequality, wherein societal perceptions do not regard discrepancies in power, wealth, and prestige as inevitable (Oyserman, 2006). Nikolov and Krumova (2019) assert that power distance serves as a strong predictive factor, particularly within European nations, in relation to specific aspects of e-governance in smart cities.

Power distance denotes the extent to which a society acknowledges formal power and status differentials among its members (Van Everdingen, Waarts, 2003). In cultures characterised by lower power distance, individuals are inclined to question established norms, procedures, and authoritative figures. Hofstede (2011) posits that societies with diminished power distance

are more inclined to adopt new technologies and foster innovative practices. In contrast, high levels of centralisation and formalisation tend to correlate negatively with the rates of innovation adoption (Rinne, Steel, and Fairweather, 2012). Thus, the first hypothesis of this inquiry can be articulated as follows:

H1: *Smart city management is positively impacted by low power distance.*

In this hypothesis, it is posited that a diminished level of power distance within organisational structures can positively influence the efficacy of smart city management. This framework emphasises collaborative governance and participatory decision-making, thereby fostering an environment where the voices of diverse stakeholders, including citizens, are duly recognised and valued. Such inclusive practices are expected to enhance transparency, responsiveness, and innovation within smart city initiatives, ultimately contributing to improved outcomes in urban development.

The constructs of individualism and collectivism represent a spectrum that reflects varying degrees to which societies endorse self-reliance over group integration. A high score on this continuum signifies a societal preference for individualism, whilst a low score indicates a tendency towards collectivism. This spectrum illustrates cultural orientations toward either individual pursuits or communal pursuits. Societies characterised by individualism typically favour individuals who demonstrate independence, whereas collectivist societies underscore the importance of mutual support and loyalty to the community.

In individualistic societies, individuals are encouraged to act autonomously, question authority, and take initiative, traits that align with entrepreneurship and knowledge creation. Individualism reflects the extent to which a society allows gratification and enjoyment while playing a facilitating role (Escandon-Barbosa et al., 2022).

Research conducted by Lee et al. (2007) establishes a positive correlation between individualism and technology acceptance, while subsequent studies by Tarhini et al. (2017) highlight that individualism not only fosters readiness for technology adoption but also mediates other cultural dimensions. Furthermore, Masimba, Appiah, and Zuva (2019) have confirmed a significant relationship between individualistic orientations and technology adoption rates.

In individualistic societies, there exists a heightened emphasis on personal goals. Shane (1993) notes that these societies exhibit enhanced levels of innovation. Additional empirical evidence suggests that cultures classified as individualistic are more inclined to adopt technologically innovative solutions. A positive correlation is also identified between elevated individualism and indicators of innovation (Rinne, Steel, Fairweather, 2012). Consequently, it can be anticipated that societies with stronger individualistic orientations are likely to exhibit greater levels of innovation (Khazanchi et al., 2007). Recent studies indicate that greater individualism among urban populations correlates with greater efficacy in managing smart cities. Individualism is posited to stimulate innovative thinking and personal accountability,

both of which are essential attributes in the development and implementation of smart technologies and urban policies.

As citizens engage more actively in their communities, their unique perspectives and contributions may yield more adaptive and responsive governance structures, ultimately resulting in improved outcomes for smart city initiatives. This relationship underscores the importance of cultivating individualistic values in the promotion of collaborative, technology-driven urban environments (Marchesani, 2023).

The dimension of individualism pertains to the dynamics between individuals and their respective groups. In individualistic cultures, individuals are more inclined to make autonomous decisions, while those in collectivist contexts are often more susceptible to conforming to group norms. A heightened degree of individualism is associated with a greater openness to novel digital solutions and citizen-centric services within smart city initiatives. Individualistic societies prioritise personal benefit and innovation, thereby enhancing the adoption of technology. Individuals in these societies feel empowered to voice their opinions, making them more inclined to innovate and embrace new concepts. Thus, individuals within individualistic cultures often exhibit self-reliance and independent thinking, which is anticipated to foster creativity and, by extension, heightened levels of innovation (Dirsehan and Zoonen, 2022). In light of this comprehension, the second hypothesis posited in this study is articulated as follows:

H2: *Smart city management is positively impacted by a higher degree of individualism.*

The dichotomy of masculinity versus femininity serves as a critical framework for understanding how various societies prioritise distinct values traditionally associated with gender. Masculinity is characterised by a preference for values such as economic growth, power, and high achievement, whereas femininity emphasises values like care, cooperation, and the cultivation of harmonious environments. In this context, high scores on masculinity indicate a societal inclination towards competitive and performance-driven norms, while low scores reflect an affinity for cooperative and relationship-oriented principles.

Cultures that exhibit a strong masculine orientation are often marked by ambition and a pronounced focus on material success. In contrast, feminine cultures typically prioritise solidarity, equality, and consensus-building, thereby fostering social relationships and communal well-being. According to Hofstede (2001), organisations operating within masculine frameworks tend to prioritise performance-related rewards and recognition, alongside individual training and development – a combination that is frequently linked to innovative organisational characteristics.

Moreover, gender-role-related behaviours effectively illustrate masculinity as a significant cultural dimension. Societies classified as masculine often demonstrate lower levels of gender egalitarianism and are more steadfastly focused on achievement metrics. Conversely, feminine cultures demonstrate a heightened emphasis on relational dynamics. Research indicates that cultures with a feminine orientation are generally more supportive of the adoption of new

technologies, as they are influenced by subjective norms and positive behavioural intentions (Tarhini et al., 2017).

On the other hand, Sunny, Patrick, and Rob (2019) attest that masculine societies may tend to negative attitudes towards technological innovations. Nonetheless, Negara and Setyohadi (2020) contend that masculinity alone may not serve as a definitive predictor of technology acceptance, particularly concerning smart city initiatives. Additional research conducted by Meyer-Waarden et al. (2021) suggests that femininity plays a moderating role in uncertainty avoidance, thus enhancing trust in smart solutions that promote individuals' subjective well-being. Whereas masculinity often undermines collaboration and social openness, which are crucial for long-term innovation success (Prim et al., 2017).

In summary, Hofstede (2001) posits that organisations within masculine cultures are predominantly orientated towards performance recognition and rewards, alongside individual development, traits commonly associated with innovation. Therefore, this study proposes a positive correlation between masculinity and the propensity for innovation within smart city management contexts.

H3: *A higher level of masculinity has a positive influence on smart city management.*

Uncertainty avoidance is a critical cultural dimension that delineates the extent to which societies endeavour to mitigate unpredictability in their environments. A society exhibiting a high score on this dimension typically places a premium on tradition and established norms over innovative practices, whereas a society with a low score demonstrates a preference for pragmatic approaches that prioritise functional implementation over stringent adherence to established principles. The integration of new technologies inherently entails a degree of uncertainty, which is particularly pronounced in contexts where the functionality of such technologies is validated, but their economic viability remains contentious (Stoneman, 2001). This underscores the significance of economic risk as a primary concern in the adoption of technology.

The concept of uncertainty avoidance reflects individuals' inherent desires for structured and regulated environments. An excessively high level of uncertainty avoidance is often indicative of a society characterised by anxiety and a striving mentality, in contrast to societies with lower scores, which tend to exhibit greater adaptability and a more laid-back disposition. Venkatesh and Zhang (2010) evidenced that the process of adopting new technology can engender a state of uncertainty, culminating in heightened perceived stress and discomfort within cultures characterised by elevated levels of uncertainty avoidance. Furthermore, research conducted by Negara and Setyohadi (2020) identified uncertainty avoidance as a robust predictor of technology acceptance, particularly in the context of smart city initiatives. Supporting this premise, studies by Meyer-Waarden et al. (2021) reveal that individuals originating from cultures with high uncertainty avoidance manifest heightened anxiety when confronted with transformative changes and the introduction of novel technologies, accompanied by an increased need for control.

Consequently, uncertainty avoidance emerges as a vital dimension that differentiates societies based on their propensity to embrace risk. According to Hofstede (2011), cultures marked by low levels of uncertainty avoidance exhibit a greater willingness to engage in risk-taking behaviours and to entertain divergent viewpoints, both of which are instrumental in fostering the processes of innovation and the adoption of new technologies. In contrast, societies characterised by high uncertainty avoidance demonstrate a pronounced reluctance to experiment with unproven solutions in the realm of smart city initiatives. Populations that are risk-averse often require substantial assurances regarding privacy, security, and reliability before consenting to the adoption of such innovations. Therefore, the fourth hypothesis of this study can be articulated as follows:

H4: *A lower level of uncertainty avoidance positively impacts the effectiveness of smart city management.*

Long-term orientation represents a significant cultural dimension that encompasses a multifaceted understanding of temporal perspectives, integrating considerations of the past, present, and future. Cultures characterised by long-term orientation exhibit a societal time perspective influenced by enduring cognitive frameworks, wherein technology and situational evaluations are grounded in both present and prospective implications, rather than exclusively prioritising immediate, short-term outcomes (Van Everdingen, Waarts, 2003). This dimension of long-term orientation pertains to the value a culture places on its traditions and the degree to which it emphasises historical and future considerations.

Fundamentally, long-term orientation is intricately linked to societal pragmatism, as contrasted with a proclivity for traditionalism. A high score on the long-term orientation scale indicates a cultural predisposition towards pragmatic problem-solving approaches that transcend mere adherence to tradition and social norms. This cultural orientation is also associated with attributes such as frugality, perseverance, the cultivation of enduring relationships, and the prioritisation of future rewards (Chopdar, Sivakumar, 2019). Moreover, according to Tran Le Na and Hien (2021), long-term orientation exerts a positive influence on the functional, social, and emotional values attributed to emerging technologies, thus fostering technology acceptance.

Van Everdingen and Waarts (2003) analysed the relationship between national culture and the adoption of innovations and new technologies through the lens of Hofstede's dimensions. Their findings reveal that cultures exhibiting higher degrees of long-term orientation tend to demonstrate increased receptivity to the adoption of innovations and novel technologies. In this context, cultures with elevated long-term orientation scores emphasise traditional values to a greater extent than those with lower scores. Consequently, cultures marked by low long-term orientation often assign diminished significance to tradition, thereby demonstrating greater openness to novel concepts. This phenomenon suggests that the rate of technology adoption is expected to be higher in nations with a lower long-term orientation compared to those where a more pronounced long-term orientation is prevalent. Long-term orientation has been

associated with innovation through a focus on future-oriented investment, persistence, and adaptive change. It supports strategic patience and planning -two critical attributes in building innovation infrastructure (Celikkol et al., 2019).

Furthermore, societies that score high on long-term orientation are inclined to invest significantly in sustainable, future-oriented smart city infrastructures, such as Internet of Things (IoT)-based environmental monitoring systems and predictive analytics. This propensity leads to a higher adoption rate of such solutions. Accordingly, the following hypothesis emerges from this analysis:

H5: *A higher level of long-term orientation has a positive influence on smart city management.*

Culture significantly influences the management of smart cities, as demonstrated by numerous studies. This impact arises from culture's ability to foster either a conducive or a challenging environment for innovation. Smart cities should prioritise enhancing the quality of life alongside improving the efficiency and quality of services provided by government entities and businesses (Mutambik, Almuqrin, 2024). As smart cities emerge as a solution to challenges posed by urban population growth and rapid urbanisation, understanding Hofstede's cultural dimensions becomes crucial for effective management. This understanding enables the implementation of technology solutions that are widely accepted, equitable, and sustainable. By customising strategies across Hofstede's five dimensions—power distance, individualism, masculinity, uncertainty avoidance, and long-term orientation—cities can convert generic rollouts into culturally relevant initiatives that actively engage stakeholders at all levels. Tailoring strategies to each dimension enhances the effectiveness of technology adoption and promotes sustainability.

3. Materials and methods

The presented study was conducted in September and October 2025. Its purpose was to determine the relationship between culture dimensions defined by Hofstede and the effectiveness of smart city management in the form of the city's position in the global smart cities ranking – the Oxford Economic Global Cities Index.

Multiple regressions were used to identify the relationship between the independent variables - value of Hofstede's culture dimensions: power distance, individualism, masculinity, uncertainty avoidance, and long-term orientation (<https://www.hofstede-insights.com/country-comparison-tool>) and the dependent variable – value of the Oxford Economic Global Cities Index (<https://www.oxfordeconomics.com/global-cities-index/>).

This index contains five categories: Economics, Human Capital, Quality of Life, Environment, and Governance, which are aggregated to create an overall score for each city. Each category comprises multiple indicators (four to six, depending on the category), which aim to address some of the most important considerations within their respective categories. As a result, the Global Cities Index provides a more complete comparison of cities by ranking them not just on their economic performance but also considering other important factors that influence their relative strengths (<https://www.oxfordeconomics.com/global-cities-index/>).

A city's economy plays a crucial role in its prosperity and attractiveness. Economic vitality is a fundamental aspect of urban development, driving a city's wealth generation, employment opportunities, access to goods and services, and much more. Including economic metrics in the index acknowledges the pivotal role that the economy plays in shaping urban landscapes and driving investment. This category allows for an assessment of a city's potential for sustained growth and development, essential for any comprehensive comparison of cities around the world.

Human capital encompasses the collective knowledge and skills of a city's population, underpinning the economic potential of every city. It reflects the dynamics of educational attainment, innovation, and demographics at play across metropolitan areas. In today's knowledge-based economy, cities with diverse, highly skilled workforces and innovative businesses are better positioned to adapt to technological change and compete globally. Incorporating human capital indicators into the index emphasises the importance of people in driving economic prosperity and recognises cities that invest in education, business, and diversity.

Quality of Life encapsulates the well-being and satisfaction of a city's residents, reflecting the intersection of various socioeconomic factors. This category provides insights into the liveability and attractiveness of a city, which can play a role in migration patterns, talent retention, and the overall happiness of residents. Evaluating quality of life metrics in the index underscores the importance of urban policies that not only prioritise economic prosperity but also health, equality, and cultural vibrancy, enhancing residents' overall well-being. At the top of the Quality of Life category are cities with lower inequality and residents who live long lives. Most of them also provide residents with access to a range of recreation and cultural amenities.

The Environment category evaluates a city's commitment to environmental sustainability and its predisposition to climate change risks, critical factors for ensuring long-term resilience. Incorporating environmental metrics into the index reflects the growing recognition of the interconnectedness between economic prosperity and the natural environment, highlighting the imperative for cities to adopt climate change-conscious policies and initiatives and the hazards of not doing so.

The Governance category is measured slightly differently than the other four, in recognition of the fact that national governments-not just those at the city level-have a significant influence on these outcomes. As a result, scores in this category are calculated at the national level rather than the city level, meaning that every city in a given country is given the same score for a given indicator. Cities at the top of the Governance category have a pedigree of institutions that protect the rights of their residents and foster political stability. Governance is the basic foundation for city prosperity across the other four categories. Good governance fosters trust, social cohesion, and equitable access to opportunities, while poor governance can lead to inefficiencies, corruption, and social unrest. Including governance indicators in the index acknowledges the category's pivotal role in shaping the overall trajectory of a city, influencing policy outcomes, public services delivery, and resident protection and engagement.

After collecting data for each indicator for all cities, normalised scores were created for each indicator by assigning the highest-scoring city a score of 100 for that indicator, the lowest-scoring city a score of 0, and distributing the rest of the cities' scores across that range. The scores for each indicator within a category were combined to create a total score for that category for each city. The total scores for each category were then normalised. The city's final overall score was calculated by taking a weighted average of each category's normalised score, using the following weights: Economics – 30%, Human Capital – 25%, Quality of Life – 25%, Environment – 10%, Governance – 10% (<https://www.oxfordeconomics.com/global-cities-index/>).

The result is an overall score for each of the 1000 Global Cities that considers not only the city's economic performance but also how well educated it is, the well-being of its residents, the volatility of its climate, any political risks facing the city, and much more. This allows cities to be ranked in a more holistic manner and helps identify relative strengths and weaknesses for each city across the five categories.

The top cities overall in the Global Cities Index possess strong scores in all five categories. Not only do they provide important economic contributions to the global economy, but they are also hubs for education and business innovation and invest in the infrastructure necessary to maintain a high quality of life. They also prioritise policies that focus on the environment and good governance.

The Oxford Economics Global Cities Index provides a holistic assessment of the 1000 largest cities in the world. Smart Cities were selected based on their rankings in the Oxford Economics Global Cities Index 2025. The 10 cities with the highest ranking were included in the analysis. The following cities were taken into consideration: New York (United States), London (United Kingdom), Paris (France), San Jose (United States), Seattle (United States), Melbourne (Australia), Sydney (Australia), Boston (United States), Tokyo (Japan), San Francisco (United States).

4. Results and discussion

Multiple regression analysis was employed to examine the relationship between the independent variables, specifically Hofstede's cultural dimensions, and the dependent variable, the Oxford Economic Global Cities Index. The impact of cultural factors on the adoption of new technologies is increasingly recognised as a critical area for investigation by researchers (Khan, 2022; Blut et al., 2022; Venkatesh, 2022). Studies that utilise and validate Hofstede's national culture dimensions demonstrate that these constructs are both relevant and significant, indicating that variations in national cultures significantly influence a wide range of organisational and individual behaviours and outcomes across different cities. The results of the regression analysis are presented in Table 1.

Table 1.

The results of the regression analysis

Independent variables - national culture dimensions	Standardized coefficients Beta	t	Significance level
Low power distance	0.093	0,369	0,650
Individualism	0.481	4,243	0,000
Masculinity	0.072	0,321	0,630
Low uncertainty avoidance	0.259	3,782	0,000
Long-term orientation	0.568	4,516	0,000
Dependent variable: the Oxford Economic Global Cities Index $R^2 = 0.786$, $F = 29.641$, significance level = 0.01.			

Source: own study based on <https://www.oxfordeconomics.com/global-cities-index/> and <https://www.hofstede-insights.com/country-comparison-tool>

The reliability assessment utilised in this study was Cronbach's alpha, which revealed that all research variables exceeded 0.8. This indicates a high level of internal consistency, suggesting that the measures employed are reliable and that the evaluation instrument is suitable for research purposes.

The findings indicate that the R-squared value was 0.786, demonstrating that the independent variables explain 79.8% of the variance in the adoption of smart city solutions, as measured by the Oxford Economic Global Cities Index. Furthermore, the linear relationship between Hofstede's cultural dimensions and the adoption of smart city solutions was statistically significant, with an F-value of 29.641 at the 0.01 significance level, thereby affirming the model's suitability for this study.

Analysis of individual hypotheses yielded the following results: low power distance (beta = 0.093) did not establish a statistically significant relationship with the Oxford Economic Global Cities Index, as evidenced by a significance level of 0.650, which exceeds the 0.05 threshold; therefore, Hypothesis 1 is rejected.

Conversely, the significance level for individualism related to the Oxford Economic Global Cities Index was 0.000, considerably less than 0.05, validating Hypothesis 2. The coefficient for individualism was notably substantial ($\beta = 0.481$), thereby indicating that higher levels of individualism positively influence the adoption of innovative solutions.

Further analysis revealed that masculinity ($\beta = 0.072$) did not demonstrate a statistically significant relationship with the adoption of smart city solutions, with a significance level of 0.630, leading to the rejection of Hypothesis 3. The significance level for low uncertainty avoidance in relation to the Oxford Economic Global Cities Index was set at 0.000, thus confirming Hypothesis 4. The beta value associated with this variable is 0.259, suggesting that a lower level of uncertainty avoidance exerts a significant positive effect on the adoption of smart city solutions.

Moreover, the significance level for long-term orientation in relation to the adoption of smart city solutions was also 0.000, confirming Hypothesis 5. This test indicated that long-term orientation possesses the highest coefficient ($\beta = 0.568$) in comparison to other cultural dimensions, signifying its predominant positive impact on the adoption of smart city solutions.

The outcomes of this investigation yield some unexpected insights. Notably, power distance and masculinity were found to be insignificant predictors in this model. In contrast, long-term orientation, individualism, and low uncertainty avoidance emerged as the three cultural dimensions that exhibited significant correlations. As hypothesised, long-term orientation positively influences the adoption of smart city solutions and the Oxford Economic Global Cities Index. Alongside this, both low uncertainty avoidance and individualism demonstrated significant and favourable effects on the adoption of smart city solutions. Consequently, hypotheses 1 and 3 are rejected, while hypotheses 2, 4, and 5 are confirmed.

These results present a noteworthy discourse on the role of cultural dimensions in the adoption of smart city solutions. Specifically, the analysis reveals that power distance does not play a critical role in the adoption process, as its insignificance challenges the expected impact of this cultural dimension on effective smart city management. Similarly, the masculinity dimension appears to lack relevance in this context, suggesting that the values typical of masculine and feminine cultures present an uncertain influence on the adoption of smart city solutions. For instance, while masculine values such as achievement and motivation may suggest a correlation to positive outcomes in innovation adoption, feminine cultures, characterised by values of equality and cooperation, may foster a more favourable environment for the acceptance of new technologies in urban management.

In terms of long-term orientation, the study affirms that cities in nations exhibiting higher levels of this dimension realise a greater value on the Oxford Economic Global Cities Index. National cultures with pronounced long-term orientation are generally more receptive to innovative ideas and solutions, showcasing practical and problem-solving characteristics that facilitate the adoption of new technologies in urban management. The hypothesised positive relationship between uncertainty avoidance and the Oxford Economic Global Cities Index has

also been substantiated; this finding posits that risk aversion, among other factors, may influence a culture's innovation capacity and readiness to implement modern technologies.

Finally, the confirmed positive association between high levels of individualism and the adoption of smart city solutions reinforces the assertion that more individualistic societies are predisposed to embracing innovative approaches in urban management.

5. Conclusion

The findings of this study indicate that the adoption of smart city solutions is significantly influenced by cultural dimensions, specifically higher levels of individualism and long-term orientation, alongside a reduced level of uncertainty avoidance. However, the hypothesised relationships between masculinity and the adoption of smart city solutions, as well as the impact of low power distance, remain unsubstantiated and warrant further empirical investigation.

Effective management within smart cities is intricately shaped by both national and local cultural dimensions, particularly individualism, uncertainty avoidance, and long-term orientation. These dimensions play a crucial role in informing organisational strategies as well as fostering citizen engagement. A comprehensive understanding of these cultural factors equips policymakers and city managers to design interventions that not only enhance adoption rates but also promote equitable outcomes across diverse urban settings.

The study acknowledges several limitations, chief among them being the relatively small sample size of cities included in the analysis. Furthermore, there exists a lack of a holistic measurement framework that encompasses all phases of the smart city management process, potentially constraining the scope of the findings.

Despite these limitations, the research has made progress towards achieving its primary research objective by substantiating that certain relationships between selected national culture dimensions and the adoption of smart city solutions are valid, as evidenced in the cities analysed within the context of the Oxford Economic Global Cities Index 2025. Conversely, the study raises pertinent questions regarding the relationship between masculinity and power distance, as well as their respective influences on the adoption of smart city solutions, indicating an urgent need for future scholarly inquiry. One proposition for subsequent research includes expanding the sample to encompass a broader range of national cultures and analysing differing clusters of these cultures.

Future investigations should aim to explore additional variables that may affect the adoption of smart city solutions and the overall performance of city management. Subsequent studies must strive for validation of the findings by leveraging a more extensive sample. As the performance of smart cities cannot be fully elucidated through cultural dimensions alone, future research will also need to examine other elements that contribute to creating a conducive

environment for enhancing smart city management. Additionally, as this study has illustrated the presence of applicable technological solutions across the selected cities, a more comprehensive and diverse comparative analysis involving other urban areas would prove beneficial in identifying broader trends in city management practices.

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THE USE OF ARTIFICIAL INTELLIGENCE IN LOGISTICS ON THE EXAMPLE OF A FORWARDING COMPANY

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Purpose: Identification of artificial intelligence applications in freight forwarding and evaluation of their role as tools supporting managerial decisions in logistics.

Design/methodology/approach: The objectives are achieved through the use of three research methods: a systematic literature review, an individual in-depth interview (IDI) and an analysis of secondary data. The article is qualitative in nature, with elements of quantitative analysis. The theoretical scope includes issues related to logistics management, forwarding, digital transformation and artificial intelligence in supply chains. In contrast, the subject scope focuses on the operational applications of artificial intelligence in a forwarding company, with particular emphasis on delivery planning, rate analysis, automation of administrative processes and support of managerial decisions.

Findings: Analysis of secondary data revealed a growing level of digitalization in the transport and storage sector in the European Union, while Poland still maintaining a relatively low level of digital intensity. The study indicates that artificial intelligence is primarily applied in freight forwarding for freight rate analysis, matching loads with carriers, automating the search for offers, monitoring order execution, and controlling documentation. AI-based systems support managers in making faster and more transparent operational decisions, especially in the areas of transport planning and coordination. The qualitative study confirmed that the use of AI improves work efficiency, shortens order completion time and increases access to structured data. At the same time, significant limitations were identified, such as the lack of flexibility of algorithms, dependence on data quality, and the inability to replace interpersonal relationships and the experience of the freight forwarders.

Research limitations/implications: The main limitation of the study is its qualitative nature and the fact that only one respondent was interviewed, which limits the possibility of generalizing the results. In addition, the dynamic development of artificial intelligence may cause some applications to become outdated relatively quickly. Future research should therefore include a larger research sample and compare different types of freight forwarding companies in order to increase the representativeness of the results and deepen the analysis.

Originality/value: The article presents a new perspective on the use of artificial intelligence in freight forwarding by presenting it from the perspective of management practice in a forwarding company. Combining a literature review with a qualitative in-depth interview enables the presentation of the manager's real experience, the identification of actual areas of artificial

intelligence application, and the indication of both the benefits and barriers to its implementation.

Keywords: artificial intelligence, logistics, forwarding, supply planning, management.

Category of the paper: Case study, literature review.

1. Introduction

Logistics, and particularly freight forwarding as its specialized segment, plays a key role in the functioning of modern enterprises, directly influencing the level of customer service, operating costs, and market competitiveness (Christopher, 2016). Under conditions of increasing globalization, shortening product life cycles and growing demand volatility, decisions made by freight forwarding managers must increasingly be based on complex and dynamic data sets (Ivanov, Dolgui, 2020b). In such conditions, classical methods of analysis are increasingly proving to be insufficient in the face of the scale and complexity of modern supply chains and logistic processes (Toorajipour et al., 2021). Maintaining continuity of order fulfilment, effective delivery planning, and responding to disruptions in the short term are becoming decision-making priorities, increasing the demand for tools supporting managers' decision-making processes (Belhadi et al., 2021). In this context, increasing attention is being paid to artificial intelligence (AI)-based solutions that enable big data analysis, pattern identification, and prediction generation to support decision-making.

In response to these challenges, the literature indicates that the implementation of artificial intelligence in logistics can lead to increased operational efficiency and improved quality of managerial decisions. At the same time, the process of implementing these solutions is burdened with numerous barriers, such as insufficient data quality, high investment costs, or limited employees' analytical skills (Culot et al., 2020; Sony, Naik, 2020). This means that the technological potential of artificial intelligence does not always translate directly into organizational outcomes, and the effectiveness of its use depends on organizational structure and employee competencies of the company.

Despite the steadily increasing number of publications on the applications of artificial intelligence in logistics and supply chain management, a significant part of the research focuses on mathematical optimization, process simulation and quantitative analyses carried out in large manufacturing and retail companies. At the same time, these studies often overlook the specific characteristics of service companies, including freight forwarding companies, in which short-term operational decisions, intensive coordination of information and ongoing communication with customers and transport partners play a key role (Ivanov, Dolgui, 2020b; Pournader et al., 2021). At the same time, there is a noticeable shortage of qualitative research enables an in-depth analysis of the experiences of managers responsible for the implementation and use of AI-based solutions in organizational practice.

The aim of the article is to identify the applications of artificial intelligence in freight forwarding and to assess their role as tools supporting managerial decisions in logistics. In particular, the article focuses on assessing the impact of AI-based solutions on the quality, speed and effectiveness of decisions made by managers of freight forwarding companies. In addition, the paper identifies the key benefits resulting from the use of artificial intelligence in forwarding processes, as well as technological, organizational and competency barriers that may limit the effectiveness of implementing these solutions in business practice.

2. Research methods

A fundamental element of the study was the analysis of the available literature, the aim of which was to compare applications of artificial intelligence supporting managerial decision-making in logistics, with particular emphasis on forwarding processes. The literature review conducted in a systematic manner and in accordance with the methodology of secondary research, commonly used in the field of management and quality sciences.

Initially, the scope of the analysis was defined, focusing on publications on the use of artificial intelligence in logistics and forwarding, including in the planning and coordination of deliveries, supply chain management and in improving managerial decision-making processes. Databases were then selected to provide access to verified and reliable scientific sources. The analysis was conducted using three databases: Scopus, Web of Science and Google Scholar. The choice of these platforms was due to their wide range of topics, high-quality indexed publications and their widespread use in management and logistics research. An important criterion for the selection of literature was the date of publication. Publications from the years 2009-2025 were included in the analysis, with particular emphasis on the latest works, which made it possible to ensure that the presented findings are up-to-date and take into account the dynamic development of technologies based on artificial intelligence. The literature search was conducted using keywords such as “artificial intelligence”, “logistics”, “freight forwarding”, “decision support systems”, and “supply chain management”.

As a result of the selection, publications were identified, which were then analysed in terms of scientific quality and thematic scope. The aim of the analysis was to identify the key areas in which artificial intelligence is used in logistics and forwarding, to classify AI applications and to assess their impact on managers' decision-making processes. The results of this analysis were the basis for further theoretical considerations and analysis of the results of empirical research presented in the following parts of the article.

To obtain in-depth information on the practical use of artificial intelligence in logistics, a qualitative method in the form of an individual in-depth interview (IDI) was used. The choice of this method was justified by the need to capture subjective assessments and managerial

experiences, which would be difficult to obtain using quantitative methods (Kvale, Brinkmann, 2009; Myers, 2013). Individual in-depth interviewing is one of the most commonly used methods in qualitative research in management research, especially in the analysis of complex organizational phenomena and decision-making processes (Guest et al., 2017). This method allows for flexible interaction, adjusting the order and scope of questions to the respondent's answers, and exploring selected topics in greater depth that are relevant to the purpose of the study (Kvale, Brinkmann, 2009).

The interview was conducted on the basis of a previously prepared interview guide covering issues related to the use of IT systems and elements of artificial intelligence in logistics management and delivery planning. This form of interview allows to maintaining a balance between the comparability of the data obtained and the respondent's freedom of expression (Myers, 2013). The selection of the respondent was purposive, which is in line with the assumptions of qualitative research, in which access to expert knowledge and practical experience of the studied phenomenon is of key importance (Patton, 2015). The study included one specialist in a managerial role in a company using AI technologies in freight forwarding.

The qualitative study was complemented by a quantitative analysis of secondary data from Eurostat data on the use of artificial intelligence in enterprises in the European Union. The use of statistical data made it possible to place the results of the in-depth interview in a broader macroeconomic context and to identify general trends related to the adoption of AI technologies in the business sector.

3. Result

3.1. Key findings from previous research on the impact of AI in logistics management

An analysis of the literature indicates that the use of artificial intelligence in logistics and supply chain management focuses primarily on improving operational processes characterized by high decision-making complexity, high data variability, and the need to make decisions in near real time (Toorajpour et al., 2021; Pournader et al., 2021; Riahi et al., 2021). Research is dominated by approaches aimed at demand forecasting, inventory optimization, transportation route planning and delivery scheduling, which in forwarding practice translate directly into decisions regarding order allocation, carrier selection and coordination of transport services (Helo, Hao, 2021).

Research on the automation of logistics processes draws attention to the growing role of AI-based systems in the management of warehouses and distribution centers. It is indicated that solutions using AI support the processes of order picking, inventory allocation, and goods flow control, leading to reduced lead times for warehouse operations and reduction of

operational errors (Min, 2019). From a forwarding perspective, these improvements indirectly affect the quality of decisions regarding delivery planning and coordination of inter-cell flows (Boysen et al., 2019). Some of the analyzed publications indicate that AI enables ongoing monitoring of transport processes, forecasting disruptions and supporting operational decisions in a dynamic logistics and forwarding environment (Bhargava et al., 2022; Rajalakshmi et al., 2024).

At the same time, the literature clearly indicates the existence of significant barriers to the implementation of artificial intelligence in logistics. The most commonly identified problems include poor data quality, integration difficulties between IT systems, high implementation costs, and limited analytical competencies of employees (Kozar, 2023). The authors emphasize that the effectiveness of AI implementations is strongly dependent on the organizational maturity of the company, decision-making culture and the active involvement of managerial staff, which is particularly important in forwarding companies based on the knowledge and experience of decision-makers (Janczewska, Janczewski, 2020; Bughin et al., 2017).

In summary, previous research indicates that artificial intelligence has significant potential in improving managerial decisions in logistics and forwarding, but its effective use requires meeting specific technological, organizational and competency conditions. These conclusions provide a basis for further empirical analyses presented in this article (Hao, Demir, 2024).

3.2. The importance of logistics and forwarding in the functioning of modern enterprises

Logistics is one of the key areas of management in modern enterprises, responsible for coordinating the flow of goods, information and financial resources within supply chains. Its importance is steadily increasing with the globalization of markets, the shortening of product life cycles and the increase in customer expectations regarding delivery time and quality of service. As defined by the Council of Supply Chain Management Professionals, logistics involves planning, implementing, and controlling the efficient and effective flow and storage of goods, services, and information from the point of origin to the point of consumption to meet customer requirements (CSCMP, 2023).

Freight forwarding is a specialized segment of logistics, whose main role is the organization and coordination of transport operations. Unlike transport, which involves the physical movement of cargo, freight forwarding focuses on making decisions regarding transport planning, carrier selection, cargo consolidation, documentation and communication with customers and logistics partners. It should first be noted that this concept is often identified with logistics and transport. In practice, this means that forwarding activities are developing dynamically, and its functional scope includes both elements of the organization of logistics processes and the transport activities themselves (Wojewoda, Škoda, 2017).

In conditions of increasing demand volatility, time pressure and disruptions in supply chains, freight forwarding managers make decisions in an environment of high uncertainty and limited availability of information. Classical analytical tools are increasingly proving to be

insufficient, which increases the demand for advanced IT solutions to support decision-making processes (Christopher, 2016; Ivanov, Dolgui, 2020b).

3.3. Digital transformation of logistics processes and the role of artificial intelligence

The digital transformation of logistics processes is a complex and multidimensional phenomenon involving the automation of operational activities, the integration of IT systems and the increasing use of real-time data in supply chain management. In the literature, this transformation is seen as a response to the increasing complexity of the market environment, the pressure to shorten delivery times, and the need to increase the flexibility and resilience of logistics processes (Christopher, 2016; Ivanov, Dolgui, 2020a; Buer et al., 2021).

One of the key elements of the digital transformation of logistics is artificial intelligence (AI), understood as a set of methods and techniques that enable IT systems to learn from data, recognize patterns and support decision-making processes by generating forecasts and recommendations for actions (Russell, Norvig, 2021). Unlike traditional IT systems, AI-based solutions are characterized by the ability to adapt to changing conditions and process large volumes of data from various sources (Nowicka, Szymczak, 2020).

In logistics and forwarding, AI applications focus primarily on operational areas where decision-making requires taking into account many variables and reacting quickly to changes in the environment. The literature indicates the use of AI in m.in in planning transport routes and schedules, demand forecasting, fleet management, monitoring of transport execution and automation of customer service (Toorajipour et al., 2021; Min, 2010). These solutions allow you to increase the transparency of logistics processes, reduce operational risk and improve the quality of decisions made.

From a management perspective, AI is not seen as a substitute for managers, but as a tool to support them in making decisions in conditions of high complexity and uncertainty. Research highlights that AI generates the greatest value when it is integrated with the experience of decision-makers and embedded in appropriate organizational and process structures (Dubey et al., 2020). This means that the effectiveness of AI implementations in logistics and freight forwarding depends not only on the availability of technology, but also on organizational maturity, data quality and managerial competencies.

3.4. Areas of AI application supporting managerial decisions in freight forwarding

The literature analysis indicates that artificial intelligence finds a variety of applications in logistics, especially in areas that require the processing of large data sets and decision-making under conditions of uncertainty.

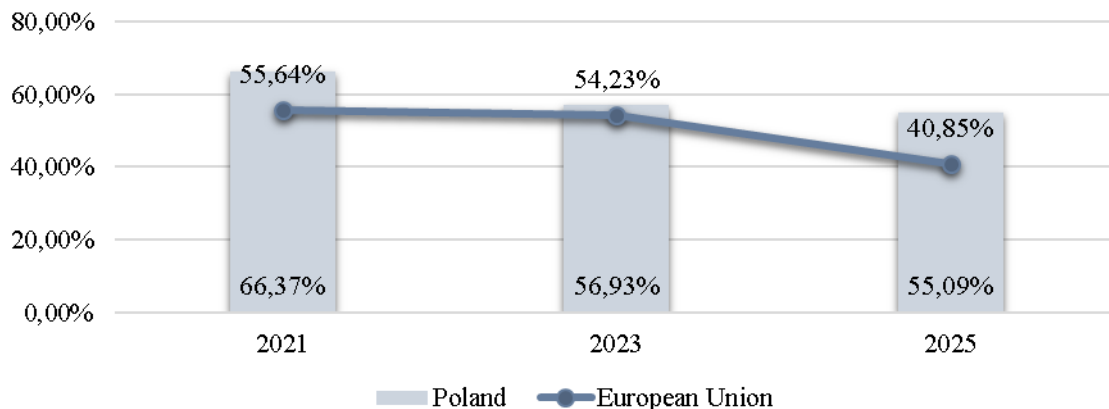


Figure 1. Companies operating in the field of transport and storage with a very low digital intensity index – Poland against the background of the European Union in the years 2021-2025.

Source: Eurostat, Digital Intensity by NACE Rev. 2 activity, [isoc_e_diin2] Digital Intensity by NACE Rev. 2 activity, 05.02.2026.

The increasing level of digitalisation is reflected in the results of a survey published every two years by Eurostat. Despite the fact that artificial intelligence is used in an increasing number of companies, still more than half of organizations (55.09%) in Poland have a very low digital intensity index. Over the past few years, there has been a downward trend in this regard, which means that more and more companies operating in the field of transport and warehousing decide to implement modern AI-based solutions to improve processes (figure 1).

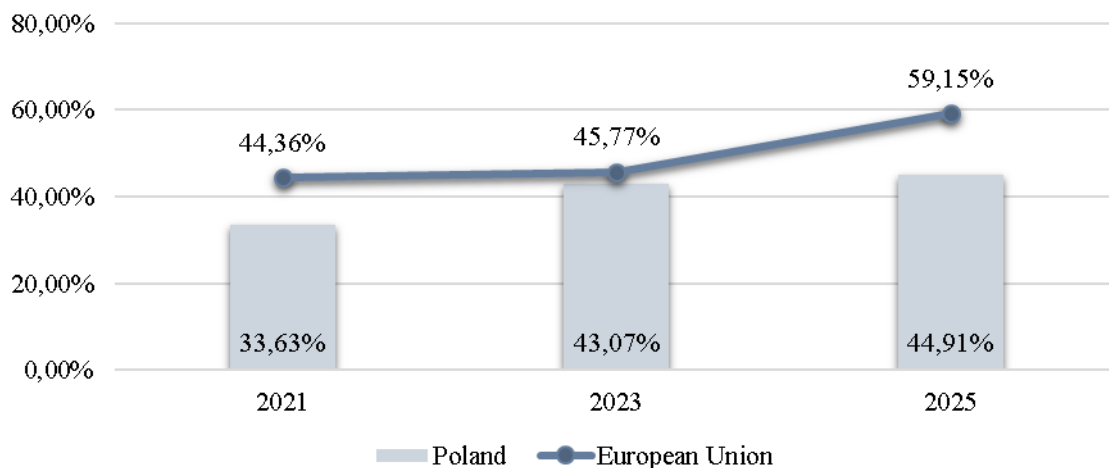


Figure 2. Companies operating in the field of transport and storage with at least a basic level of digital intensity - Poland against the background of the European Union in the years 2021-2025.

Source: Eurostat, Digital Intensity by NACE Rev. 2 activity, [isoc_e_diin2] Digital Intensity by NACE Rev. 2 activity, 05.02.2026.

Over the past few years, there has been a noticeable increase in enterprises characterized by at least a basic level of digital intensity in the European Union, including Poland. However, despite continuous development in this area, Poland still remains below the average level registered by enterprises in the European Union. In 2025, 59.15% of EU enterprises had at least a basic level of digital intensity, while in Poland the rate was 44.91% (figure 2).

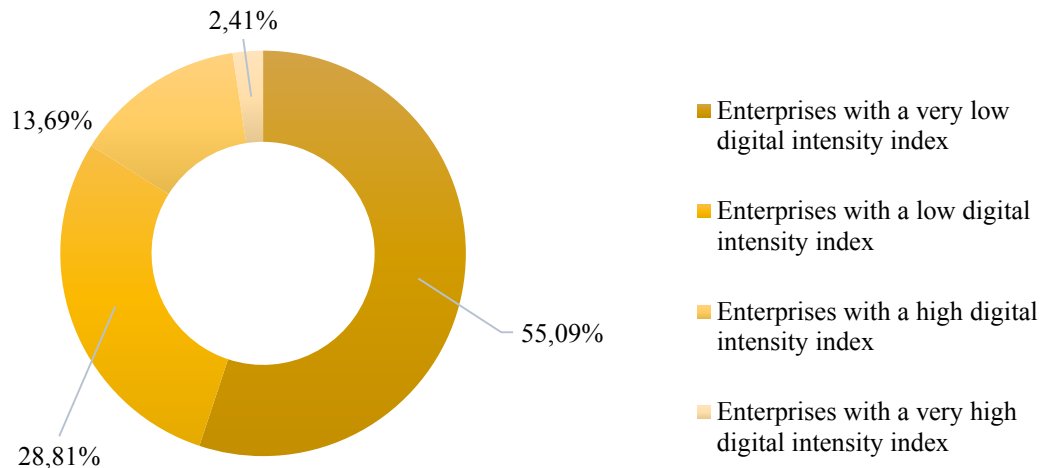


Figure 3. Companies in Poland operating in the field of transport and warehousing broken down by level of digital intensity in 2025.

Source: Eurostat, Digital Intensity by NACE Rev. 2 activity, [isoc_e_diin2] Digital Intensity by NACE Rev. 2 activity (accessed: 05.02.2026)

Among enterprises whose activities are based on transport and warehousing, as many as 55.09% have a very low digital intensity index, the rest are units with at least a basic indicator, i.e. low, high or very high. In 2025, only 2.41% of Polish enterprises achieved the highest rate. 13.69% of enterprises have a high ratio, while 28.81% of operations have a low one (figure 3).

3.5. Individual In-Depth Interview (IDI)

In the empirical part of this article, an individual in-depth interview was conducted. The respondent was a person holding a managerial position, whose role focuses on leading the organization from a strategic perspective, supporting tasks related to administration, supervision of documentation, work organization and making development decisions. The expert's tasks are mainly focused on ensuring that processes in the company are well-organized, effective and supported as best as possible by IT tools.

From the perspective of a person managing a company, the respondent perceives new technologies as an indispensable element of the functioning of modern freight forwarding. He points out that time pressure, high competition and growing customer expectations make it difficult to maintain efficiency without system support in the current market environment. In addition, the respondent notes that artificial intelligence is no longer a curiosity, but a tool that effectively supports planning, data analysis and decision-making, especially in the administrative and operational areas.

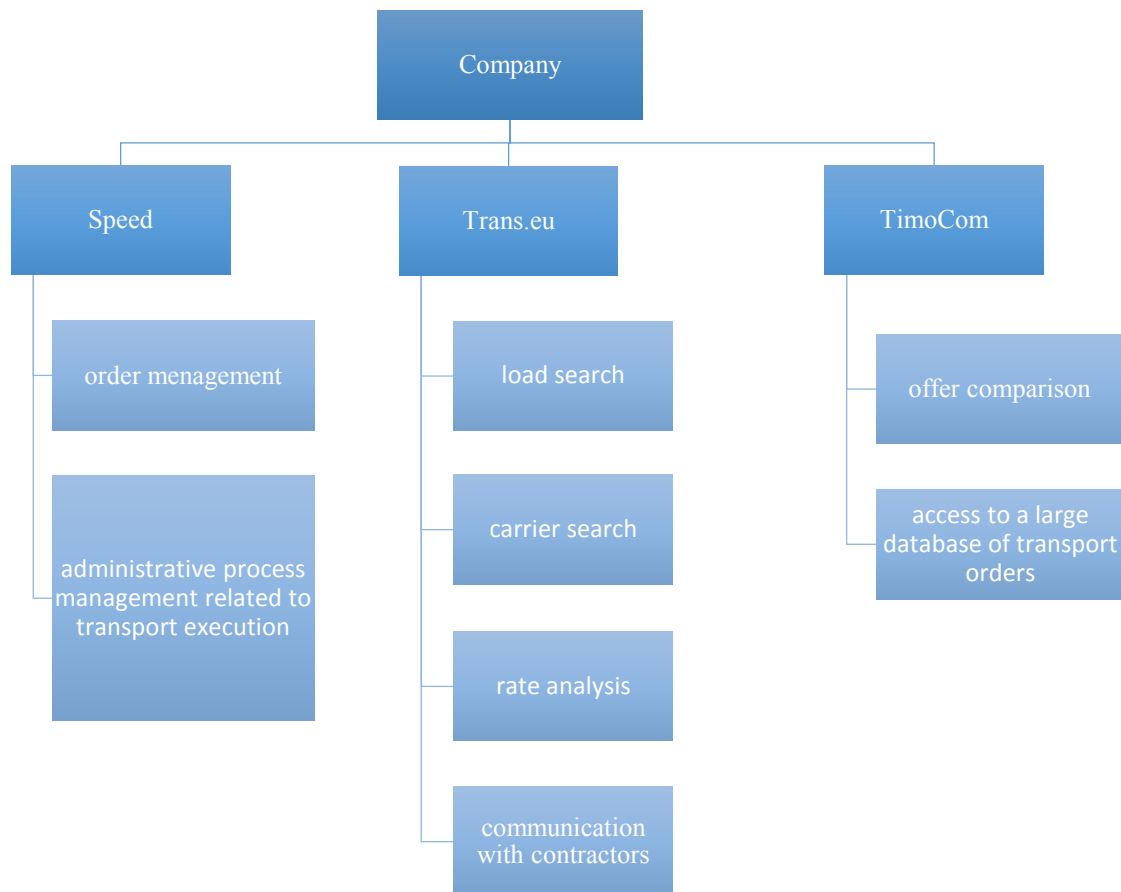


Figure 4. Systems and the scope of their use in the examined company.

Source: Own study based on an individual in-depth interview.

In its daily operations, the company uses three main systems: Speed, the Trans.eu platform and the TimoCom freight exchange. Each of them is responsible for a different area of forwarding work, but together they create a coherent operating environment. The Speed system is mainly used to handle orders, organize documentation and control administrative processes related to the transport execution. It facilitates information management within the company and ensures data consistency at the next stages of order execution. The Trans.eu platform, on the other hand, plays a key role in interaction with the market. It is used to search for loads and carriers, analyze rates and communicate with contractors. The system also develops modules based on market data analysis to support shippers in making operational decisions. TimoCom, on the other hand, functions as an international freight exchange, allowing users to quickly compare offers and access a wide database of orders. This is also where automation and intelligent recommendations come in, which streamline the process of searching and selecting offers (figure 4).

The elements of artificial intelligence and advanced automation in the systems that are used in the surveyed company are not a single, separate tool, but are built into individual functionalities supporting the daily work of freight forwarding. In the case of platforms such as Trans.eu or TimoCom, these are primarily modules that analyse large sets of market data, including historical freight rates, freight availability, transport directions and user activity. On this basis, the systems generate recommendations on the attractiveness of offers, suggest possible adjustments of orders to available resources and support forwarders in making pricing decisions. An important element is also the automation of search processes and filtering offers. Algorithms reduce the need to manually browse through hundreds of ads, indicating those that best match the set criteria. From a management perspective, this means shorter response times and more efficient use of the team's work. The Speed system, although primarily an internal organizational tool, also uses automation mechanisms in the field of organizing data, document control and monitoring the execution of orders. This allows for the ongoing detection of irregularities and improves the supervision of administrative processes. From a managerial perspective, it can be said that these modules act as a decision support – they do not replace a person, but provide them with structured information and recommendations that facilitate quick and more informed decisions in a dynamic forwarding environment.

During the conversations between by the expert with employees, it is clear that the approach to AI is more practical than enthusiastic. Employees appreciate above all the time savings, faster job search and support in the analysis of rates and routes. The so-called AI agents are currently an important support for the daily work of teams. After proper preparation, i.e. after a series of well-structured prompts, they can greatly speed up the implementation of routine tasks, such as detailed verification of documents in foreign languages, analysis of insurance policies or checking the correctness of arrangements with the contractor. At the same time, there are also voices of caution. Employees emphasize that algorithms do not always take into account the context of the relationship with the client, the specifics of cooperation or non-standard terms of orders. Therefore, AI is treated as a supportive tool, not a substitute for the freight forwarder's experience.

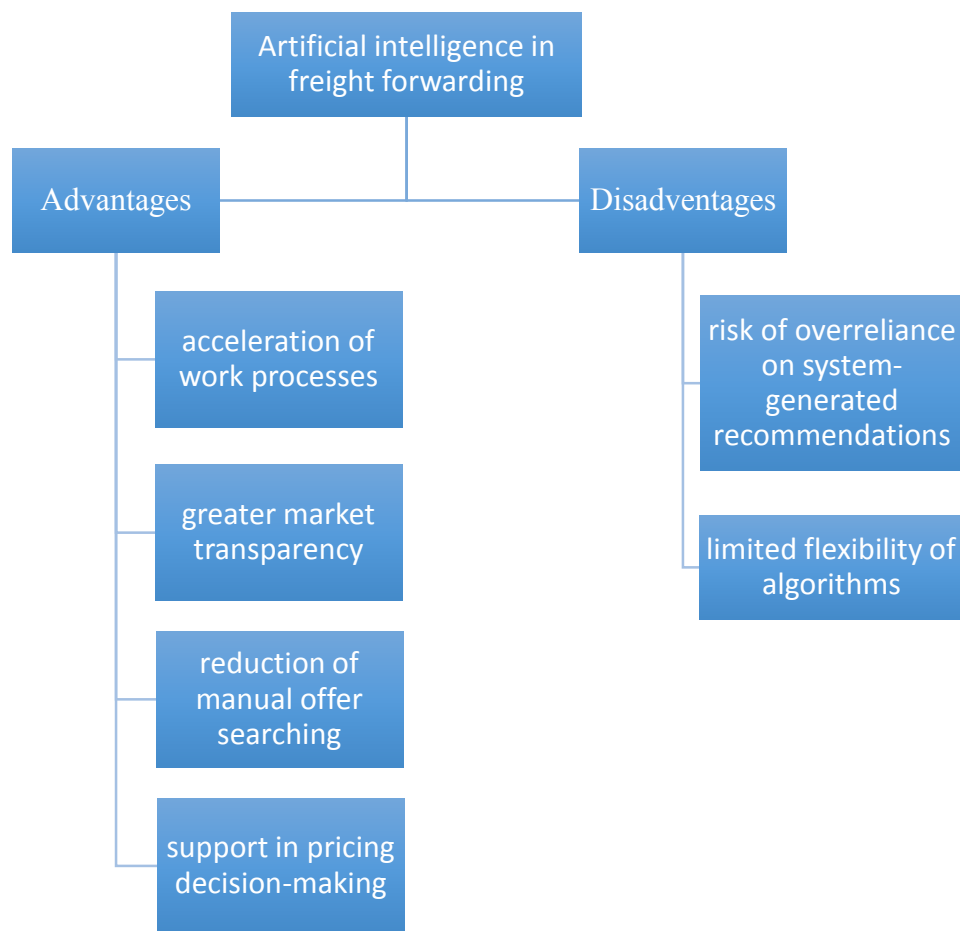


Figure 5. Advantages and disadvantages of using artificial intelligence in a freight forwarding company.
Source: Own study based on an individual in-depth interview.

The most frequently mentioned advantages are speeding up work, reducing manual search for offers, greater market transparency and support in making pricing decisions. Employees point out that systems such as Trans.eu are increasingly capable of analyzing historical data and predicting trends, which makes it easier to assess the profitability of shipping orders. The most frequently cited limitations include the lack of flexibility of algorithms, which cannot cope with dynamically changing situations, such as road accidents, sudden changes in traffic volume, non-compliance of goods with the arrangements, difficult weather conditions, fluctuations in fuel prices or changes in national regulations. Another problem is the risk of over-reliance on system prompts. Employees emphasize that artificial intelligence will not replace negotiations, building interpersonal relationships, or knowledge and intuition gained from many years of experience. There is also often a concern that automation that goes too far may lead to the unification of decisions made and the loss of an individual approach to the customer (figure 5).

The expert emphasizes that artificial intelligence is developing at a dizzying pace. It learns, analyses, maps our reactions and the way we communicate. It is becoming more and more common to hear about companies that openly declare their willingness to replace freight

forwarders with AI. What's more, paradoxically, it is the forwarders themselves who teach these systems – they show them how they respond to customers, how they react in specific situations, how they build relationships. In this way, they create a tool that is theoretically supposed to replace them. From the perspective of the management team, everything looks exemplary – lower costs, no sick leave, no vacations, conflicts, greater predictability and potentially higher profits. However, this is a situation in which the human factor, which is always an unpredictable element, is not taken into account. The customer does not want to talk to the algorithm, but wants to feel that someone listens to him, understands him and approaches him in an individualized way. A freight forwarder is very rarely only a freight forwarder for the customer. Over time, trust and a relationship are born that goes beyond the framework of the contract and valuation. It cannot be programmed. The respondent believes that technology should support people, not replace them.

The use of AI in an organization causes a clear shift in roles in the team of employees. Today, some administrative and analytical tasks are supported by systems, which allows employees to focus on activities that require contact with the customer and decision-making. From a management perspective, this means greater transparency of processes and the possibility of better supervision without having to interfere with every operational stage. The biggest challenge in implementing AI-based solutions is preparing the organization for change. It's not just about implementing technology, it's about changing the way we work and think. It is crucial to convince the team that AI is to support their work, not replace it. From the owner's point of view, it is also important to rationally select tools for the scale of the business so that investments are justified. The respondent believes that AI can provide a competitive advantage for smaller freight forwarders if implemented sensibly and consciously. Well-chosen tools allow smaller organizations to operate more efficiently, without the need to expand organizational structures. From a management perspective, AI can be a way to scale your business while keeping costs under control.

According to the expert, the key managerial competencies in the context of further development of AI in logistics will be data analysis, openness to change and the ability to combine technology with operational realities. Management is increasingly based on the interpretation of information provided by systems, but the final decisions still have to belong to the human. The respondent believes that the role of artificial intelligence will grow steadily, especially in the areas of data analysis, planning and administration. At the same time, he believes that the human factor will remain crucial. The employees of the surveyed company clearly indicate that technology is a great support, but it will not replace experience, responsibility and customer relations. The most important thing will be to maintain a balance between automation and flexibility.

The results of the interviews with the expert confirmed the observations resulting from the literature review. The respondent noted that the implementation of artificial intelligence has improved the quality of decisions in planning and increased the transparency of logistics

processes. He also drew attention to the importance of data quality and the need for active participation of managers in the process of introducing solutions based on artificial intelligence.

4. Discussion

The results of the study confirm that artificial intelligence is an important tool supporting managerial decision-making in logistics, in particular in the area of freight forwarding operations. An analysis of the literature on the subject and the results of an individual in-depth interview indicate the growing importance of artificial intelligence technology in the implementation of forwarding processes, such as operational planning, coordination of information flow, and relationship management with customers and transport partners. The ability of AI-powered solutions to analyze big data in near real-time and adapt to dynamically changing market conditions is crucial.

At the same time, the results of the research indicate the existence of significant barriers in the practical use of artificial intelligence in shipping companies. The most commonly identified limitations include insufficient analytical competence of employees, difficulties in integrating AI-based solutions with existing IT systems, and poor quality of data used in decision-making processes. This points to the need for a holistic approach to the implementation of AI, including not only technological investments, but also the development of management and employee competencies and the adaptation of organizational structures to new decision-making models.

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SOCIAL INNOVATION MANAGEMENT IN NON-GOVERNMENTAL ORGANIZATIONS (NGOs)

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Purpose: The aim of this article was to present the specific nature of social innovation management in NGOs, present models for social innovation and tools supporting this process, and conduct an empirical analysis of selected cases of social innovation in Poland and around the world. The article uses examples of NGOs with different territorial scopes and resources.

Design/methodology/approach: The objectives of this article are achieved by combining theoretical analysis with empirical research. The study primarily involves a literature review on social innovation management in non-governmental organizations, a comparative analysis of existing models and tools supporting this process, and case studies of selected social innovations in Poland and internationally. The approach is qualitative and exploratory, focusing on identifying the processes, practices, and conditions associated with implementing social innovations. The scope of the work encompasses both theoretical foundations in the field of innovation management and the NGO sector, as well as empirical material in the form of descriptions and analyses of actual initiatives.

Findings: Based on the research, it was concluded that effective social innovation management in NGOs requires a balance between flexibility and structured processes, as well as strong transformational leadership based on co-creation. It also demonstrates that organizational learning, collaborative networks, and cross-sector partnerships are key factors enabling the development, scaling, and sustainability of innovations. Furthermore, it was found that public policies and appropriate impact assessment tools significantly enhance the effectiveness and impact of social innovations.

Research limitations/implications: It should be emphasized that the study's limitations include the relatively small sample size of the analyzed cases, which prevents the results from being fully generalized. Furthermore, the lack of a uniform, measurable indicator of innovation effectiveness poses a significant barrier to assessing the effectiveness of social innovation management. At the same time, these limitations serve as an impetus for further, in-depth research on developing measurement tools and expanding the research sample.

Practical implications: The research indicates that, in practice, NGOs and collaborating organizations should strengthen their culture of co-creation, develop transformational leadership competencies, and build lasting partnership networks, which can increase the effectiveness of implemented innovations and improve the management of social projects. The results also suggest the need to implement measurable evaluation tools, such as SROI, which has a potential economic impact, enabling better resource allocation, increased transparency, and improved organizational credibility in the eyes of businesses and funding institutions.

Social implications: From a social perspective, the research highlights that more effective social innovations can contribute to improved quality of life, increased resilience of local communities, and strengthen corporate social responsibility through the development of cross-sectoral collaboration. They can also support the development of public policies aimed at simplifying grant procedures, ensuring stable funding, and more precise measurement of social impact. As a result, this work has the potential to contribute to increasing the effectiveness of systemic actions to solve social problems.

Originality/value: This article brings a new perspective on managing social innovation in NGOs, emphasizing the importance of balancing flexibility with structure, the role of transformational leadership, and cross-sector collaboration in scaling innovation. Its value lies in integrating a theoretical approach with empirical analysis and identifying practical mechanisms—such as SROI and digital tools supporting co-creation—that can significantly improve the effectiveness of organizational activities. This article is addressed to researchers of public management and social innovation, NGO practitioners, public policy makers, and business representatives interested in social partnerships.

Keywords: social innovation, management in NGOs, transformational leadership.

Category of the paper: Research paper.

1. Introduction

Today's societies are facing complex challenges, such as demographic change, the climate crisis, social inequality and digital exclusion. Traditional state institutions and market mechanisms often prove inadequate in responding to these problems (Mulgan, 2019). In this situation, non-governmental organizations (NGOs) which, with their flexibility and proximity to local communities, are becoming laboratories for innovative solutions, are gaining particular importance. Increasingly, they are seen not only as implementers of public tasks, but as incubators of social innovation complementing and supporting the activities of social welfare centers.

The concept of social innovation focuses on innovative solutions and is defined as new ideas, services, models or practices that address unmet social needs better than the existing ways (Murray et al., 2010). Social innovation does not focus on generating financial profit, but on creating social value, increasing the quality of people's lives and promoting social inclusion as a community responsible to the society (Szejnwald, Chmielewski, 2018; Phillips et al., 2019; Phills et al., 2008).

In recent years, the issue of social innovation management in the NGO sector has become the subject of numerous studies (Hausner, 2015; Przewłocka, 2020). However, despite the growing significance of this area, the mechanisms for managing the innovation process in NGOs are still insufficiently understood. It seems particularly important to understand how these organizations combine limited tangible resources, social values and cross-sector collaboration to generate and scale innovation (Romanowski, 2019, Romanowski, Jasiczak, 2021).

Therefore, the goals of this article are:

- identifying the specifics of social innovation management in NGOs,
- presenting models and tools to support this process,
- conducting empirical analysis of selected cases of social innovation in Poland and around the world.

The starting point is the assumption that managing social innovation in NGOs requires a specific approach that combines features of participatory leadership, project management, systems thinking and organizational learning culture.

The article is an original research paper. It is based on an analysis of the subject literature and case studies of three organizations: Ashoka, the Barka Foundation and the “Społecznik” Program. The analysis conducted is qualitative and exploratory – it aims to identify patterns of social innovation management and the factors that foster its successful implementation.

2. Theoretical Foundations of Social Innovation Management

2.1. The Concept of Social Innovation

The term “social innovation” is multidimensional and has evolved over the past decades. In OECD terms (2020), it means new solutions that address social needs in a more efficient, sustainable and equitable way than existing alternatives. Murray et al. (2010) define social innovation as “new ideas (products, services and models) that simultaneously meet social needs and create new relationships or social collaborations”. In contrast, Phills et al. (2008) emphasize that they are “a process, not just an outcome” – they involve the generation, development and implementation of new solutions by social actors.

Social innovation is distinguished, among others, by:

- goal – i.e. a solution to a social problem, not profit maximization,
- collaboration of multiple stakeholders – collective action is key to solving social problems, which are more effective and lead to innovative solutions than individual approaches,
- building on social values, such as solidarity, shared responsibility and social justice (Hausner, 2015).

A key feature of social innovation is the participatory nature of the process – solutions are created together with beneficiaries. In this sense, as Mulgan (2019) points out, social innovation is a manifestation of the democratization of innovation and a shift from the expert model to co-creation.

2.2. Social Innovation Management

Managing social innovation in non-governmental organizations (NGOs) involves developing and implementing new strategies to address social needs, creating value for the community through stakeholder engagement. This process is crucial for NGOs dealing with complex social problems and seeking to increase their impact. Successful management of social innovation in NGOs requires a balance among: organizational flexibility and process formalization, transformational leadership, cross-sector collaboration and organizational learning capacity. These elements are necessary to create an environment conducive to innovation and ensure the successful implementation of new innovative ideas (Rojas et al., 2024; Shier, Handy, 2020).

The first element is organizational flexibility and formalization of processes. NGOs need to strike a balance between flexibility to adapt to new challenges and formalization of processes to ensure consistency of action among the procedures and processes in the structure of their operations (Bibu et al., 2012).

Another element of effective management is transformational leadership. Leadership plays a key role in driving social innovation in NGOs (Ravi et al., 2025). Transformational leaders inspire and motivate their teams to find innovative and effective solutions to social problems (Bibu et al., 2012). Such leaders play a key role in building a culture of innovation and encouraging employees to take risks and be creative (Blanco-Ariza et al., 2019).

Cross-sector collaboration, including with government and private entities, increases the capacity of NGOs to implement social innovations (Sadabadi et al., 2025). These partnerships can provide the additional resources, expertise and networks needed to scale innovative solutions (Jamroży, 2024).

The ability of an organization to learn is the essence of management. NGOs need to develop mechanisms for continuous learning and adaptation to remain effective in their social innovation efforts (Sujono et al., 2025).

This involves assessing the impact of their initiatives and using feedback to refine and improve strategies (Blanco-Ariza et al., 2019). While the focus is often on the internal capabilities of NGOs, it is also important to consider external factors, such as the political environment and funding, which can significantly affect their ability to innovate. These external conditions can facilitate or hinder the implementation of social innovations, which underscores the need for supportive policies, especially social policies and funding mechanisms, to enable NGOs to thrive in their innovative endeavors.

Moulaert and Van Dyck (2013) highlighted one more supporting element of social innovation, i.e. research, which should take the form of horizontal networks. Scientific, political and economic elites have always been closely intertwined, although patterns of interaction and influence are changing. Changes in the context, content and organization of knowledge production are reflected in an increasing emphasis on science driven by practical applications,

strong market influence, temporary knowledge alliances and heterogeneous research organizations. Linking the quality of innovations with the process of their implementation and evaluation will allow coordination of management activities ensuring their relevance and effectiveness in meeting social needs.

2.3. Specifics of Management in NGOs

NGOs are a special environment for innovation management. Their structures are often flat, based on trust and volunteerism, which encourages flexibility and creativity, but at the same time makes it difficult to formalize processes.

According to Przewłocka (2020), Polish NGOs are characterized by:

- high level of community involvement,
- low level of management professionalization,
- limited access to stable sources of funding,
- being strongly embedded in local communities.

From a social innovation management perspective, this means that NGOs need to create hybrid management models that combine elements of formal planning with flexible response to change. Hausner (2015) notes that the key to success is “the ability to translate social ideas into organizational and project language”, which requires the managerial competence of the leader, while maintaining the social mission of the organization.

In this context, organizational culture plays an important role. NGOs that promote learning, experimentation and collaboration, are more likely to generate social innovations. The literature also emphasizes the importance of social capital, as a network of trust and relationships that enable the exchange of knowledge and resources (Putnam, 2008), supporting exchanges among stakeholders from different sectors of the economy.

In summary, the social innovation management in NGOs can be seen as a process of planning, organizing, directing, which aims to balance the social dimensions of activities – mission, values, participation, as well as the organizational ones – structure, processes, competencies, and the systemic ones – cooperation with other sectors and impact on public policies.

3. Research Methodology

The purpose of the empirical part of this article is to examine how NGOs manage the processes of creating and implementing social innovations. The study is qualitative, and its method is case study (Yin, 2018). This method enables a deep understanding of the organizational, cultural and social processes taking place in NGOs and the identification of factors that foster (or hinder) innovation. Three organizations differing in scale of operation,

structure and cultural context were analyzed, namely: Ashoka – Innovators for the Public (an international organization), Barka Foundation for Mutual Aid (Poland, a national and European NGO), “Społecznik” Program (a local social program operating in the Zachodniopomorskie province).

The selection of organizations was purposive, as the cases represent different levels of maturity and scale of implementation of social innovation, which allows analysis of diverse management models. The data came from an analysis of the literature, public reports, the organizations' websites, in-depth interviews available from secondary sources, and research studies (e.g. Ashoka reports, Barka Foundation publications, and websites). The analysis used a source triangulation method to increase the reliability of results (Denzin, 2017). The analysis was carried out in four stages:

- Identification of the organization's goals and areas of activity.
- Analysis of the management structure and innovation process.
- Assessment of success factors and barriers.
- Cross-case comparison.

It should be emphasized that the study relies exclusively on secondary sources, which constitutes a significant methodological limitation. The materials analyzed largely take the form of institutional self-reports, which may entail risks of bias, selective data presentation, and the overrepresentation of success narratives. The absence of primary field research, such as original interviews or participant observation, limits the ability to verify declared practices and to conduct a more in-depth examination of informal organizational dynamics. Although source triangulation was employed to mitigate these risks to some extent, the findings should therefore be interpreted in light of the methodological constraints outlined above.

4. Case Studies

4.1. Ashoka – a Global Ecosystem of Social Innovators

Ashoka was founded in the US in 1980 by Bill Drayton. Its mission is to support “changemakers” – community leaders who create innovative solutions to global social problems. The organization operates in more than 95 countries and supports thousands of social entrepreneurs through grant programs, mentoring and networking (Drayton, 2019).

Ashoka's social innovation management model is based on four pillars (The Unlonely Planet 2022):

1. Selection of social innovators – through a global process of identifying individuals who have created new, effective solutions. According to Ashoka's definition, a social entrepreneur has the same structure as a business entrepreneur – in terms of mental

attitude, vision, action mindset and skills – but a social entrepreneur strives to improve the world. (Meehana, Shorters, 2006).

2. Building a fellowship – enabling the exchange of knowledge and experience between innovators (e.g. Ashoka Support Network, Next Now).
3. Leadership competence development – Ashoka trains leaders in management, strategy and social communication (e.g. Executive in Residence).
4. Cross-sector cooperation – building multiplier partnerships with companies and public institutions (e.g. The Ashoka Globalizer).

Ashoka uses the concept of “Everyone a Changemaker”, which assumes that every citizen can be an author of social change. Innovations developed by the organization often inspire public policies – such as educational programs on social entrepreneurship, and the creation of venture capital for social start-ups.

The study diagnosed the following success factors: strong visionary leadership, global support network, knowledge transfer and mentoring, culture of trust and organizational learning (economies of scale).

The barriers that Ashoka faces are primarily the risk of bureaucratization when scaling up, and the difficulty of measuring the social impact of innovations, which must be tailored to local needs.

4.2. Barka Foundation for Mutual Help – Polish Model of Social Inclusion

The Barka Foundation was established in 1989 in Poznań. Its mission is to support socially excluded people through vocational reintegration, education and social economy programs (Szejnwald, Chmielewski, 2018). Barka is considered a pioneer of social innovation in Poland, and its solutions – such as social integration centers and social cooperatives – have become components of public policies.

The Foundation's social innovation management process is based on three principles:

1. Participation – creating solutions together with the beneficiaries, i.e. program of community houses, or places for the recovery of people in extreme life situations. A key feature is that there is no separation between employees and customers using the service.
2. Self-help and solidarity – recipients become co-authors of change; Leaders become those in the communities who have risen from difficult life crises and now, on the basis of their life experiences, by setting an example, they help others to develop morally, socially, spiritually and professionally based on the ideas of mutual aid and self-help.
3. Systemic approach – combining social, economic and institutional aspects; the Foundation's experience, in cooperation with the Ministry of Labor and Social Policy, enables legal and financial support for the development of social programs in Poland (e.g. the Education and Reintegration Program on the basis of which the Social Employment Act was created, etc.).

Barka's innovation management model can be described as a “social laboratory” in which new ideas are tested in small communities and then, after evaluation, adapted nationally and transferred to EU countries. 27 entities have been established over the years as a result of Barka Foundation's programs becoming independent: 4 foundations, associations, cooperatives and foreign branches of Barka. (O sieci Barki). Examples of Barka Foundation's social innovations include: social cooperatives linking unemployed people and local governments, supported housing programs, or a system of reintegration through education and social entrepreneurship.

The study diagnosed the following success factors: Barka has leaders with a strong social ethos, the operation of an integrated support model helps network solutions internationally as well, and sustained partnerships with local governments and the business sector allow for growth – scanning the solution and funding statutory activities. The barriers identified during the survey include dependence on public funding, bureaucratic constraints in the subsidy system limiting design flexibility for innovation, and difficulties in sustaining innovation amidst progressive institutionalization.

4.3. The “Społecznik” program – a local network innovation

“Społecznik” is a program implemented in the Zachodniopomorskie Province since 2017, funded by the province government and coordinated by Koszalińska Agencja Rozwoju Regionalnego S.A. (Koszalin Regional Development Agency) (KARR). The current edition is entitled Społecznik with grade A! Program to Support Grassroots Initiatives 2025-2029 (O programie, 2025) The Program supports local leaders and community organizations through microgrants, training and networking. Its goal is to create social micro-innovations that respond to local needs struggling with issues ranging from neighborhood integration to environmental action.

The program management model is based on:

- flexible project management, projects tailored to the current needs of the local community,
- open call for ideas (crowdsourcing of innovations), the dedicated website announces calls for the following editions,
- cyclical organizational learning (evaluation after each edition, support and mentoring before and during project implementation – meetings of animators, dissemination of results).

The “Społecznik” program is an example of a bottom-up approach to social innovation, in which the management process is based on cooperation between residents, NGOs and the province government administration. The success factors include low barriers to entry due to easy access to funding, networking of local players, and open communication and promotion of good practices. In turn, the main barriers are limited financial resources (in the current edition, the amount of support is PLN 6000) and human resources, dependence on the political priorities of local authorities, and the lack of a long-term strategy for scaling innovation.

5. Discussion

The analysis of the three cases shows that managing social innovation in NGOs depends on a combination of three factors: leadership, organizational culture and networking.

The Role of Transformational Leadership. Leadership plays a key role in driving social innovation in NGOs. Transformational leaders inspire and motivate their teams to find innovative solutions to social problems (Bibu et al., 2012). In all the organizations analyzed, the key role is played by leaders – visionaries capable of inspiring, connecting stakeholders and translating social ideas into concrete actions. In Ashoka it is the leader of the global network (Drayton), in Barka it is the founders Barbara and Tomasz Szejnwald, and in Społecznik – it is local social animators. Such leaders play a key role in building a culture of innovation and encouraging employees to take risks and be creative (Blanco-Ariza et al., 2019). Transformational leadership fosters a culture of innovation in which members of the organization feel a shared responsibility for change (Bass, Riggio, 2006). NGO leaders are more likely to act as facilitators of innovation rather than managers in the traditional sense.

The Significance of Organizational Culture and Learning. The literature emphasizes that innovative organizations are characterized by a culture of experimentation, openness and learning (Senge, 2013). NGOs need to strike a balance between being flexible to adapt to new challenges and formalizing processes to ensure consistency and accountability in their operations (Bibu et al, 2012). This balance allows NGOs to innovate while maintaining the necessary structure to effectively implement and scale new solutions, which is required for a culture of experimentation.

The results of the analysis confirm that Barka and Społecznik, due to limitations, develop organizational learning through small-scale solution testing and iterative improvement. At Ashoka, on the other hand, knowledge management is key – the creation and diffusion of good practices between countries and the transfer of ready-made solutions into the international social space.

Networking as an Infrastructure for Innovation. All the organizations analyzed operate in local, national or global networks. They provide an “infrastructure for social innovation” (Nicholls, Ziegler, 2019), enabling the exchange of knowledge, resources and inspiration. Each of these organizations shares knowledge and experience in creating and implementing social innovations. It also strengthens interpersonal relations especially among the excluded.

In NGOs, networking often replaces formal organizational structures, and social capital becomes a key management resource.

Barriers to Managing Social Innovation. The most frequently cited barriers refer to several areas, i.e.: finance, related to the lack of long-term funding sources; organization, due to limited managerial competence; institutional issues, including a rigid legal framework and lack of systemic incentives for innovation; and cultural ones, related to aversion to risk and experimentation.

However, these barriers should be situated within a broader geopolitical and macroeconomic context. Since 2024, organizations in Central and Eastern Europe have faced reductions in international funding, intensifying competition for public resources, inflationary pressures, and political instability. These conditions disproportionately affect small and medium-sized NGOs with limited institutional capacity.

These barriers underscore the need for the development of an ecosystem to support social innovation, involving cooperation between public institutions, the private sector and the research community. All of these institutions together will allow social innovation to be better matched to current needs.

In this context, evaluation tools such as the Social Return on Investment (SROI) method serve not only as instruments for measuring impact but also as strategic tools for demonstrating organizational sustainability and effectiveness. An illustrative example is a training program for individuals excluded from the labour market in France, evaluated in 2025, which showed that each unit of investment generated substantial social value, including enhanced vocational competencies, improved employment prospects, and positive spillover effects for local communities (Murtada, Hutchinson, 2025). Similarly, in NGOs such as the Bagázs Association, SROI supports not only evaluation processes but also strategic decision-making and more efficient resource allocation, reflecting the growing maturity and practical relevance of this approach (Révész et al, 2025).

6. Conclusions and Recommendations

Based on the analysis, the following conclusions were drawn:

1. Managing social innovation in NGOs requires a combination of flexibility and structure – effective organizations put planning processes in place, but retain the ability to adapt and respond quickly to emergencies (such as the Covid-19 pandemic, or the war in Ukraine).
2. Transformational leadership and a culture of co-creation are key to generating innovation and better matching solutions to the needs of innovation beneficiaries.
3. Organizational learning and networking act as a mechanism to drive continuous innovation while supporting effective social solutions.
4. Cross-sector collaboration (NGO-business-government-universities) is essential for the scaling and sustainability of innovation.
5. Public policies should support social innovation through stable funding, simpler grant procedures and systemic mechanisms for assessing social impact (e.g. SROI – social return on investment).

In this context, the latest reports highlight the growing role of digital technologies and artificial intelligence in co-creating and scaling social innovations. According to the 2024/2025 reports (e.g., *AI for Impact: Strengthening AI Ecosystems for Social Innovation*, or *AI for Impact: The Role of Artificial Intelligence in Social Innovation*), AI can generate substantial social value, yet ecosystems supporting AI applications focused on social outcomes remain underdeveloped, emphasizing the need for stronger collaboration between technology organizations, funders, and NGOs. Furthermore, over 70% of social innovators have already implemented machine learning in areas such as health and the environment, providing a reference point for future technological support of social innovation.

In future research, it is worth focusing on measuring the effectiveness of social innovation management and the role of digital technologies, especially AI technologies and machine language, in the process of co-creating innovation in NGOs, and assessing the social return on investment (SROI) as a key indicator of the effectiveness of social innovation.

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BUSINESS PROCESS AUTOMATION: CASE STUDY ON BENEFITS AND IMPLEMENTATION BARRIERS

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Purpose: The purpose of this paper is to analyse the impact of business process automation on the functioning of an industrial enterprise in the context of digital transformation.

Design/methodology/approach: The paper is based on a qualitative case study supported by a literature review. The research methods included analysis of internal company documentation, workplace observation, and in-depth semi-structured interviews with key managers.

Findings: The results indicate that business process automation significantly improves operational efficiency in the company. Automation reduced the time required to complete repetitive tasks (e.g., invoicing, order processing, inventory management), improved data quality and availability, enhanced cross-departmental cooperation, and increased customer service quality; moreover, it strengthened the company's ability to make data-driven decisions in real-time.

Research limitations/implications: The main limitation of the study is its single-case nature, which restricts the generalisation of results to other organisations and industries. The research is based on qualitative interviews with a limited number of respondents. Future studies should include comparative analyses across multiple companies and sectors and incorporate quantitative performance indicators to measure the long-term economic effects of automation.

Practical implications: The study highlights the importance of process standardisation, employee training, effective change management, and close cooperation with the implementation partner. The results demonstrate that automation can lead to reduced cost, greater efficiency, scalability of operations, and improved customer satisfaction.

Social implications: Automating business processes influences the work organisation and employee roles by reducing routine tasks and increasing the demand for digital competencies.

Originality/value: The paper provides an in-depth empirical insight into the real-life implementation of an ERP system in a medium-sized industrial enterprise in the Polish market. Contributes to the literature by combining theoretical aspects of digital transformation with practical evidence from business process automation in manufacturing.

Keywords: business process automation; digital transformation; ERP systems; Microsoft Dynamics 365; process management.

Category of the paper: research paper, case study.

1. Introduction

Digital transformation has become one of the most important strategic challenges for contemporary enterprises operating in an increasingly dynamic, competitive, and technology-driven business environment (Anggraito et al., 2025; Lin, 2025; Gkika et al., 2025; Yu et al., 2022). Rapid technological progress, growing customer expectations, globalisation, and pressure for operational efficiency require organisations to continuously adapt their structures, processes, and business models. In this context, business process automation is widely recognised as a crucial enabler of digital transformation and a key driver of organisational performance and competitiveness.

Business process automation involves the use of advanced information technologies—such as Enterprise Resource Planning (ERP) systems, Customer Relationship Management (CRM) platforms, Robotic Process Automation (RPA), cloud computing, and artificial intelligence—to streamline operations, eliminate manual and repetitive tasks, and optimise information flows within organisations (Katsonis et al., 2019; Abdelwahab, Helal, 2023; Kukhareenko, Mankov, 2022; Garad et al., 2024; Guerrero et al., 2025; Ermolaev, Guseva, 2024). The implementation of such solutions allows enterprises not only to reduce operating costs and minimise the risk of human error, but also to increase speed, transparency, data quality, and customer service effectiveness. As a result, automation has evolved from a purely technological initiative to a strategic tool that supports long-term organisational development.

In manufacturing and industrial enterprises, the importance of automation is particularly evident. These organisations face complex production structures, extensive supply chains, large volumes of transactional data, and strict quality and regulatory requirements. Digital technologies enable real-time monitoring of operations, better coordination between departments, improved resource planning, and faster response to market changes (Kozma et al., 2024; Moreira et al., 2024; Jyothi et al., 2024). Consequently, business process automation plays a fundamental role in the transition toward Industry 4.0, smart manufacturing, and data-driven management.

Despite the undeniable benefits, the implementation of automation and digital transformation is a complex and challenging process. Organisations must address not only technical issues such as system integration, data migration, and cybersecurity, but also organisational and social aspects, including change management, employee resistance, and the need for continuous development of digital competences (Mishra et al., 2019; Jyothi et al., 2022; García-Vidal et al., 2025). Many digital transformation projects do not fully achieve their intended goals due to insufficient preparation, lack of strategic alignment, or inadequate employee involvement. Therefore, empirical research on real-life implementation processes remains highly relevant for both theory and managerial practice.

This paper addresses these issues by analysing the implementation of business process automation in a medium-sized industrial enterprise from the chemical sector operating in Poland. The study focusses on the implementation of the ERP system as a key element of the company's digital transformation strategy. The main objective of the paper is to evaluate the impact of business process automation on organisational performance, efficiency, and innovation, as well as to identify the benefits and challenges associated with the implementation process.

The contribution of this study lies in its empirical, practice-orientated perspective, combining theoretical insights into digital transformation and process automation with an in-depth case study of an actual ERP implementation. The purpose of the paper is to provide valuable knowledge for researchers and practitioners involved in planning and managing digital transformation initiatives in industrial enterprises.

2. Literature review

2.1. 2.1. Digital transformation as a strategic organisational process

Digital transformation is commonly defined as the comprehensive integration of digital technologies into all areas of an organisation, resulting in fundamental changes in business processes, organisational structures, and value creation models (Kawalec, 2021; Ostrowski, 2022). Unlike digitisation, which refers to the conversion of analogue data into digital form, and digitalisation, which focusses on automating existing processes, digital transformation entails a holistic reconfiguration of organisational strategy and culture.

The literature emphasises that digital transformation is no longer a purely technological initiative but a strategic imperative that influences competitiveness and long-term growth (Britchenko, 2024; Chądzyński et al., 2021). Modern enterprises operate in an environment characterised by rapid technological change, high customer expectations, and increased market volatility. As a result, digital transformation enables organisations to improve flexibility, improve decision-making, and build a sustainable competitive advantage.

A crucial element of digital transformation is the use of advanced digital technologies such as cloud computing, artificial intelligence (AI), big data analytics, and the Internet of Things (IoT). These technologies support real-time data processing, automated complex operations and predictive decision-making (Puślecki, 2021; Marzec, Olszowy, 2024). Gartner forecasts confirm that AI is becoming a central investment area for modern enterprises, shaping the architecture of contemporary IT systems.

Digital transformation also significantly affects organisational culture and human capital. Employee' openness to innovation, continuous learning, and the development of digital competencies are considered key success factors (Parviainen, 2017; Kotarba, 2022). Resistance to change and shortages of digital skills remain among the most frequently reported barriers.

2.2. 2.2. Technological innovation versus digital transformation

The literature clearly distinguishes between technological innovation and digital transformation. Technological innovation refers to the implementation of specific tools, systems, or solutions that improve selected areas of organisational functioning (Łazarz, 2023). In contrast, digital transformation represents a systemic change throughout the organisation that encompasses strategy, business models, processes, and organisational culture.

An enterprise may implement technological innovations—such as CRM systems or analytical platforms—without undergoing full digital transformation. However, digital transformation always involves coordinated technological innovation embedded within a broader strategic framework (Teece, 2018). The main distinction lies in the scale, scope, and strategic impact of these processes.

Digital transformation is widely perceived as a multi-stage, continuous process. According to Teece (2018) and Kotler (2021), organisations typically progress from initial digitisation through formalisation, strategic integration, convergence, and ultimately full digital maturity. Schwab's concept of the Fourth Industrial Revolution further emphasises the unprecedented pace of technological change and the growing integration of cyber-physical systems, AI, and automation into economic activity.

Despite its benefits, digital transformation poses numerous challenges. Cultural resistance to change, insufficient digital competencies, integration of legacy systems, and cybersecurity risks are among the most significant obstacles (Mądry, 2021; Univio, 2025). Manufacturing enterprises face additional constraints due to complex technological infrastructures and high capital intensity. However, the literature consistently confirms that successful digital transformation leads to higher productivity, flexibility, innovation, and customer satisfaction (Czepiel, 2025; Sufin, 2024).

The concept of business processes has evolved since the early works of Smith (1776), Taylor (1919), and Gantt (1910), who emphasised task specialisation, standardisation, and work efficiency. Contemporary process management is grounded in quality-orientated methodologies such as Total Quality Management (TQM) (Deming, 2000), Six Sigma (Lis, Ratajczak, 2014), Lean Manufacturing (Pomietlorz, 2014), and Business Process Reengineering (Borawska, 2012).

A business process is generally defined as a structured sequence of interrelated activities that transform inputs into outputs delivering value to the customer (Davenport, 1993; Hammer, Champy, 1996; Skrzypek, Hofman, 2010). Modern definitions emphasise customer orientation, cross-functional integration, and measurable performance results.

Process orientation assumes that organisations should be managed through end-to-end processes rather than functional silos (Nowosielski, 2008; Jedynek, 2019). The key principles include customer focus, result orientation, decentralisation of management, teamwork, and continuous improvement. Empirical studies confirm that process orientation improves operational efficiency and organisational adaptability.

Business processes are commonly classified into core and supporting processes (Porter, 1985). Core processes directly generate customer value and include operations, logistics, marketing, sales, and after-sales service. Supporting processes—such as human resource management, IT infrastructure, and finance—enable the effective execution of core activities.

More comprehensive frameworks, such as the Process Classification Framework (PCF) developed by APQC, provide detailed categorisations of organisational processes across operational and managerial dimensions (Ossowski, 2012). Regardless of the classification model, proper identification and structure of processes is a prerequisite for successful automation and digital transformation.

Business process automation is defined as the use of digital technologies to automate repetitive rules-based tasks previously performed manually (Remlein, 2024). Automation is commonly implemented through ERP systems, RPA tools, workflow platforms, and integrated analytical systems.

The literature highlights numerous benefits of automation, including cost reduction, time savings, improved data quality, higher process reliability, and improved customer service (Remlein et al., 2024; Butryn, Hauke, 2018). Automation also enables employees to move from routine work to more value-adding and analytical tasks, increasing job satisfaction and organisational innovation.

At the same time, automation entails significant risks, including job displacement, technological dependency, digital exclusion, cybersecurity threats, and high implementation costs (Remlein, 2024; Chumphong et al., 2020). Successful automation therefore requires careful planning, strong managerial support, employee participation, and continuous monitoring of outcomes.

ERP systems are recognised as one of the most important technological infrastructures that supports automation and digital transformation. They enable the integration of data and processes across functional areas, support real-time reporting, and facilitate coordinated decision-making. Cloud-based ERP solutions, such as Microsoft Dynamics 365, further increase scalability, accessibility, and analytical capabilities.

The literature confirms that the implementation of ERP significantly improves operational efficiency, transparency, and cross-departmental collaboration, provided that organisational readiness and change management are addressed adequately (Jelonek et al., 2019; Puślecki, 2024).

3. Material and Methods

3.1. Objective and research design

The study adopts a qualitative research design based on a single case study approach. This method was selected because of its suitability for in-depth analysis of complex organisational phenomena occurring in real-life business environments. The research focusses on the implementation of business process automation through an ERP system in a medium-sized industrial company operating in the chemical sector in Poland. The case study approach allowed for a comprehensive examination of both technological and organisational aspects of digital transformation. The research was conducted in the first half of 2025 and followed a structured research plan that included literature analysis, empirical data collection, and qualitative data analysis.

The main objective of the study was to assess the role and effects of business process automation as a key element of digital transformation in an industrial enterprise. The detailed research objectives included:

- Defining the role of process automation in accelerating digital transformation.
- Analyse the course of implementation of the ERP system, including preparation, execution, and evaluation of effects.
- Identifying the key benefits resulting from automation, such as improvements in customer service and innovation.
- Examining the main challenges and limitations associated with the implementation of process automation.

The subject of the research was the implementation and operation of the Microsoft Dynamics 365 system, while the object of the study was ADLER Polska as the enterprise undergoing digital transformation.

3.2. Data collection methods

To ensure methodological triangulation and improve the credibility of the findings, several qualitative research methods were applied:

Literature analysis (desk research): An extensive review of scientific publications, industry reports and online sources was conducted to develop the theoretical background of the study. The literature review focused on digital transformation, process management, business process automation, RPA, and ERP systems.

Analysis of internal company documentation: Internal documents provided by the company were analysed to gain insight into the structure of business processes, the scope of the ERP implementation, project documentation, and implementation schedules. This allowed for

a precise identification of the stages of system deployment and the organisational changes introduced.

Workplace observation: Direct observation of operational activities was conducted in the company's branches in Bydgoszcz and in Poznań. This method enabled the researcher to become familiar with the daily functioning of key departments and observe changes in the organisation of work after automation.

In-depth semi-structured interviews: Individual in-depth interviews constituted the main source of empirical data. Three interviews were conducted with key management representatives. The interviews were conducted online in June 2025 using a videoconferencing platform. Each interview was semi-structured, based on a prepared interview scenario, and lasted approximately 80 minutes. All interviews were conducted with the informed consent of the respondents and recorded for research purposes. The interview scenario covered seven thematic areas: introduction, digital transformation in the company, implementation of the ERP system, impact of automation on company operations, barriers and challenges, assessment and future prospects, and summary.

3.3. Data analysis and research limitations

Qualitative data obtained from interviews, observations, and document analysis were subjected to thematic content analysis. The analytical process included the transcription of interviews, the coding of statements, the identification of recurrent patterns, and the categorisation of the findings according to the main research objectives.

The analysis focused on the process of implementation of the ERP system, organisational and technical challenges, measurable and perceived benefits of automation, employee adaptation and change management, future development perspectives of digital transformation.

The results of different data sources were compared to ensure consistency and strengthen the validity of the findings.

The study has several limitations. First, the research is based on a single case study, which restricts the possibility of generalising the results to other organisations and industries. Second, the qualitative nature of the study and the limited number of interviewees can introduce a degree of subjectivity. Third, at the time of the investigation, the ERP system had been implemented only recently; therefore, the long-term economic and performance effects could not yet be fully assessed.

Despite these limitations, applied research design allows an in-depth understanding of the process of implementing business process automation in an industrial company and provides valuable insights for both theory and managerial practice.

4. Research Results

4.1. Characteristics of the implemented system

The analysed enterprise implemented the Microsoft Dynamics 365 system as an integrated cloud-based ERP and CRM platform supporting key business areas, including sales, finance, logistics, warehousing, production planning, and customer service. The system is based on a modular architecture, which allowed the company to gradually implement functionalities tailored to its operational needs. The primary objectives of the implementation were process automation, data centralisation, improvement of information flow, and improvement of decision-making based on real-time data.

The implemented solution enabled full integration of transactional, financial, and operational data within a single digital environment. Automation covered processes such as order processing, inventory control, invoicing, reporting, purchasing, and production planning. The system also introduced advanced analytical tools that support managerial reporting and performance monitoring.

The implementation of the ERP system was carried out in successive stages according to the adopted project methodology. The process started with a detailed analysis of organisational needs and existing business processes. This was followed by system design, configuration, data migration from legacy systems, testing, and employee training.

Key organisational units—sales, warehouse, finance, and logistics—were actively involved throughout the implementation process. Considerable emphasis was placed on preparing employees for technological change through training sessions, consultations, and ongoing support. This approach significantly reduced resistance to change and facilitated a smoother transition to the new system.

The project was implemented according to the planned schedule, although it required close cooperation with the implementation partner and continuous monitoring of progress to minimise technical and organisational risks.

4.2. Effects and benefits of business process automation

The research results indicate that the implementation of Microsoft Dynamics 365 had a significant positive impact on the operational functioning of the company. The main benefits identified by the respondents include:

- Increased operational efficiency: Automating repetitive tasks such as invoicing, order processing, and inventory management reduced processing time and eliminated many manual activities. The employees were able to focus on more analytical and customer-orientated tasks.

- Improvement in data quality and availability: Centralisation of information in one integrated system improved data consistency, reduced duplication, and enabled real-time access to up-to-date operational and financial data.
- Enhanced customer service quality: Faster order processing, improved availability of customer information, and better coordination between departments translated into more flexible and responsive customer service.
- Cost reduction: Automatization of routine operations and better control over inventory and finances resulted in the first observable reductions in administrative and operational costs.
- Improved cross-departmental cooperation: Integration of processes within a single platform facilitated communication and coordination between departments, particularly between sales, logistics, and finance.

According to the respondents, the first measurable effects included time savings in transactional processes, reduction of human errors, and gradual improvement of service quality. Although long-term financial effects were still under observation at the time of the study, the initial results clearly confirmed the economic and organisational value of automation.

4.3. Challenges and limitations of the implementation

Despite the overall success of the project, several significant challenges were identified during the implementation of business process automation.

- Complexity and scale of implementation: The large scope of the ERP system and the number of departments involved significantly increased the complexity of the project and the coordination requirements.
- Data migration and system integration: Transferring large volumes of data from legacy systems and ensuring compatibility with existing IT infrastructure was one of the most technically demanding phases of the project.
- Process standardisation: Automation required the unification and formalisation of business processes. The presence of numerous non-standard procedures and exceptions initially hindered the configuration of automated workflows.
- Change management and employee resistance: The introduction of the new system required changes in daily work habits. Initial concerns among employees about increased control or technological complexity were observed, although gradually mitigated through training and communication.
- Schedule and budget control: As with most ERP projects, maintaining the planned timeline and budget required continuous supervision and flexible response to unexpected difficulties.

These challenges confirmed that business process automation is not only a technological undertaking, but also a profound organisational change requiring strong managerial engagement and effective change management.

4.4. Evaluation of the system and future development perspectives

The general assessment of the implementation of Microsoft Dynamics 365 by company managers was clearly positive. The respondents emphasised the smoothness and safety of the implementation process, as well as the visible improvement in daily operational activities. Automation was perceived not only as a tool for cost optimisation, but also as a driver of innovation and organisational learning.

The system created a solid foundation for the further digital development of the company. The company plans to expand the use of advanced analytical tools, increase the scope of automation, and integrate additional digital solutions that support production and supply chain management. The respondents also emphasised the importance of continuous development of the digital competencies of the employees to fully exploit the potential of the implemented system.

5. Discussion and Conclusions

5.1. Discussion

The results of the study confirm that business process automation constitutes a fundamental pillar of digital transformation in contemporary industrial enterprises. The case of ADLER Polska demonstrates that the implementation of an integrated ERP system can significantly improve operational efficiency, data quality, and cross-departmental coordination, which is consistent with the findings reported in the literature on digital transformation and ERP systems.

The observed benefits of Microsoft Dynamics 365—such as automation of repetitive tasks, real-time access to data, improved customer service quality, and improved decision-making—correspond closely with prior research emphasising the strategic role of ERP systems in process integration and organisational performance. The literature consistently highlights that ERP systems enable transparency, standardisation, and synchronisation of processes across functional units, which was also evidenced in the analysed enterprise.

The study also confirms that the success of automation initiatives depends not only on technological aspects but also on organisational and social factors. The challenges identified in the implementation process—such as data migration, process standardisation, change management, and employee resistance—align with previously reported barriers to digital

transformation. This confirms that automation projects should be treated as complex organisational change processes rather than purely IT implementations.

Employee participation, systematic training, and continuous communication proved to be key success factors in mitigating resistance to change. These findings support the view that human capital and organisational culture are decisive determinants of successful digital transformation. The results further indicate that early visible benefits of automation—such as time savings and reduction of manual errors—play an important motivational role and strengthen the acceptance of new technologies among employees.

From a strategic perspective, the implementation of Microsoft Dynamics 365 contributed not only to cost optimisation, but also to strengthening the company's readiness for further digital development. The system created a digital infrastructure that enables scalability, advanced analytics, and long-term innovation. This confirms that business process automation should be perceived as an investment in organisational resilience and competitiveness rather than as a short-term efficiency tool.

5.2. Conclusions

The main objective of this study was to assess the impact of business process automation as a key element of digital transformation in an industrial company, using the example of Microsoft Dynamics 365 implementation in ADLER Polska. The research carried out allowed for the achievement of all specific research objectives and provided empirical evidence confirming the positive organisational effects of automation.

The findings demonstrate that business process automation significantly improved the operational functioning of the company in areas such as sales, logistics, warehousing, finance, and customer service. Integration of processes within a single ERP platform enabled real-time data access, increased transparency of operations, and supported faster, more accurate decision-making. Automation also reduced the workload associated with repetitive tasks, which positively influenced employee efficiency and job quality.

At the same time, the study confirmed that automation projects involve substantial technical and organisational challenges. The complexity of ERP implementation, data migration issues, the need for process standardisation, and the need for effective change management constitute critical risk areas. The experience of ADLER Polska indicates that these challenges can be successfully overcome through careful planning, strong managerial commitment, employee involvement, and close cooperation with the implementation partner.

From a practical perspective, the study provides clear managerial implications. Enterprises planning digital transformation initiatives should treat automation as a strategic organisational change rather than a purely technological upgrade. Particular emphasis should be placed on change management, employee training, and the continuous development of digital competencies. In addition, early identification and standardisation of business processes significantly improve the effectiveness of ERP-based automation.

The study is subject to certain limitations, primarily related to its qualitative nature and single-case design, which restricts the generalisation of the results. Future research should include comparative studies across multiple industries and integrate quantitative performance indicators to assess the long-term economic impact of automation.

In conclusion, the automation of business processes implemented through modern ERP systems constitutes a crucial driver of digital transformation in contemporary enterprises. The case of ADLER Polska confirms that properly designed and managed automation projects can generate measurable operational benefits, improve organisational agility, and strengthen long-term competitive advantage in a dynamically changing market environment.

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LEADERSHIP STYLE AND EFFECTIVENESS AND ENGAGEMENT IN A MANUFACTURING ENTERPRISE – CASE STUDY

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Purpose: The purpose of this article is to attempt to assess the impact of two different leadership styles, coercive and democratic, on employee effectiveness and engagement, using a selected manufacturing enterprise as an example.

Design/methodology/approach: The study was conducted in a small manufacturing enterprise. The primary data came from personal interviews with an operator and a leader, observations, and paper-based surveys (direct survey), while the secondary data used came from measurements taken by the health and safety department and the quality department in the enterprise under study.

Findings: The study showed that leadership style has a significant impact on the effectiveness of improvements in the production process in the enterprise under study. The democratic leadership style proved to be particularly effective in increasing employee engagement and improving performance.

Research limitations/implications: Due to the small number of respondents and observations conducted in only one small manufacturing enterprise, it is not possible to determine the strength of the influence of leadership style on employee engagement and effectiveness, therefore future research may cover a wider group of enterprises.

Practical implications: The article provides information on how employees of a manufacturing enterprise perceive changes in leadership style.

Originality/value: The article provides empirical evidence of the importance of the leadership style represented by the leader and the ability to adapt the leadership style to the specific nature of the enterprise and the organizational situation.

Keywords: leadership, coercive leadership style, democratic leadership style.

Category of the paper: Case study based on scientific research.

1. Introduction

Contemporary manufacturing enterprises operate under increasing pressure to improve process efficiency, product quality, and optimize operating costs. In this context, more and more attention is being paid not only to technological aspects, but also to organizational and social factors, in particular leadership style and its impact on the functioning of production teams.

The leadership style represented by a leader can significantly affect employee engagement, motivation, and effectiveness in performing tasks. However, these relationships are not always clearly analyzed in real production processes. Previous research on leadership style has focused mainly on declarative analyses or general indicators of organizational effectiveness. Empirical studies conducted directly in the production environment, which combine leadership style analysis with measurable technological parameters of the process, such as cycle time, machine efficiency, or product quality, are much less common. In particular, there is a lack of research showing the impact of leadership style change on the effectiveness of machine operators in specific, repetitive production processes.

The research problem addressed was to determine whether changing the leadership style of a production team leader from coercive to democratic affects the parameters of the packaging process and the commitment of machine operators. In addition, it was considered whether a change in leadership style could be an effective tool to support the implementation of improvements to the production process.

The analysis was conducted in the real-life conditions of a manufacturing enterprise and was based on objective process data, such as the cycle time of packaging machines, the number of packaged products, and the number of defects. Another key element was the observation of the effects of a real change in leadership style.

The aim of this article is therefore to attempt to assess the impact of two different leadership styles, coercive and democratic, on employee effectiveness and engagement, using a selected manufacturing enterprise as an example. The expected scientific contribution of the article is empirical confirmation of the impact of the democratic leadership style on measurable parameters of the production process. The study provides evidence that leadership style can be an important factor in supporting the effective implementation of improvements in the production environment.

2. Literature review

The concept of leadership has been the subject of debate in academic literature for many years. There are many definitions of leadership, which have evolved alongside the development of theoretical thinking and management practice. Concepts of leadership focus on the behavior of leaders in the process of organizational change and processes such as creating a vision for the future or gaining employee commitment to the changes being made. (Van Seters, Field, 1990). According to B. Bass and J.M. Burns, leadership is the ability to shape employee behavior in order to achieve specific goals, and the basis of leadership is authority and power that employees willingly accept. Leadership is a combination of specific character traits and talents that allow a leader to persuade others to act in accordance with expectations (Bass, 1990;

Dźwigoł-Barosz, 2013). It involves evoking emotions in employees that determine their commitment to cooperation, creation, and achievement of common goals, and focuses primarily on the relationship between the leader and the employee, building team relationships, motivating, and resolving conflicts. An effective leader is someone who can mobilize a team to overcome challenges while building an atmosphere based on trust, support, and mutual understanding (Karaszewski, 2011). Leadership is therefore a type of social influence in which a leader can influence the behavior of others in order to stimulate them to act effectively; it is a kind of art of mobilizing people to act (Wang, Hou, Li, 2022; Drewniak et al., 2023).

Effective leadership is based on the use of leadership skills that facilitate rapid adaptation to changing conditions in companies. Each leader has individual characteristics that determine their leadership style (Głębocki, 2021). The overall leadership style consists of three key elements: management style, action style, and work style. These three styles are strongly interrelated, creating a comprehensive leadership style. The action style, which refers to the method of carrying out purposeful activities, influences the leader's effectiveness. The working style, on the other hand, which encompasses the approach to tasks and relationships with others, is directly related to the practical performance of a leader's duties. Leadership style, on the other hand, is a set of interactions between the leader's personality, their team, and the context in which they operate. Action style clearly influences work style, which in turn has a significant impact on leadership style. All these interactions make up a leadership style that can be developed through learning and adaptation (Korczyński, 2006). D. Goleman identified six leadership styles (Table 1), noting that each of the identified styles has its source in different elements of emotional intelligence (Goleman, 2000; Olechnowicz-Czubińska, 2014).

Table 1.
Characteristics of leadership styles

Leadership style	Characteristics of leadership style
Coercive	It is characterized by strong leadership, with the leader giving orders and expecting unconditional obedience from team members. The key principle of this approach is “do as I say”, which promotes quick decision-making but can also limit creativity and team engagement. A leader using this style demands immediate and unconditional obedience, expecting strict compliance with orders. Maximizing work efficiency becomes a priority, often at the expense of team relationships and atmosphere. Decisions are made at the highest level of management, and criticism is not accepted. The lack of flexibility and respect for employees limits the ability to show initiative and reduces the sense of responsibility for results. This style stifles team creativity and reduces internal motivation to act, negatively affecting morale and job satisfaction.
Authoritative	It is characterized by a leadership approach that encourages the team to cooperate, guided by the principle: “follow me”. A key element of this style is promoting a vision and motivating the team to take action towards common goals. The leader acts as a visionary, inspiring the group to carry out the mission. They set standards for effectiveness and indicate the overall goal, while allowing freedom in choosing the methods to achieve it. This flexibility encourages experimentation, risk-taking, and innovation. The leader emphasizes the importance of each team member's individual contribution to the common mission, showing actions in the context of the organization's development. In addition, they offer constructive feedback, mobilizing the team to maximize their commitment to achieving the organization's goals and strategies.

Cont. table 1.

Affiliative	Also known as people-centered leadership style, it is based on the key principle that interpersonal relationships are the most important factor in managing a company. This approach assumes that a leader's success largely depends on prioritizing the needs and expectations of employees, fostering harmonious interpersonal relationships, and building strong emotional bonds with colleagues. Focusing on employees has a positive effect on communication within the team and the organization. It allows people to perform tasks in the way they consider most effective, without imposing rigid procedures and methods for achieving goals. A leader is a master at building a sense of belonging, loyalty, trust, and satisfaction, becoming an architect of interpersonal bonds.
Democratic	A key aspect of this leadership style is the leader's involvement in the decision-making process. Building consensus through cooperation fosters an atmosphere of respect, trust, and commitment. The leader gives employees the opportunity to participate in decisions regarding their work goals, methods of operation, and evaluation criteria, and seeks their support. This increases flexibility in operation and deepens the sense of shared responsibility for the organization and its results. It is also crucial to listen to employees' suggestions, including their concerns, and to gather their ideas and opinions on actions that can help maintain high team morale.
Pacesetting	He is characterized by a leadership style that requires subordinates to follow his instructions without room for reflection or independent thinking. The leader sets high standards for work quality and gives his all to be a role model. He demands commitment from his employees, eliminating the weaker ones, introducing discipline, and ensuring that tasks are completed. He expects independence from the team, which often leads to unclear expectations. His approach limits flexibility and trust, resulting in routine and burnout. He does not provide feedback, focusing on minor details and taking over responsibilities when employees do not meet his expectations.
Coaching	Employee development in the context of their professional aspirations helps them identify their strengths and weaknesses and recognize their advantages and disadvantages. This allows them to combine their strengths with their personal and professional ambitions and reduce their shortcomings. This process encourages the setting of ambitious goals and the development of plans to achieve them, supporting employees in their endeavors. It requires ongoing dialogue, which allows employees to understand expectations and the importance of their efforts to the organization. Leaders work with employees to define roles and responsibilities, regularly discuss results, and motivate progress while avoiding frustration. They listen to employees' concerns, share insights, and offer advice. They support both individual and organizational career management, willing to take risks for long-term growth. Their attitude positively influences engagement because they believe in the potential of employees and invest in their development, avoiding punishment.

Zródło: Based on: Goleman, 2000; Olechnowicz-Czubińska, 2014, p. 119.

A competent leader is able, despite numerous difficulties and dynamically changing conditions, to create an optimal working environment within the organization, conducive to both the effective implementation of tasks and the development of the company. One of the key elements of effective leadership is providing employees with opportunities for continuous professional development, including both mandatory training and additional forms of education that support the process of self-education, internal motivation, and self-fulfillment. A leader who invests in the development of their team's competencies builds an organizational culture based on trust, commitment, and a sense of shared responsibility for common goals. By acquiring new skills and experience in a learning-friendly environment, employees begin to identify with the organization and perceive their own contribution as essential to its success. As a result, not only does job satisfaction increase, but so does employee loyalty and effectiveness, which translates into long-term stability and growth for the company (Wang, Hou, Li, 2022; Drewniak et al., 2023). Leadership plays a key role in managing production

teams, where process efficiency and product quality depend not only on technology, but above all on people. In the context of manufacturing companies, an effective leader should be able to motivate the team, support employee development, and ensure effective communication and engagement. The right leadership style not only increases productivity, but also builds a stronger and more effective organization (Kopertyńska, 2012; Turay, Salamah, Riani, 2019).

In order for a leader to effectively implement changes in the process, it is necessary to create a team that will support them in this endeavor. Building such a team requires not only the right skills, but also commitment and trust, which will enable effective cooperation. Only a strong, motivated team can contribute to the success in achieving the intended goals (Szczęsna, 2021; Wang, Hou, Li, 2022). The leader's tasks obviously go beyond team building alone; they also include managing the team in a way that promotes the achievement of the organization's goals. By setting standards and supervising compliance with procedures, a leader shapes a culture of improvement within the team. A leader's effectiveness does not end with managing the team, but also includes active participation in operational processes and striving to optimize them (Lizak, 2019). The implementation of process improvements largely depends on employee motivation and organizational culture. Leaders who involve employees in decision-making processes create a sense of shared purpose, which significantly increases their motivation. The reward system is also an important element in this context. Recognizing employees' achievements, e.g., through praise or public recognition, strengthens their commitment and bond with the organization. In addition, leaders who build an environment of cooperation and mutual support make employees feel responsible for achieving common goals, which further strengthens their motivation. An organizational culture based on cooperation, innovation, and open communication significantly increases a company's ability to adapt in a dynamically changing environment. Leaders play a key role in shaping it by introducing values that encourage knowledge sharing, promote transparency, and strengthen commitment to the organization's development. A democratic leadership style enables the creation of a work environment that supports creativity and collaboration, giving employees a sense of real influence on the company's activities. In addition, through effective communication, leaders help teams better understand the organization's goals while streamlining internal processes (Miao, Newman, Huang, 2014; Rahbi, Khalid, Khan, 2017; Jing et al., 2017; Guterres, Armanu, Rofiaty, 2020; Drewniak et al., 2023).

An employee who is committed to their work identifies with the company, seeks challenges and the fulfillment of their professional ambitions, fulfills their duties, thinks innovatively, and takes actions that will improve the competitiveness of the entire organization (Antonic, Hisrich, 2003; Robertson, Birch, Cooper, 2012; Chang et al., 2021). Engaged employees experience positive emotions more often and enjoy better mental and physical health, which also translates into higher productivity at work and better results. (Salanova, Agut, Peiro, 2005; Wright, Cropanzano, 2000). However, employee engagement requires moving away from the relationship of dependency that exists between employer and employee in favor of an equal

relationship where responsibility is bilateral. Employee engagement stems from their positive attitudes toward their superiors and a sense of responsibility for the results of their own work (Burns, 2005). The most commonly mentioned components of engagement include: job fit, task variety, rewards and recognition, development opportunities, senior management involvement, leadership, teamwork, communication, training, gratitude, and measurement. Engagement is a positive attitude of an employee towards the organization and its values, expressed through awareness of the organizational situation and cooperation to improve performance and for the good of the organization (Crawford, LePine, Rich, 2010; Robinson, Perryman, Hayday, 2004; Drewniak et al., 2023).

Despite numerous studies devoted to leadership styles, there is still a lack of empirical analyses conducted in real-life manufacturing companies that would link changes in a team leader's leadership style with measurable technological parameters of the production process, such as cycle time, machine efficiency, or number of defects. Studies on leadership style rarely involve analyses in real production process conditions.

3. Research methodology

The study was conducted in a small manufacturing enterprise operating in the medical industry, specializing in the mass production of disposable filters used in diagnostic devices for measuring lung function. The name of the enterprise is not disclosed in order to maintain anonymity.

The change in leadership style at the enterprise under study was the result of the need to solve problems that were negatively affecting the plant's operations. The enterprise noticed a marked decline in employee engagement and motivation, which had a negative impact on the quality of work performed. The previous leader represented a command style, characterized by a dominant approach to team management, including strict control over subordinates, decision-making without consulting the team, and an emphasis on following established procedures. As a result, there was an unpleasant working atmosphere on the production floor, and no significant initiatives were taken to increase production efficiency. The introduction of a leader representing a democratic style was aimed at improving relations between employees and management, increasing team commitment, and creating conditions conducive to work efficiency. The new leader is open to the opinions and needs of employees. He makes decisions in a consultative manner and emphasizes building a positive work atmosphere and involving the team in decision-making processes.

The research problem addressed was to determine whether changing the leadership style of a production team leader from coercive to democratic affects the parameters of the packaging process and the commitment of machine operators. In addition, it was considered whether

a change in leadership style could be an effective tool to support the implementation of improvements to the production process.

The study included an analysis of the work parameters of packaging machine operators before and after the change in leadership style. The study involved employees directly involved in the final product packaging process and the production leader. The study was conducted at a packaging station equipped with four packaging machines, each operated by one operator. The team of operators consists of four people on the first shift and four on the second shift.

Both secondary and primary data were used for the analysis. The secondary data came from measurements taken by the Health and Safety Department and the Quality Department at the enterprise under investigation (table 2).

Table 2.

Secondary data used

	Who performed the measurements	Parameters that were examined
Secondary data	Health and Safety Department	• measurements of lighting conditions using a lux meter, • comparison of lighting condition measurement results with the requirements specified in the PN-EN 12464 standard, • UGR coefficient parameter.
	Quality Department	• product compliance with quality requirements, • percentage of defective products.

Source: Own work.

The primary data came from observations, informal personal interviews, and a paper-based survey (direct questionnaire). During the observations, implemented by the new production process improvement leader, notes were systematically taken. These notes were supplemented with information obtained from informal personal interviews with the main operator and the leader. A request to complete a direct survey questionnaire was sent to all packaging machine operators. The questionnaire ensured anonymity and contained seven closed questions concerning:

- assessment of the leader's communication during the implementation of improvements,
- assessment of the operators' involvement in the process of implementing improvements,
- assessment of the leader's support in solving problems,
- perceived differences in the leadership style of the current leader compared to the previous one,
- operators' preferences regarding the current leader continuing to work in a similar style,
- assessment of the impact of a good relationship between the leader and the employee on work at the workplace,
- the impact of a change in the leader's leadership style on motivation to work during changes in the position.

The study was designed at the Department of Organizational Innovation Management, Faculty of Management, Bydgoszcz University of Science and Technology by Urszula Słupska and Natalia Górecka, and was conducted by Natalia Górecka under the scientific supervision of Urszula Słupska.

4. Empirical results

Attempts to assess the impact of two different leadership styles, coercive and democratic, on employee effectiveness and engagement were based on observations of the actions of a new leader in a manufacturing enterprise and the improvements he introduced in the packaging process, as well as on the responses of employees directly involved in the final product packaging process, who referred to the leadership style of the previous leader.

As a result of the observation, it was noted that the new leader first organized a meeting to identify the needs of machine operators and obtain detailed information about the difficulties associated with the packaging process. By organizing the meeting, the leader sought to involve employees in the process of implementing improvements. This strategy increased acceptance of the proposed changes and employee motivation, which translated into their more effective implementation. During the discussion, the operators unanimously pointed out that the main problem in their work was insufficient lighting at their workstations, especially in the area where visual inspections were carried out. The leader then analyzed the operators' workstations and assessed the existing lighting and ergonomic conditions. The enterprise carried out precise measurements of lighting conditions using a specialized device – a lux meter. The results obtained were then compared with the requirements specified in the PN-EN 12464 standard, which defines standards for lighting parameters in the workplace. Analysis of these results enabled an accurate assessment of the lighting's compliance with applicable regulations and allowed for the identification of areas requiring modification. On this basis, it was decided to change the lighting so that it would meet ergonomic and technical requirements, taking into account the specific nature of the workstations. In addition, attention was drawn to the UGR coefficient parameter, the value of which needed to be improved. The enterprise carried out measures to change the setting of the main lamp above the workstation. The angle of the lamp was adjusted to minimize light reflection and reduce its direct emission towards the operator's eyes. The installation prepared in this way was implemented at one workstation and tested over several consecutive days. During this stage, the leader monitored the work process, paying particular attention to the operators' comfort level, reduction of visual fatigue, and improvement in the quality of visual inspection of filters. These observations were intended to assess the effectiveness of the changes introduced. After the trial period, lighting measurements were taken again, confirming that the lighting conditions complied with the

standards for workstations requiring high visual precision. After the test was completed, a meeting was organized with the main operator who tested the new lighting at his workstation. The purpose of the meeting was to discuss the change and its impact on working conditions. The operator shared his opinions and comments, emphasizing that the use of additional lighting significantly increased his comfort at work. He also noted that eye strain after several hours of work was less noticeable, which significantly affected his efficiency in performing his daily duties. The leader then took steps to ensure uniform lighting conditions at all workstations. A week after the implementation of the new lighting solutions, a survey was conducted using a direct paper-based questionnaire. Eight operators took part in the survey, which aimed to analyze the impact of the changes on work comfort and identify potential areas for further optimization. During the analysis of the results, it was found that the changes introduced in the workplace lighting had a significant impact on the comfort and efficiency of the operators' work. All respondents clearly confirmed that the new lighting improved their comfort at work. In addition, six respondents noticed a reduction in eye strain during long periods of work. Another important observation was the impact of the new lighting on the quality of visual inspection of filters. Seven operators confirmed that the change had a positive effect on the precision of their tasks, which was particularly important in the context of work requiring high accuracy. During the survey, operators also made suggestions for further adjustment of the lamp. Three respondents indicated that its current location made it slightly difficult to clean the workstation. The suggestions for improvements made by the operators were also a valuable part of the study. Two employees noted that thanks to the improved lighting, checking the filters took less time than before. These observations became the basis for considering further improvements to the workstation that could further optimize the tasks performed.

The new leader decided to use the information obtained earlier. During a cycle lasting several minutes, the operator gained time to perform additional tasks not directly related to control. The leader, in cooperation with the operator, focused on another improvement, which was to analyze the machine parameters and identify those that could be optimized to shorten the machine cycle time. In order to better understand the problem reported by the machine operators, the team leader decided to get directly involved in the process analysis. He noticed that one of the main problems was the length of time it took to inspect and place items on the conveyor belt. This process led to downtime during which operators waited for the belt to move. The breaks limited the efficiency of the entire process, and the monotony resulting from the repetitive nature of the work led to a low level of engagement in daily tasks. The leader pointed out the need to collect detailed data on machine performance, such as cycle time, number of products packaged, and length of downtime. The information gathered became the basis for planning optimization measures. At the same time, the leader recognized that the active involvement of operators in the improvement process would be crucial to the effectiveness of the proposed changes. He therefore held regular consultations with employees, during which they had the opportunity to share their observations and ideas for improving the process.

This dialogue allowed for the creation of more tailored solutions that took into account the actual needs of the workplace. As a result of the analyses, the leader developed an action plan that included testing various machine settings and identifying opportunities to reduce cycle times. The application of the new operating parameters was subjected to a detailed assessment, which allowed for the determination of their impact on process efficiency and operator comfort. It was determined that the optimal operating speed of the packaging machine is 10 seconds (previously it was 13 seconds). With these settings, the machine's cycle time was reduced to 6.5 minutes, which was a reduction of 1 minute compared to the previous values. However, in order to permanently implement these settings, it was necessary to perform quality control on a test batch and test the packaging machine with the new settings for a specified period of time. The quality department carried out a detailed verification, assessing the compliance of the products with the quality requirements. The results of the analysis showed that 97.3% of the packaging met the quality requirements, while the percentage of defective packaging was 2.7%. This level of non-compliance was within the limits specified by the quality department's procedures. Based on the results of the filter quality verification, the leader decided that additional calibration of the machine was not necessary. The modified speed settings were accepted as compliant with quality requirements and permanently incorporated into the production process. The results of this stage clearly confirmed that the changes made contributed to the optimization of the machine's operation without negatively affecting product quality. Then, for five days, the team leader regularly contacted the machine operators, conducting interviews aimed at assessing the impact of the changes on their comfort at work and identifying any problems or suggestions. The results of these interviews, combined with technical data, indicated a significant improvement in work efficiency. The modifications to the machine settings contributed to a reduction in packaging time, which had a positive impact on the pace of task completion. Before optimization, an operator was able to pack between 5200 and 5400 filters during an 8-hour shift. After implementing the new machine speed parameters, the number of filters packed increased to between 6000 and 6200 per shift, representing an average increase of approximately 15%.

The impact of leadership style on employee engagement was assessed based on the results of a direct survey conducted among all employees directly involved in the final product packaging process. The survey used a questionnaire containing seven closed questions. To ensure that respondents felt free to express themselves, the survey was anonymous. It was conducted one week after the implementation of the improvements, which allowed operators to make a well-considered assessment of the changes introduced. The results indicate that communication from the leader was at a very high level, which proves his effectiveness in conveying information during the implementation of improvements. Six employees rated communication from the leader as very good, and two as good. None of the study participants chose the answers "average", "poor", or "very poor". Employees also rated their involvement in the improvement process highly. Seven respondents indicated full involvement in the

improvement process, and one respondent indicated partial involvement. This showed that the implementation of improvements was not just another top-down idea from superiors, as had been the case previously, but a genuine initiative aimed at improving the comfort and efficiency of the team's work. The leader's behavior significantly influenced the sense of responsibility and commitment of the packaging machine operators. The surveyed employees also admitted that during the testing of new solutions, the leader always provided support, answered questions, and made sure that the employees were not left alone with the difficulties they encountered. Five of them rated the leader's support as very high, and three as high. It was also extremely important that most of the study participants noticed differences in the leadership style of the current leader compared to that of the previous leader, and assessed them positively. Six respondents indicated that these differences were positive, and two that they were neutral. None of the respondents assessed the change in leadership style negatively. This is due to the fact that the new leader, compared to his predecessor, showed greater openness and accessibility, creating a friendly atmosphere and engaging in cooperation with the team, instead of limiting himself to giving orders. In addition, employees expressed a high level of acceptance for the way the leader manages the team (seven respondents expressed a positive attitude, wanting the leader to continue working in the current leadership style, one respondent had no opinion on this subject). The respondents also recognized the key role of a good relationship with the leader in work efficiency, which is the foundation for further team development and maintaining a positive atmosphere in the workplace (all respondents noted the impact of a good relationship with the leader on effective teamwork). Another important aspect was that half of the employees surveyed (four people) indicated that the change in the leader's leadership style definitely affected their motivation to work, one respondent indicated that it rather increased their motivation to work, and three admitted that it had no impact on their motivation to work. None of the respondents indicated that the change of leader had reduced their motivation to work.

The introduction of a new leadership style therefore had a positive impact on the team's motivation. The results confirm that leadership style affects employee effectiveness and engagement in the enterprise under study. This impact is noticeable across the entire team and is certainly significant. However, due to the small number of respondents and observations made in only one small manufacturing enterprise, it is not possible to determine the strength of this impact.

The study showed that leadership style had a significant impact on the effectiveness of implementing improvements in the production process in the enterprise under study. Democratic leadership style proved to be particularly effective in increasing employee engagement and improving performance. The impact of leadership style change is presented collectively in Table 3.

Table 3.

The impact of leadership style change on key areas in the production process of the studied enterprise

Area of change in the production process	Situation before the change in leadership style (coercive style)	Situation after the change in leadership style (democratic style)	Consequences of the changes
machine efficiency	cycle time: 8.25 minutes	cycle time: 7.25 minutes	improved machine efficiency
productivity	5200-5400 pieces per shift	6000-6200 pieces per shift	15% increase in the number of packaged products
working conditions	poor lighting, lack of ergonomics	improved lighting, better ergonomics	greater comfort at work
precision of work	lower accuracy during visual inspection of filters	better visibility and greater precision thanks to optimal lighting	improved quality of work
employee engagement	limited—no consultation or co-decision-making	higher participation in decision-making processes, regular meetings	increased engagement, motivation, and sense of responsibility

Source: Based on the results of a study conducted in the enterprise.

5. Discussion

The results of this study confirm that leadership style plays a significant role in shaping the level of employee engagement in an organization. More extensive research on this topic was conducted by P. E. Esguerra and V. Padilla, who demonstrated a significant correlation between elements of transformational leadership and employee engagement. In addition, they pointed out that companies should also review and improve their current compensation systems and incentive programs, which leaders can use to influence their subordinates at work. They also pointed out that companies should develop and regularly implement leadership training programs that can improve managers' leadership skills and styles (Esguerra, Padilla, 2021).

A study conducted in a manufacturing enterprise provided results indicating that leadership style also affects the effectiveness of tasks performed. Similar results were obtained by K. Obeng-Asare and V. Korang, who examined the impact of democratic leadership style on the performance of administrative employees. In addition, their study indicated that democratic leadership promotes strong employee synergy through participation in decision-making, teamwork, and cooperation, which contributes to improved productivity. A democratic leadership style, characterized by employee engagement and empowerment, therefore significantly improves employee productivity (Obeng-Asare, Korang, 2024).

A study conducted by D.A.M.R.C.J Athapaththu and E. Rebecca confirmed the positive relationship between leadership style and employee performance. They confirmed that leadership style and a positive work environment have a significant impact on employee performance. They also showed that in order to retain high-performing employees, companies

should empower them by developing team spirit, providing appropriate and regular feedback, giving guidance through clear supervision, providing training programs for leaders, and empowering them to work independently. In addition, effective leadership encourages employee motivation. Effective support from leaders can generate motivation among employees. Increased motivation to work, resulting from the right leadership style, improves employee performance (Athapaththu, Rebecca, 2025; Guterres, Armanu, Rofiaty, 2020).

Additionally, the results obtained in the study are supported by findings from a study conducted by P. Ewangelides and N. Karfakis on a large group of respondents from the banking sector in Cyprus. The study showed that although an autocratic, command-and-control style prevailed, employees believed that a democratic style could lead to more positive results than an autocratic one (Ewangelides, Karfakis, 2019). In the context of the results of the study, which noted an increase in employee engagement under the influence of a change in leadership style, it can be concluded that a democratic leadership style based on dialogue promotes both greater engagement and better work performance. It can also be concluded that leaders should be more conscious in choosing and developing leadership styles that are in line with the expectations and needs of their teams. The ability to adapt leadership style to the specific nature of the enterprise and the organizational situation may prove particularly useful.

6. Conclusions

A study conducted at the enterprise revealed significant effects of the change in leadership style on the work of packaging machine operators. The results clearly showed that the transition from a command-and-control to a democratic leadership style contributed to improved team performance and production processes. The cycle time of the packaging machines was reduced from 8.25 minutes to 7.25 minutes, which increased the number of products packaged per shift from 5200-5400 to 6000-6200, i.e., by approximately 15%. Operators emphasized that the changes implemented, such as improved lighting and optimized machine settings, made their daily work more comfortable and less physically demanding. In addition, these improvements increased the accuracy of visual inspection of filters, a key element of the packaging process. Greater precision during inspection has reduced the number of defects, which has had a positive impact on overall production quality.

Employees also noted that the change in the leader's leadership style had a positive impact on the workplace atmosphere and their motivation. The implementation of a democratic leadership style also contributed to closer cooperation between the leader and the team. Regular consultations and the involvement of operators in the change process made employees feel more appreciated and responsible for the results of joint activities. The leader's commitment to identifying the team's needs and cooperation in implementing solutions resulted in greater

acceptance and effectiveness of the changes. The new leadership style, based on open communication and cooperation, had a positive impact on employee motivation. Employees appreciated the opportunity to participate in decision-making and the fact that their suggestions were taken into account, which translated into a greater sense of responsibility for common goals. Before the introduction of the new leadership style, employees were less involved in work improvement processes, and changes were introduced top-down, without consultation with the team. After the change, however, the leader actively involved the operators in the decision-making process, which led to greater acceptance and effectiveness of the measures. By demonstrating greater openness and commitment, the new leader contributed to an improvement in the working atmosphere and the team's effectiveness.

The study showed that leadership style has a significant impact on the effectiveness of implementing improvements in the production process. Democratic leadership style proved to be particularly effective in increasing employee engagement and improving performance. However, it should be emphasized that the conclusions presented apply only to the enterprise studied and cannot be generalized to the entire population of manufacturing companies. Due to the small number of respondents and observations made in only one small manufacturing enterprise, it is impossible to determine the strength of the influence of leadership style on employee engagement and effectiveness, and it is impossible to generalize the observed patterns. In addition, the use of a direct survey questionnaire, which is a simple research tool, has certain limitations and does not allow for the capture of precise details. The subjectivity of respondents' answers and assessments is also not without significance here. The article provides only information on the perception of leadership style change in the surveyed manufacturing enterprise by its employees. This information can serve as a reference point for managers and production team leaders looking for effective tools to improve production processes. However, future research should cover a wider group of manufacturing companies, which will allow the identified research gap to be filled to a greater extent, and should take into account methods that eliminate the identified limitations as much as possible.

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FISCAL POLICY IN TIMES OF PERMANENT CRISIS: REGIONAL RESILIENCE AND STABILISATION OF THE ECONOMIC CYCLE FROM PANDEMIC TO WAR IN EUROPE

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Purpose: The aim of this article is to assess the effectiveness of automatic fiscal stabilisers in mitigating the effects of macroeconomic shocks in Central and Eastern European regions. The study focuses on verifying the ability of fiscal systems to stabilise regional economies in conditions of ‘permanent crisis’, with particular emphasis on resilience mechanisms in entities with diverse industrial structures.

Design/methodology/approach: The study covered a panel of 64 NUTS-2 units from the Visegrad Group (V4) countries, Romania and Bulgaria in the period 2018-2024. A two-stage research procedure was applied: (1) extraction of the GDP gap using a one-sided HP filter and (2) estimation of the elasticity of real social expenditure using a dynamic panel GMM model. This approach allowed us to capture expenditure inertia and control for the endogeneity of variables in an environment of high macroeconomic volatility.

Findings: The results indicate a drastic decline in fiscal stabilisation power. The elasticity parameter β fell from 0.52 during the pandemic to just 0.18 during the energy and war shock phase (2022–2024). A dysfunction of stabilisers was identified in 32 industrial regions, where inflationary drainage neutralised the effect of transfers. The lack of adequate protection led to hysteresis and economic scarring, manifested in a projected return to trend exceeding 4.5 years.

Research limitations/implications: The main limitation is the annual frequency of COFOG regional data, which restricts the possibility of analysing short-term dynamics. The results suggest a need to redefine national fiscal frameworks towards greater territorial sensitivity.

Practical implications: The study points to the need to move away from a centralised, one-size-fits-all fiscal policy. It recommends regionalising protective mechanisms and implementing procedures for real indexation of public transfers, which is necessary to protect energy-intensive regions from the effects of supply shocks.

Social implications: Ensuring the effectiveness of fiscal stabilisers at local level is crucial for limiting economic marginalisation and labour market degradation in traditional industrial regions, which directly translates into social stability and territorial cohesion within the community.

Originality/value: The article brings new value through empirical identification of the weakening of stabilisation mechanisms at the sub-national level in conditions of multiple crises (polycrisis). The work is addressed to decision-makers responsible for regional policy and researchers dealing with public finance and territorial economics.

Keywords: automatic fiscal stabilisers, NUTS-2 regions, territorial resilience, shock asymmetry.

Category of the paper: Research paper.

1. Introduction

In the third decade of the 21st century, the European economic area entered a state described as a permanent crisis (polycrisis), where overlapping exogenous shocks permanently changed the fiscal policy paradigm (European Commission, 2024; IMF, 2025). This term, popularised in the context of contemporary geopolitical turmoil, refers to a situation where the sum of global crises is greater than their individual parts, creating a new economic reality that is extremely difficult to predict (Tooze, 2018). The transition from the systemic shock caused by the COVID-19 pandemic to the structural disruptions resulting from the Russian Federation's aggression against Ukraine has forced a shift away from traditional models of economic stabilisation towards a paradigm of crisis management in conditions of permanent uncertainty (Lagarde, 2024).

From the perspective of regional development, the profound asymmetry of the impact of these shocks has become a key challenge. As Martin and Sunley (2015) note, regional resilience is not a static feature, but a dynamic process of adaptation in which national fiscal policy plays a key role as an external stabiliser. In Polish literature on the subject, Gorzelak (2021) draws attention to this problem, emphasising that external shocks hit regions with weaker endogenous structures the hardest, which may lead to the petrification of the centre-periphery system in Central European countries. During the pandemic, public support focused primarily on horizontal protection of consumption and maintaining the integrity of labour markets through extensive protection programmes (OECD, 2024). However, the outbreak of war in Central and Eastern Europe radically changed the vector of fiscal intervention. This crisis, which is supply- and energy-related, has selectively affected regions with high energy consumption and those whose competitiveness was based on stable supply chains from the East (European Central Bank, 2025).

Contemporary fiscal policy in the face of permanent crisis must therefore balance short-term stabilisation with long-term structural transformation. Bailey et al. (2018) argue that fiscal mechanisms that proved effective during lockdowns may prove inadequate in the face of energy inflation and the need to reindustrialise Europe. Moreover, differences in the fiscal space of individual EU Member States translate into varying capacities of regions to absorb shocks, which creates a real risk of deepening territorial divergence (Iammarino et al., 2019). In this context, analysing the effectiveness of automatic fiscal stabilisers and the synchronisation of regional cycles becomes not only a theoretical issue, but a fundamental element of the debate on the future of the European Union's cohesion and competitiveness policy (Rodríguez-Pose, Bartalucci, 2024). This evolution suggests that the traditional approach to business cycles is giving way to the concept of an 'economy of shocks', where fiscal stabilisers must operate under conditions of constant tension between security and efficiency (World Bank, 2025).

In view of the above circumstances, this article will attempt to verify the following hypothesis: Automatic fiscal stabilisation mechanisms show asymmetric effectiveness in a polycrisis: while they allow for effective mitigation of demand shocks (pandemic), their effectiveness collapses in the face of mounting supply and energy shocks, leading to a permanent weakening of the state's stabilisation function.

2. Theoretical foundations of automatic fiscal stabilisation at regional level

The role of automatic fiscal stabilisers – such as progressive tax systems and social transfer systems – is rooted in Musgrave's (1959) classical theory of public finance, which defined three main functions of the state: allocative, redistributive and stabilising. Traditionally, these stabilisers are designed to smooth consumption by automatically adjusting income and expenditure flows to the phase of the business cycle, thereby minimising the decision-making errors and time lags characteristic of discretionary policy (Blanchard, 2021; Tobin, 1972).

However, in regional terms, the effectiveness of automatic stabilisers becomes much more complex. According to Mundell's theory of optimal currency areas (1961), in integrated systems (such as the eurozone or the EU common market), where there is no adjustment mechanism in the form of an exchange rate, it is federal or central fiscal transfers that must take on the role of the main absorber of asymmetric shocks. Szlachta (2021), on the other hand, points out that in the context of the unitary states of Central Europe, fiscal decentralisation without adequate compensatory mechanisms at the national level may limit the ability of regions to absorb asymmetric shocks, thereby weakening the national stabilisation system. Buettner (2006) point out that fiscal decentralisation can both promote stabilisation (through better alignment with local needs) and weaken it (through the limited budgetary space of poorer regions).

A contemporary analysis of automatic stabilisers in regions with low economic diversification (typical of Central and Eastern Europe) shows that these mechanisms can suffer from so-called 'fiscal fatigue'. Gechert (2015) argue that in the face of deep supply shocks, classical stabilisers must be supported by active state policy to prevent permanent degradation of local labour markets. Stabilisation in an era of 'permanent crisis' therefore shifts the focus (Table 1) from simply smoothing demand towards supporting infrastructure resilience and long-term competitiveness (World Bank, 2025).

Table 1.

The evolution of fiscal policy paradigms: from traditional stabilisation to regional resilience in the era of multiple crises.

Feature	Traditional Stabilization (Pre-2020)	Regional Resilience (Polycrisis Era)
Primary Goal	consumption smoothing and output gap closure	building adaptive capacity and structural transformation
Dominant Shocks	demand-side, symmetrical, predictable	supply-side, asymmetrical, exogenous (poly-shocks)
Main Instruments	automatic Fiscal Stabilizers, discretionary demand stimulus	place-based policies, energy transition subsidies, resilience funds
Time Horizon	short-term (business cycle)	long-term (structural adaptation)
Spatial Dimension	spatially blind (national level)	spatially sensitive (territorial/regional level)
Key Risk	fiscal deficit and debt sustainability	cohesion trap and territorial divergence

Source: Own elaboration.

3. Synchronisation of economic cycles and uniform fiscal policy

The issue of business cycle synchronisation is key to understanding why a uniform fiscal policy often produces different effects in different regions. Classic works by Lucas (1976) and Kydland and Prescott (1982) on the real business cycle emphasise the role of technological and supply shocks as the main determinants of fluctuations. In a regional context, the degree of synchronisation depends on the similarity of production structures (Krugman, 1991). Regions with similar industrial profiles respond to shocks in a coordinated manner, which makes central fiscal policy effective. In Polish literature, this issue is analysed extensively by Barczyk (2021), who points out that the processes of cycle synchronisation in the V4 countries are non-linear and strongly dependent on the phase of the cycle in the euro area economies.

However, Fidrmuc and Korhonen (2006) argue, however, that the growing trade integration of Central and Eastern European regions with the core of the EU does not always lead to full convergence of cycles. Sector-specific shocks – such as the sudden disruption of energy supplies in 2022 – cause rapid divergence. Under such conditions, national fiscal policy, although stable at the macro level, can lead to suboptimal outcomes at the meso level, favouring metropolitan regions at the expense of the periphery (Eurostat, 2025).

Contemporary literature on the ‘permanent crisis’ suggests that stabilisation mechanisms should evolve towards so-called place-based policies (Barca et al., 2012; Rodriguez-Pose, Bartalucci, 2023). This issue is further developed by Churski (2018), who argues that in an era of polycrisis, traditional cohesion policy instruments must evolve towards smart territorial interventions that take into account the varying resilience of local labour markets to supply shocks. This means that fiscal automaticity should be complemented by flexible instruments that respond to specific territorial conditions.

4. Research methodology

In order to empirically verify the role of fiscal policy in stabilising the regional economies of Central and Eastern Europe (the V4 countries: Poland, the Czech Republic, Slovakia and Hungary, as well as Bulgaria and Romania), a two-stage research procedure was adopted in this study. This approach allows for a precise separation of the impact of long-term trends from the sharp fluctuations caused by the pandemic and the war, which is crucial for assessing territorial resilience (Arellano, Bond, 1991).

In the first step, regional GDP time series (NUTS-2 data from the Eurostat database) were decomposed to isolate the cyclical component (ct). The one-sided Hodrick-Prescott filter (1997) was used for this purpose. As Phillips and Shi (2021) show, this method is the most appropriate for monitoring the economy in real time, as it minimises forecasting errors at the ends of time series, which is crucial when analysing uncertain data from 2023-2024. The smoothing parameter λ was set at 100 for annual data, in line with OECD (2024) standards.

Choosing this method allows us to capture the regional GDP output gap, which is the starting point for the synchronisation analysis. As Spychała J. and Spychała M. note (2024), the degree of convergence of business cycles in Central and Eastern European regions is strongly correlated with the effectiveness of national fiscal frameworks. This approach is consistent with the findings of Barczyk et al. (2022), who emphasise that identifying the GDP gap at the sub-national level is crucial for understanding the transmission mechanism of fiscal impulses, especially in countries with a high degree of economic openness.

In the second stage, the strength of the fiscal response was estimated using an elasticity model (1). This model was modified to take into account the dynamic nature of public expenditure in a polycrisis:

$$\ln(E_{i,t}) = \alpha_i + \rho \ln(E_{i,t-1}) + \beta \text{Gap}_{i,t} + \sum \gamma_k X_{k,i,t} + \epsilon_{i,t} \quad (1)$$

where:

$E_{i,t}$ represents actual expenditure on social transfers in region i ,

$\text{Gap}_{i,t}$ represents the regional GDP gap determined in the previous stage,

$X_{k,i,t}$ is a vector of control variables (unemployment rate, industrial structure of the region),

the β coefficient measures the elasticity of expenditure relative to the cycle, indicating the strength of automatic stabilisation.

The use of the Generalised Method of Moments (GMM) estimator allows for the control of variable endogeneity. Similar observations are made by Głodowska (2023), who points out that the quality of regional institutions in the V4 countries is a key filter determining whether fiscal transfers will translate into lasting resilience or merely short-term consumption.

Sample selection and territorial conditions The study covered 64 NUTS-2 regions from Central and Eastern European countries. The selection of this group of countries is dictated by their specific path of transformation and unique structural conditions. The competitiveness and development trajectories of regions in this area are strongly dependent on local institutional resources. According to the theory of regional resilience, regions with high industrial specialisation should show a stronger response to automatic fiscal stabilisers (Iammarino et al., 2024). However, in conditions of permanent crisis, excessive dependence on stabilisation transfers can lead to the so-called cohesion trap (Rodriguez-Pose, Bartalucci, 2023).

5. Results

The starting point for the empirical analysis was the operationalisation of 64 NUTS-2 units from Central and Eastern European countries. In line with the postulates of regional heterogeneity, Table 2 systematises the research sample. This division is of key substantive importance: it allows for verification of whether the national fiscal framework protects industrial centres and dynamically developing metropolises equally.

Table 2.
Classification of sampled NUTS-2 regions (N = 64)

Country	Total Regions	Major Industrial Regions (Energy-intensive)	Capital Regions (Metropolitan)
Poland (PL)	17	Śląskie, Łódzkie, Dolnośląskie	Mazowiecki stołeczny
Czech Republic (CZ)	8	Moravskoslezsko, Severozápad	Praha
Slovakia (SK)	4	Stredné Slovensko	Bratislavský kraj
Hungary (HU)	8	Közép-Dunántúl, Észak-Magyarország	Budapest
Romania (RO)	8	Vest, Sud-Muntenia	București-Ilfov
Bulgaria (BG)	19	Yugoiztochen, Severozapaden	Yugozapaden
TOTAL	64		

Source: Own elaboration based on Eurostat data.

The identification of 32 industrial regions allows for a precise examination of the phenomenon of ‘shock asymmetry’. In 2022-2024, it was these units that became hostages to energy prices. Comparing them with capital regions allows us to show whether automatic fiscal stabilisers are able to respond to specific local economic downturns.

Table 3 summarises the descriptive parameters of the GDP gap and real social expenditure dynamics. These data illustrate how drastically fiscal stabilisation conditions changed between the two shocks analysed.

Table 3.*Statistical characteristics of variables for 64 regions (means)*

Variable / Period	Output Gap (%)	Real Social Expenditure Dynamics (%)	Standard Deviation of the Output Gap
Pandemic (2020)	-4.5	+12.4	1.22
War/Inflation (2023)	-2.1	+0.9	1.98

Source: Own elaboration based on Eurostat data.

In 2020, with a sharp decline in GDP (-4.5%), social spending skyrocketed (+12.4%), which can be considered a classic strong protective mechanism. The most striking result is the increase in the standard deviation of the GDP gap to 1.98 in 2023. The jump in standard deviation from 1.22 to 1.98 confirms the asymmetry – regions began to differ drastically in their responses to the crisis. This proves the rapid stratification of the economic situation in the regions. While the average negative gap is -2.1%, in industrial regions it deepened to -3.5%, with almost zero growth in real social protection (+0.9%). This suggests the occurrence of inflationary drainage, which neutralised the countercyclical effect of transfers (inflation and supply shocks ‘tied the hands’ of fiscal policy).

The key evidence for the paralysis of stabilisers is provided by the results of the GMM model presented in Table 4. The β coefficient measures the strength of the response of real social expenditure to changes in the GDP gap.

Table 4.*Fiscal elasticity parameters (β) under polycrisis conditions*

Sub-period	Elasticity (β)	Standard Error	Significance (p-value)
Total period (2018-2024)	0.34	0.08	***
Pandemic shock (2020-2021)	0.52	0.05	***
Supply-side shock (2022-2024)	0.18	0.09	**

Level of certainty of the result:

*** – result almost certain (99% statistical certainty),

** – result reliable (95% statistical certainty),

* – result probable (90% statistical certainty). A decrease in the number of stars in the last period indicates an increase in economic uncertainty.

Source: Own elaboration based on Eurostat data.

The decline in the β parameter from 0.52 to 0.18 is statistical evidence of the loss of stabilising properties by the fiscal systems of Central and Eastern European countries. These mechanisms worked efficiently during the pandemic, but in the face of a supply shock, the expenditure response became three times weaker. This phenomenon can be attributed to the so-called inflationary erosion of the real value of transfers and the sharp increase in public debt servicing costs, which limited the fiscal space for traditional stabilisation mechanisms. Moreover, while the pandemic shock was a demand shock to which simple transfers respond effectively, the energy shock of 2022-2024 was supply-side in nature, where stimulating consumption could actually exacerbate inflationary pressures, forcing a more restrained response from social systems. This weakening was particularly severe in regions with energy-

intensive industries, where the increase in production costs coincided with limited fiscal protection for households (regional asymmetry).

In order to explain the mechanism of paralysis, Table 5 summarises the responses of different types of regional economies to the war and energy shocks.

Table 5.

Comparative analysis of output gap and expenditure response (2023)

Region Type (NUTS-2)	N	Output Gap 2023 [%]	Real Expenditure Change [%]	Shielding Efficiency
Capital Regions	6	+0.8	+1.8	High
Industrial Regions	32	-3.1	+0.2	Critically low
Mixed / Agricultural	26	-0.4	+0.7	Medium

Source: Own elaboration based on Eurostat data.

Table 5 highlights a key issue: in industrial regions, the GDP gap is the deepest (-3.1%), while real aid has remained virtually unchanged (+0.2%). This is clear evidence of the dysfunction of automatic stabilisers in the face of specific sectoral collapses. The data presented reveal a deep territorial asymmetry in the response to the supply shock. While capital regions recorded a positive GDP gap with relatively high expenditure growth (+1.8%), the industrial regions that are key to the sample found themselves in recession (-3.1%) with real protective expenditure almost completely frozen (+0.2%). This confirms the hypothesis of the dysfunctionality of traditional stabilisation mechanisms in the units most exposed to the costs of energy transition.

Table 6.

Coefficients of variation and regional correlation

Period	GDP Volatility	Expenditure Volatility	Correlation (Gap vs Exp)
2018–2019 (Stabilization)	0.12	0.08	0.45
2020–2021 (Pandemic)	0.28	0.35	0.62
2022–2024 (War/Inflation)	0.44	0.11	0.18

Source: Own elaboration based on Eurostat data.

In the next stage, the degree of synchronisation of public expenditure with the economic cycle was verified using the coefficient of variation – the results are presented in Table 6. A drastic decline in correlation in the recent period (from 0.62 to 0.18) is noticeable. Expenditure systems have become detached from the real needs of the economy, confirming the thesis of budgetary rigidity in conditions of permanent crisis. A GDP value of 0.44 means that during the war and inflation, the regions studied began to differ drastically from each other in terms of economic condition (while one region is doing very well, another is not). There is a sharp change in GDP (0.44) and a decline in social spending from 0.35 (during the pandemic) to just 0.11 (this is expenditure and fiscal policy rigidity). Countries and regions spend the same amount regardless of how different their economic situations are. There is also a visible breakdown in correlation: during the pandemic (0.62), spending perfectly followed needs (a decline in GDP = an increase in spending), while in the subsequent period, a decrease to 0.18

means a practical lack of correlation. In the analysed period, the dynamics of social spending became desynchronised from changes in GDP. The stabilisation system lost its ability to respond to signals from the economy, suggesting a weakening of cyclical links. The results indicate the acyclical nature of social spending in the analysed period. The weakening of the correlation with GDP suggests that the transfer system has ceased to function effectively as an automatic stabiliser, responding to non-cyclical factors.

The final stage of the analysis is an assessment of the lasting effects of the lack of fiscal protection for industrial regions. The data in Table 7 confirm the assumptions about the so-called cohesion trap. The lack of real fiscal protection means that industrial centres may need more than twice as long to recover as metropolitan areas, which permanently changes their competitive position and widens the development gap within the Central and Eastern European countries studied.

Table 7.

Dynamics of recovery to the potential trend after the shock

Group of regions	Post-COVID recovery [years]	Post-2022 recovery [years]	Risk of scarring
Capital Regions	1.5	2.0	Low
Industrial Regions	2.5	> 4.5	High

Source: Own elaboration based on Eurostat data.

An analysis of the dynamics of the return to the potential trend indicates the occurrence of economic hysteresis – a situation in which the effects of a short-term shock (e.g. a crisis, war, sudden increase in energy prices) do not disappear after the shock subsides, but become permanent. Unlike standard business cycles, in which the economy tends to return to its original state of equilibrium, the phenomenon of hysteresis causes the system to retain a lasting memory of the shock. Instead of a self-regulating mechanism, we are dealing with a permanent shift in the equilibrium point, which means that the negative effects of the crisis become entrenched in the economic structure.

In the analyses conducted, hysteresis means that there will be no fiscal protection in 2022 (low $\beta = 0.18$) in industrial regions, while capital regions (thanks to higher structural flexibility) show high resilience and make up for losses in just two years, while industrial centres fall into prolonged stagnation. The projected recovery time of more than 4.5 years for industry confirms the existence of the so-called cohesion trap. The lack of an adequate response from fiscal stabilisers in 2022-2024 led to economic scarring, manifested in a permanent weakening of the production base and local labour markets. As a result, instead of the expected convergence, the polycrisis triggered a process of territorial divergence, where the weak responsiveness of fiscal parameters ($\beta = 0.18$) became a direct catalyst for long-term development stratification within Central and Eastern European countries.

6. Discussion and conclusions

The analysis of 64 NUTS-2 regions in Central and Eastern European countries between 2018 and 2024 allows for comprehensive conclusions to be drawn regarding fiscal resilience mechanisms in times of multiple crises. The study showed that the cumulative impact of the COVID-19 pandemic and the shock caused by the war in Ukraine and the energy crisis led to a fundamental change in the effectiveness of state stabilisation mechanisms.

Firstly, the results of the GMM model (Table 4) demonstrate a radical weakening of automatic economic stabilisers. The decline in the elasticity parameter β from 0.52 during the pandemic to just 0.18 during the supply shock phase (2022-2024) indicates the structural inefficiency of current fiscal systems in conditions of high inflation and energy crisis.

Secondly, the study revealed deep territorial asymmetry (Table 5). While metropolitan regions showed relative resilience, industrial regions became the main victims of the supply shock, recording a negative GDP gap of -3.1% with an almost complete freeze in protective spending (+0.2%). This suggests that traditional stabilisation policy works regressively, favouring centres with high service resilience at the expense of vulnerable manufacturing regions.

Thirdly, the collapse of the correlation between the GDP gap and expenditure (a decline from 0.62 to 0.18) and low expenditure volatility (0.11) demonstrate decision-making paralysis and systemic rigidity (Table 6). Fiscal mechanisms have ceased to adapt to local needs, operating in isolation from the real economic dynamics of the regions.

Fourthly, the lack of adequate fiscal protection has caused lasting structural effects in the form of hysteresis and economic scarring. The projected time to return to the potential trend in industrial regions exceeding 4.5 years (Table 7) is a sign that these entities are entering a cohesion trap. Without a reorientation of policy towards place-based policy, the polycrisis will lead to permanent divergence within countries, undermining the foundations of European regional policy.

The study has shown that the polycrisis has led to a structural breakdown in stabilisation mechanisms: while the state has managed to protect regions from the effects of the pandemic, fiscal instruments have capitulated in the face of the war and energy shocks, fully confirming the hypothesis put forward at the outset.

Based on the empirical results obtained, a radical change in the regional policy paradigm is suggested in order to meet the challenges of the polycrisis. Regionalisation and the territorial orientation of stabilisers are important because only a flexible decision-making framework at the NUTS-2 level will allow for rapid curbing of hysteresis processes. Since traditional automatic stabilisers lose their effectiveness in a polycrisis (erosion of the β parameter), a reorientation of fiscal policy is necessary. Firstly, instead of general consumption transfers, targeted support for energy-intensive regions should become a priority. Secondly, stabilisation

should be based more on building structural resilience (e.g. through investments in energy transition) than on smoothing demand. Finally, the weakening responsiveness of national systems suggests a need for greater fiscal flexibility at the NUTS-2 level, which would allow for a faster, territorial response to supply shocks. It would also be justified to develop real-time GDP gap monitoring systems at the regional level, which would allow for intervention before permanent ‘scarring’ of local labour markets and the industrial base occurs.

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SPATIAL DIVERSITY OF ENVIRONMENTAL INVESTMENTS IN POLISH REGIONS

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Purpose: The aim of this article is to present the spatial differentiation of environmental investments across Polish counties. Furthermore, the study grouped the surveyed units based on the results of implemented environmental investments.

Methodology: This study presents the scope of environmental investments based on 20 indicators derived from public statistical data from the Local Data Bank of the Central Statistical Office. The indicators included in the study cover five areas: waste management, wastewater management, pollution reduction and resource consumption, biodiversity, and the tangible effects of investments. The scope of environmental investments was presented based on a synthetic measure showing the taxonomic distance of a given district from the established development pattern.

Findings: The research presented the spatial diversity of environmental investments in 380 counties in Poland. The results of the study are presented by voivodeship. The surveyed counties were grouped based on the synthetic indicator, its mean value and standard deviation.

Originality/value: This article presents the results of extensive research conducted on a group of 380 entities, based on 20 indicators that uniquely illustrate the environmental orientation of investments in Polish counties. The study results can serve as a source of inspiration for EU institutions in formulating environmental strategies covering the entire European Union.

Keywords: environmental investments, counties, distance from the pattern, Hellwig reduction, grouping.

Category of the paper: Research paper.

1. Introduction

In the face of ongoing climate change, environmental degradation, and growing regulatory requirements for environmental protection, environmental investments are playing an increasingly important role in the development policies of European Union member states, including Poland. These activities constitute a key element in implementing the concept of sustainable development, combining ecological goals with economic development and improving the quality of life of society (Tukker, 2004). Contemporary conditions for socio-

economic development are increasingly determined by the need to reduce the negative impact of human activity on the natural environment (Yang, 2023). Consequently, environmental investments constitute a key instrument for implementing environmental protection policy and the principles of sustainable development, both at the level of the European Union and individual member states (Tietenberg, Lewis, 2023).

In Poland, environmental investments encompass a wide range of projects, such as the development of renewable energy sources, modernization of water and sewage infrastructure, improvement of energy efficiency, waste management, and protection of biodiversity. The implementation of these activities is supported by both national funds and European Union funds, which have long been a significant source of financing for ecological transformation. Despite the growing importance of environmental initiatives, a research gap has been identified in the literature regarding the importance of environmental investments in local development. To fill this gap, the author of this study decided to analyze the spatial diversity of environmental investments across Polish counties.

This paper will present the spatial differentiation of environmental investments across all 380 counties in Poland, based on 20 indicators. The basis for calculating the indicators will be statistical data for the period 2015-2024 from the Local Data Bank of the Central Statistical Office. The scope of environmental investments in individual counties will be presented based on a synthetic measure representing the taxonomic distance of a given county from an established investment scope benchmark. This paper aims to test the hypothesis that highly industrialized counties with high economic potential lead in environmental investments, while less environmental investments are implemented in regions with a lower degree of industrialization and urbanization.

The main goal of this study is to identify and assess the spatial diversity of environmental investments across Poland's counties. The adopted analysis scale (NUTS-4) captures local specificities, which often remain invisible in analyses with a higher level of aggregation (voivodeship). Achieving the main goal required a multidimensional comparative analysis based on a set of 20 partial indicators reflecting key components of environmental protection, including water and sewage management, air and climate protection, and waste management.

To eliminate the influence of the size of the studied units, raw statistical data from the Central Statistical Office's Local Data Bank were subjected to a relativization procedure (by relating them to the number of inhabitants or the area of the unit). The next stage of the research involved the application of taxonomic methods, including grouping procedures, which allowed the identification of types of counties with similar investment profiles. This approach allows not only for a description of the actual state of affairs but also for verification of whether clusters (agglomerations) of units with similar levels of pro-ecological activity exist in the Polish geographic space, which is associated in the literature with the neighbourhood effect and the diffusion of good practices (Churski et al., 2021).

This article will first review the literature on the scope and importance of environmental investments. Next, the research methodology will be described, along with a description of each stage of the research procedure. The obtained results will then be discussed in detail. Finally, the final section will outline conclusions and recommendations regarding the spatial differentiation of environmental investments across Polish counties.

The scientific contribution of this article consists in: developing a multi-criteria ranking of poviats based on an original set of 20 indicators, identifying spatial investment clusters using taxonomic methods, and verifying the hypothesis of progressive spatial polarization between industrial growth centres and peripheral areas in terms of environmental infrastructure.

2. The importance and scope of environmental investments – Literature Review

Environmental investments constitute a key analytical category in contemporary research on sustainable development and environmental economics. Their importance is growing with the increasing anthropogenic pressure on the natural environment and the increasing internalization of environmental costs in the decision-making processes of public and private entities. Despite widespread research interest, the concept of environmental investments lacks a single, universally accepted definition, reflecting the interdisciplinary nature of the subject and the evolution of theoretical approaches to environmental protection (Fiedor, 2010; Ocko, Hamburg, 2022).

In the classical approach to environmental economics, environmental investments are defined as long-term capital expenditures incurred to limit environmental degradation, reduce pollution, or restore the quality of natural resources to a socially acceptable level (Pearce, Turner, 1990; Anderson, 2024). These authors point out that environmental investments are a response to market failure in the allocation of environmental goods, the value of which is not fully reflected in the pricing mechanism, and their implementation favors the internalization of negative externalities.

The literature on the subject emphasizes the technological dimension of environmental investments. For a long time, *end-of-pipe* investments dominated, involving the installation of emission-reducing devices at the final stage of the production process (OECD, 2000). However, with the development of cleaner production and eco-innovation concepts, integrated investments encompassing technological, organizational, and product changes that lead to reduced environmental pressures at the source are gaining increasing importance (van den Bergh, 2013; Rulli, Saviori, D'Odorico, 2013).

The specificity of environmental investments lies in their limited ability to generate direct financial benefits, while simultaneously generating high potential for social and ecological benefits (Żylicz, 2004; Song, Zou, Liang, 2023). These benefits often constitute public or common goods, justifying government intervention. As Stiglitz (2000) emphasizes, without appropriate public policy instruments, the level of private environmental investments remains below the socially optimal level. Consequently, their effectiveness is assessed using extended analytical methods, particularly cost-benefit analysis that takes into account non-market effects.

The importance of environmental investments extends beyond immediate ecological goals and also encompasses macroeconomic aspects. These investments contribute to reducing the social costs of environmental degradation, such as health costs, loss of natural capital, and reduced labor productivity (Stern, 2007). Failure to invest in this area leads to the accumulation of so-called ecological debt, which in the long term may limit the development potential of the economy (Fiedor, 2002; Rogall, 2010).

The scope of environmental investments is broad and encompasses both infrastructure and intangible assets. The most common investments include those aimed at air protection, water and sewage management, waste management, soil protection, and biodiversity protection, as well as investments related to climate change mitigation and adaptation (GUS, 2023). Investments in environmental management systems, research and development of green technologies, and the development of environmental competencies are also playing an increasingly important role (OECD, 2009).

Recent literature also analyzes environmental investments in the context of economic competitiveness and innovation. According to Porter's hypothesis, appropriately designed environmental regulations and accompanying investments can stimulate innovation and lead to increased business efficiency (Porter, van der Linde, 1995). In this perspective, environmental investments are an important element in transforming the economy towards a low-emission and resource-efficient model (OECD, 2011; European Commission, 2019; Bhuiyan, Huang, de Villiers, 2021).

Local governments play a crucial role in implementing environmental investments, as they operate at a level that directly impacts residents' living conditions and the state of local environmental resources. The literature emphasizes that the scope of environmental investments undertaken by local government units is closely linked to their statutory competences and responsibility for providing environmental public services (Wang, Tian, Zheng, 2025). These investments primarily focus on the development and modernization of municipal infrastructure, including water and sewage management systems, waste management, and air quality, which constitute the primary areas of local government influence (Hamel, Tan, 2022).

Another significant area of local government investment activity is projects aimed at improving energy efficiency and reducing pollutant and greenhouse gas emissions. These include, among others, thermal modernization of public buildings, modernization of

heating systems, development of renewable energy sources, and investments in sustainable public transport (OECD, 2011; Central Statistical Office, 2023). Local governments are also increasingly engaging in climate change adaptation initiatives, such as investments in green and blue infrastructure, stormwater retention, and protection of green areas (Manero, Mach, 2023).

The scope of environmental investments implemented by local governments also encompasses planning and organizational activities, including the development and implementation of local environmental strategies, low-emission economy plans, and environmental monitoring systems. Although these investments are often intangible, the literature indicates that they play a key role in ensuring the coherence and effectiveness of local environmental policy and in increasing the absorption capacity of external funds allocated for environmental purposes (Fiedor, 2010; Rogall, 2010).

Contemporary economic analysis redefines the role of environmental investments, embedding them within the paradigm of sustainable development. In this approach, natural capital is not treated solely as an exploitable resource, but as a key determinant of exogenous and endogenous growth processes (Pearce, Turner, 1990). Investments in ecological infrastructure (e.g., water and sewage management or renewable energy sources) constitute a significant element in shaping the investment and settlement attractiveness of regions. According to the *Environmental Kuznets Curve (EKC)*, initial economic growth generates pressure on the environment, but after reaching a certain level of prosperity (a tipping point), pro-ecological investments become a condition for further economic expansion (Grossman, Krueger, 1995; Domański, 2005).

From the perspective of local development, environmental protection expenditures act as a stimulant for regional innovation. According to Porter's hypothesis, rigorous environmental standards and the resulting investments in modern technologies (so-called *eco-innovations*) may force enterprises to improve resource efficiency, which in the long term builds the competitive advantage of territorial units (Porter, van der Linde, 1995). In Poland, researchers emphasize that the spatial differentiation of these investments is closely correlated with the availability of European Union structural funds, which constitute the main development stimulus for peripheral regions, enabling them to converge with more urbanized areas (Guzal-Dec, 2020).

Furthermore, environmental investments should be interpreted through the lens of public goods theory and their impact on quality of life. Improving air quality or reclaiming degraded areas increases land rents and attracts human capital, which is crucial in building regional resilience to demographic crises (Stanny, Czarnecki, 2011). Lack of appropriate investment in this area leads to the accumulation of negative externalities, which is identified in the literature as a barrier limiting the development potential of so-called "lagging regions" (Wojewódzka-Król, 2015).

Empirical analyses of the diversity of environmental protection expenditures in Poland indicate a persistent disproportion between the regions of Western Poland and the so-called Eastern Wall. Research by Rosik et al. (2015) demonstrates that the proximity of foreign markets and innovation centers determines the higher dynamics of pro-ecological investments in voivodeships such as Greater Poland and Lower Silesia. Piontek (2020), in turn, points out that in regions with an industrial profile (Silesia), investments are reactive (remedial), while in tourist regions (Warmia-Masuria), they are proactive, focused on protecting landscape values.

Previous empirical studies on the diversity of environmental protection expenditures in Poland have focused mainly on analyzing the correlation between the size of investments and the level of economic development measured by GDP (Mickiewicz et al., 2021) or on assessing the efficiency of absorption of funds from structural funds (Klepacki et al., 2021). However, most available studies are based on data aggregated to the national or regional level (NUTS-2), which often obscures significant intra-voivodeship differences and local conditions specific to smaller territorial units.

This study fills an identified research gap in two respects:

- **Timeliness:** While existing literature largely focuses on the 2014-2020 financial perspective, this article analyzes investment dynamics in the post-pandemic period, taking into account new challenges arising from the energy crisis and the acceleration of the digital and green transformation.
- **Multidimensional approach:** Unlike studies focusing on a single component (e.g., wastewater management alone), this study compares various investment categories, allowing for the identification of regional pro-ecological specializations.

The lack of broad, comparable research in this context justifies addressing this issue and allows for the formulation of new recommendations for environmental investments.

In summary, the analysis of the definition, significance, and scope of environmental investments indicates their complex and multidimensional nature. In the literature, these investments are viewed not only as an instrument for environmental protection but also as a crucial element of modern development policy, integrating economic, ecological, and social goals. The lack of a uniform definition of environmental investments reflects the interdisciplinary nature of this category and the evolution of theoretical approaches—from classical environmental economics, through institutional approaches, to contemporary concepts of green growth and sustainable finance.

3. Characteristics of the research procedure – Methodology

To examine the spatial diversity of environmental investments across Polish counties, a synthetic measure of distance from the benchmark was used (Spychała, 2023). The research procedure consisted of four successive stages:

1. variable selection – construction of a geographic information matrix,
2. reduction of the multi-feature space,
3. determination of the results of environmental investments using the synthetic measure of distance from the benchmark,
4. classification of counties into four groups: based on the standard deviation and the mean value of the synthetic measure.

In the first stage of the research procedure, a geographic information matrix was constructed based on 20 indicators (Table 1), which were used to determine the scope of environmental investments in the counties. The indicators included in the study concern the results of environmental investments achieved cumulatively up to and including 2024 and concern five areas: waste management, sewage management, pollution reduction and resource consumption, biodiversity, and the tangible effects of the investments (Table 1). After determining the matrix, Pearson linear correlation coefficients were calculated between all the studied output indicators. It is crucial that the indicators selected for the synthetic measure of distance from the benchmark are weakly correlated with each other. This increases the information capacity of these indicators.

Table 1.

Indicators included in the analysis of the scope of environmental investments

Scope of the study	Indicators
Waste management (3 variables)	selectively collected waste in relation to total waste; share of waste subject to recovery; maintaining order and cleanliness - number of waste bins per 100 inhabitants.
Wastewater management (4 variables)	percentage of the population using sewage treatment plants; sewage treatment plants with increased nutrient removal as a percentage of the population; pollutant loads in sewage discharged into waters or into the ground per 1000 inhabitants; length of the sewage disposal network (in km per 1000 inhabitants).
Reducing pollution and resource consumption (4 variables)	asbestos-containing products remaining to be disposed of in relation to the total inventoried volume of asbestos-containing products (destimulant); water consumption per capita (destimulant); electricity consumption per capita (destimulant); capacity of installed devices and installations to reduce dust and gaseous air pollution (in tonnes per year per 1000 inhabitants).
Biodiversity (3 variables)	planting of trees and shrubs per 1 km ² of area; share of legally protected areas in the total area; afforestation in ha per 1000 inhabitants.
Material effects of environmental investments (6 variables)	bicycle paths per 100 km ² ; number of apartments in which heat sources were replaced per 1000 inhabitants; investment outlays in enterprises per 1 inhabitant; length of flood embankments (in km per 1000 inhabitants); daily capacity of water treatment plants (in m ³ per 1000 inhabitants); share of residential buildings for which the primary energy indicator EP was demonstrated as part of the energy performance of buildings.

Source: own research.

The created matrices of Pearson's linear correlation coefficients were the basis for reducing the output variables using Z. Hellwig's method – that is, for extracting diagnostic features – those indicators that will be included in the subsequent research procedure (Miłek, 2018). In Z. Hellwig's feature reduction method, the diagnostic feature is the indicator whose sum of the absolute values of the correlation coefficients with the remaining features is the highest (it is then called the central feature). Then, variables for which the value of the correlation coefficient with the diagnostic feature is higher than the critical value determined based on the following formula are eliminated (Neumayer, 2000):

$$r^* = \sqrt{\frac{(t^*)^2}{n-2+(t^*)^2}} \quad (1)$$

where:

r^* – critical value of the Pearson linear correlation coefficient,

t^* – value of Student's t-statistic,

n – number of output variables.

As a result of implementing this method, variables that are statistically significantly correlated with the diagnostic feature (called satellite features) are eliminated. In each subsequent step, the correlation matrix is reduced by the central feature and the satellite features. The Z. Hellwig method is repeated, obtaining new reduced correlation matrices, until the set of features is exhausted or isolated features are identified (Tester, Langridge, 2010).

In the next step of the research process, the pattern and anti-pattern of environmental investment scope were determined. The maximum standardized values of individual diagnostic features were considered the pattern, while their minimum values were considered the anti-pattern (Spychala, 2023). In the next step, the taxonomic distance of each studied county from the environmental investment pattern was determined based on the following formula (Cheng, Feng, 2023):

$$d_{i0} = \sqrt{\sum_{j=1}^m (z_{ij} - z_{0j})^2} \quad (2)$$

where:

d_{i0} – taxonomic distance of the district and from the adopted investment scope pattern,

z_{ij} – standardized value of indicator j for district I ,

z_{0j} – standardized value of the j indicator for the investment scope pattern.

In the next stage of the research procedure, a synthetic measure was determined for each district, which was an indicator of the scope of environmental investments in a given unit. The synthetic measure was calculated based on the following formula (Neumayer, 2000):

$$v_i = 1 - \frac{d_{i0}}{d_0} \quad (3)$$

where:

v_i – a synthetic measure of the scope of environmental investments in the district I,

d_{i0} – taxonomic distance of the district and from the adopted investment pattern,

d_0 – taxonomic distance of the pattern from the anti-pattern of investments.

The synthetic index of environmental investment scope ranges from 0 to 1, with the higher the value, the higher the level of the phenomenon being studied. Based on the calculated synthetic indices, a ranking of 380 counties was established and then divided into four groups: very high (counties with the highest synthetic index value, exceeding the average value of the synthetic measure calculated for all counties plus the standard deviation – Group I), high (counties next in the ranking whose index value exceeded the average – Group II), average (counties whose synthetic index value was below the average – Group III), and low (counties whose synthetic index value was below the average minus the standard deviation – Group IV) in environmental investment scope.

4. Results of the conducted research procedure

The research procedure presented the spatial diversity of environmental investments in Poland across 380 counties (Figure 1). In the studied group of units, the value of the synthetic measure representing the scope of environmental investments ranged from 0.121 to 0.336, with the lowest value recorded in Lubin County and the highest in Racibórz County (Table 2).

Racibórz County has become a leader in implementing environmental investments primarily because it has consistently, and for many years, implemented large-scale initiatives that combine environmental protection with the safety of its residents and economic development. A prime example is the Racibórz Dolny dry flood control reservoir – one of the largest hydrotechnical investments in Poland, protecting not only the county but the entire Oder River basin from flooding. Thanks to this investment, the county has become a model for adapting to extreme weather events. Additionally, a wind farm project with a capacity of over 40 MW is underway in Racibórz County, which will contribute to reducing CO₂ emissions and improving air quality. Furthermore, Racibórz County is very successful in securing EU funds for environmental investments. The county does not focus on a single area, but rather works in a multifaceted manner: improving air quality (through the replacement of heat sources and anti-smog measures), protecting nature and biodiversity (Łęczczok nature reserve), and implementing investments in sustainable transport and water management. This shows long-term thinking, not single, “point” investments.

Scope of environmental investments in Polish counties (synthetic index value)

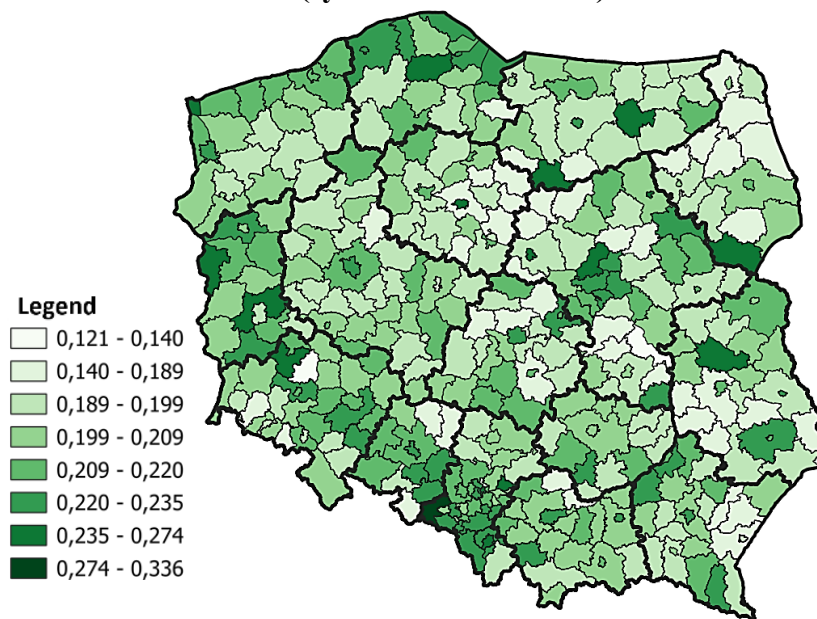


Figure 1. Spatial diversity of environmental investments in the district system.

Source: own research.

Płock's high ranking stems from its consistently implemented, long-term environmental policy, which combines environmental protection with economic development and improved quality of life for its residents. The city's initiatives are characterized by a comprehensive approach and the effective use of modern technological and financial solutions. A significant factor influencing Płock's position is the development of investments related to energy transition. The presence of large-scale industry, particularly the petrochemical sector, promotes the implementation of innovative technologies that reduce pollutant emissions and increase energy efficiency. These initiatives are consistent with sustainable development and climate policy. Investments in water and sewage management and the waste management system are also important areas. Modernization of technical infrastructure, development of selective waste collection, and protection of water resources, including the Vistula River ecosystem, contribute to improving the natural environment and the city's ecological safety.

Polkowice County's high ranking, in turn, may be the result of its consistent implementation of a sustainable development policy, based on leveraging the region's economic potential and effectively implementing modern pro-ecological solutions. Cooperation between local government and the industrial sector, as well as long-term strategic planning, are crucial here. One of the most important factors influencing Polkowice County's position is the presence of a strong industrial base. While the mining and processing industries generate significant environmental burdens, they also facilitate the implementation of advanced investments that mitigate negative environmental impacts. These include, among other things, the modernization of industrial facilities, the remediation of degraded land, and the implementation of technologies that reduce pollutant emissions into the air, water, and soil. Investments in water

and sewage management and the protection of water resources are also important areas of activity. Modernization of sewage treatment plants, expansion of the sewer network, and efforts to promote rational water management contribute to improving the natural environment and the region's ecological safety.

Table 2.

Counties with the highest and lowest synthetic index values

The highest and lowest values of the synthetic index					
MAX			MIN		
Place	County	Value	Place	County	Value
1	raciborski	0.336	380	lubiński	0.121
2	Płock	0.274	379	koziński	0.140
3	polkowicki	0.260	378	brodnicki	0.175
4	mragowski	0.255	377	rypiński	0.176
5	Bielsko-Biała	0.255	376	moniecki	0.176
6	Dąbrowa Górnicza	0.252	375	krasnostawski	0.176
7	siemiatycki	0.252	374	żuromiński	0.177
8	ślubicki	0.250	373	pultuski	0.177
9	nowodworski	0.249	372	kolneński	0.177
10	zielonogórski	0.249	371	suwalski	0.178

Source: own research.

The detailed results of the study are presented in Table 3. It lists three counties with the highest synthetic index values and three counties with the lowest index values in each voivodeship. Large cities are relatively common among the counties with the highest index values. They have specific organizational, financial, and functional conditions that favor the implementation of costly and complex pro-environmental projects. Above all, large cities are characterized by greater financial capacity. Higher revenues enable the co-financing of environmental investments, which often require significant own contributions. This allows these cities to more effectively utilize EU and national funds. Another factor is the scale and concentration of environmental problems. Large urban centers experience higher traffic congestion, higher pollutant emissions, and greater demand for water, energy, and waste management systems. This necessitates intensive investment activities that simultaneously deliver significant and measurable environmental benefits. Better institutional and human resources also play a significant role. Large cities have specialized organizational units and staff experienced in planning, implementing, and settling environmental projects. This facilitates the preparation of documentation and the effective implementation of large-scale investments. Furthermore, large cities often serve as centers of innovation and technological development. Collaboration with universities, research institutes, and the private sector fosters the implementation of modern solutions in energy, transport, and water and sewage management, further strengthening their position as leaders in environmental protection.

Table 3.*Counties with the highest and lowest synthetic index values in the voivodeships*

Voivodeship	Counties with the highest index value			Counties with the lowest index value		
	1	2	3	1	2	3
Dolnośląskie	polkowicki	wrocławski	strzebiński	lubiniński	kamiennog.	lwówecki
Kujawsko-pomorskie	Toruń	Bydgoszcz	tucholski	brodnicki	rypiński	toruński
Lubelskie	lubartowski	zamojski	Chełm	krasnostawski	hrubieszowski	kraśnicki
Lubuskie	ślubicki	zielonogórski	gorzowski	Zielona Góra	wschowski	żarski
Łódzkie	Łódź	skierniewicki	Piotrków T.	piotrkowski	poddębicki	łowicki
Małopolskie	Kraków	Tarnów	suski	miechowski	proszowicki	nowotarski
Mazowieckie	Płock	nowodworski	Ostrołęka	kozienicki	żuromiński	pułtowski
Opolskie	kędzierz.-koz.	krapkowicki	strzelecki	oleski	kluczborski	głubczycki
Podkarpackie	Rzeszów	leski	mielecki	jarosławski	przemyski	przeworski
Podlaskie	siemiatycki	Białystok	Suwałki	moniecki	kolneński	suwalski
Pomorskie	kartuski	Słupsk	Gdańsk	sztumski	bytowski	człuchowski
Śląskie	raciborski	Bielsko-Biała	Dąbrowa G.	zawierciański	lubliniecki	kłobucki
Świętokrzyskie	pińczowski	jędrzejowski	staszowski	ostrowiecki	włoszczowski	opatowski
Warmińsko-mazurskie	mragowski	działdowski	Olsztyn	nidzicki	nowomiejski	kętrzyński
Wielkopolskie	Poznań	poznański	śłupecki	wągrowiecki	Konin	grodziski
Zachodnio-pomorskie	Świnoujście	Szczecin	kamieński	pyrzycki	drawski	łobeski

Source: own research.

It is also worth noting the extreme values of the synthetic index in individual voivodeships (Table 4). The highest average value of the synthetic index was recorded in the counties of the Silesian Voivodeship, while the lowest was recorded in the counties of the Podlaskie Voivodeship. This can be explained by differences in economic structure, the degree of urbanization, environmental pressures, and the financial capacity of local governments. Above all, the Silesian Voivodeship is one of the most industrialized and urbanized regions in Poland. It has a high population concentration, developed heavy industry, and a dense network of technical infrastructure. Many years of industrial activity have resulted in numerous environmental problems, such as air pollution, soil degradation, and high greenhouse gas emissions. This necessitates the implementation of costly and advanced environmental investments, including those related to improving air quality, reclaiming brownfield sites, waste management, and modernizing energy systems. The high financial and institutional potential of the counties in the Silesian Voivodeship is also a significant factor. The Podlaskie Voivodeship, on the other hand, is characterized by a lower degree of urbanization and industrialization. It is a region dominated by agriculture and natural resources, with a large share of protected areas such as national parks and nature reserves. Environmental pressure is significantly lower there, limiting the need for large, costly technical investments. Considering the above, it can be concluded that the hypothesis posed in the introduction of this article has been positively verified.

Table 4.

Average, lowest and highest values of synthetic indicators by voivodeship along with the classification structure of counties

Voivodeship	synthetic indicator			Classification structure of counties			
	average value	minimum value	maximum value	I group	II group	III group	IV group
Dolnośląskie	0.205	0.121	0.260	13.3%	36.7%	40.0%	10.0%
Kujawsko-pomorskie	0.198	0.175	0.237	4.3%	30.4%	39.1%	26.1%
Lubelskie	0.201	0.176	0.239	8.3%	25.0%	41.7%	25.0%
Lubuskie	0.215	0.193	0.250	28.6%	35.7%	35.7%	0.0%
Łódzkie	0.201	0.182	0.221	0.0%	33.3%	50.0%	16.7%
Małopolskie	0.206	0.179	0.226	13.6%	27.3%	50.0%	9.1%
Mazowieckie	0.204	0.140	0.274	19.0%	28.6%	28.6%	23.8%
Opolskie	0.209	0.184	0.231	25.0%	41.7%	16.7%	16.7%
Podkarpackie	0.203	0.184	0.225	4.0%	36.0%	48.0%	12.0%
Podlaskie	0.196	0.176	0.252	5.9%	17.6%	35.3%	41.2%
Pomorskie	0.212	0.187	0.248	30.0%	30.0%	35.0%	5.0%
Śląskie	0.220	0.194	0.336	30.6%	41.7%	27.8%	0.0%
Świętokrzyskie	0.203	0.191	0.229	7.1%	28.6%	64.3%	0.0%
Warmińsko-mazurskie	0.205	0.186	0.255	14.3%	9.5%	71.4%	4.8%
Wielkopolskie	0.202	0.185	0.225	2.9%	28.6%	65.7%	2.9%
Zachodniopomorskie	0.208	0.192	0.239	4.8%	52.4%	42.9%	0.0%
Total	0.206	0.121	0.336	13.2%	31.6%	43.2%	12.1%

Source: own research.

Based on the data presented in Table 4, it can also be concluded that the Świętokrzyskie Voivodeship is the most homogeneous in terms of the scope of environmental investments, with the smallest difference between the maximum and minimum values of the synthetic indicator. In contrast, the greatest diversity in the scope of environmental investments was observed in the Silesian Voivodeship, where the leader in environmental investments (Racibórz County) is located, as well as in the Zawiercie and Lubliniec counties, where the scale of environmental investments is much smaller.

In the final stage of the study, the counties were classified based on the synthetic index value of each county relative to the mean value of the entire group (0.206) and the standard deviation (0.018). The results of this grouping are presented in Table 4 and Figure 2.

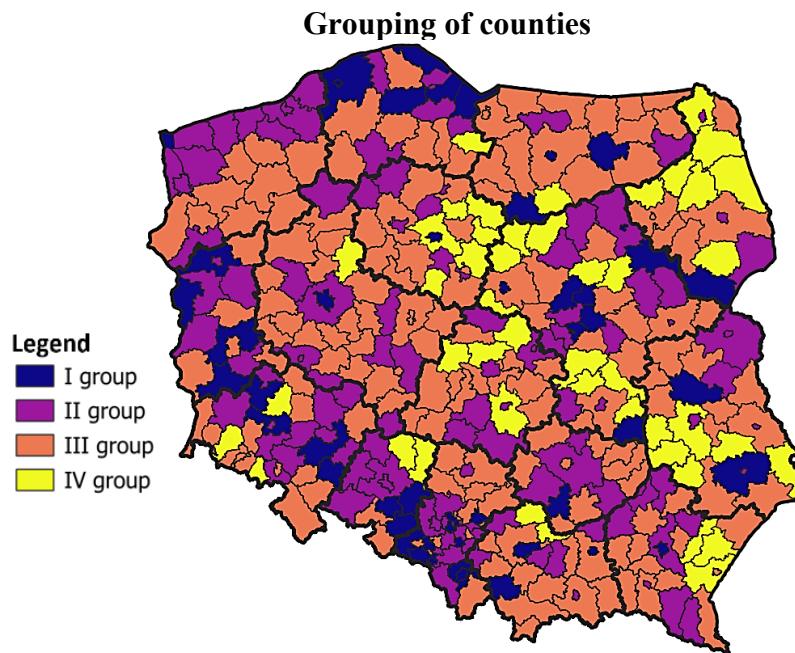


Figure 2. Grouping of counties based on the value of the synthetic index.

Source: own research.

Counties with the highest synthetic index values, classified as Groups I and II, are mostly located in southwestern, western, and northern Poland. These areas are characterized by a specific set of economic, historical, demographic, and environmental conditions that favor the implementation of extensive pro-ecological initiatives. Above all, these regions are among the most industrialized and urbanized parts of the country, where heavy industry, the energy sector, and transportation have been developing for decades. Long-term anthropogenic pressures have led to environmental degradation, necessitating comprehensive and costly investments in air protection, post-industrial land reclamation, waste management, and energy transformation. Historical and structural conditions are another factor. Western and northern Poland have a well-developed technical infrastructure, inherited and modernized from the post-war period, facilitating the implementation of modern environmental solutions. Natural and spatial factors are also significant. In northern Poland, investments related to marine and inland water protection, water and wastewater management, and adaptation to climate change, including flood protection and counteracting the effects of rising sea levels, are of significant importance. In the southwestern part of the country, investments related to protection against floods and the effects of mining activities are crucial.

In turn, the counties with the lowest synthetic index values, classified in group IV, are located primarily in central, northeastern, and southeastern Poland. These areas are characterized primarily by lower levels of urbanization and industrialization. Agricultural and natural functions dominate there, and anthropogenic pressure on the environment is significantly lower than in highly industrialized regions. Consequently, there is no urgent need for large-scale infrastructure investments, such as the reclamation of post-industrial areas or the modernization of advanced air protection systems. Another significant factor is the limited

financial capacity of local governments. These counties typically have smaller budgets resulting from lower revenues and a weaker tax base. This limits their ability to co-finance environmental projects, which often require significant own contributions. Another reason is the nature of the environmental activities undertaken. In northeastern and southeastern Poland, investments related to nature and landscape conservation predominate, including in national and landscape parks. These activities, while crucial for biodiversity conservation, typically do not generate significant financial outlays and are not considered large-scale infrastructure investments. Furthermore, the central part of the country has a dispersed settlement structure, which limits the profitability of large-scale infrastructure investments, such as extensive public transport systems or heating networks.

5. Discussion and Conclusions

The analysis of environmental investments in Poland indicates that they constitute a significant element of national development policy and a key tool for achieving environmental protection goals and the transition towards a low-emission economy. The scale and structure of investment activities confirm the growing importance of environmental issues in decision-making processes at both the national, regional, and local levels. At the same time, these investments demonstrate a clear connection to the legal and financial conditions resulting from Poland's membership in the European Union.

The positive verification of the hypothesis that highly industrialized counties dominate the structure of environmental investments confirms the existence of an ecological modernization mechanism in Poland, driven by the structure of the economy. The high ranking of units such as Płock County (refining industry), Polkowice County (mining industry), and Racibórz County (machinery and energy industry) indicates a direct relationship between endogenous economic potential and the propensity to incur pro-ecological expenditures. These results are consistent with the findings of Piontek (2020), who argued that in regions with high industrial concentration, environmental investments are a priority due to the need to mitigate negative externalities and stringent emission standards imposed by EU law.

The identified advantage of industrialized leaders over regions with a low degree of urbanization (the so-called "eastern wall" or agricultural regions) can be interpreted through the lens of economic base theory. Counties with a strong industrial base have higher revenues and a more stable tax base (property taxes, corporate income tax), which constitutes a necessary contribution to obtaining structural funds. As noted by Rosik et al. (2015), regions with high economic potential demonstrate higher institutional efficiency in absorbing earmarked funds. In this context, the lower scope of investment in less industrialized counties does not necessarily

result from a lack of need, but rather from a financial gap and a lack of economies of scale, which confirms the phenomenon of spatial polarization described by Churski et al. (2021).

It's also worth relating the obtained results to the concept of the Environmental Kuznets Curve. The fact that the wealthiest and most industrialized counties are implementing the greatest volume of investments suggests that these units have already passed a critical point where further economic growth must be integrated with the preservation of natural resources. This phenomenon, described in the international literature by Grossman and Krueger (1995), at the local scale in Poland takes the form of "ecological efficiency" clusters, where industrial capital paradoxically becomes the main financier of environmental improvements.

Based on the conducted analysis, several key conclusions can be drawn. First, environmental investments in Poland rely heavily on external financing sources, particularly EU funds, which favors the implementation of costly infrastructure projects, primarily by counties with strong economic potential, but also increases dependence on the fluctuating EU financial framework. Second, despite visible progress in the development of environmental protection infrastructure and renewable energy sources, the pace of investment implementation remains insufficient in the context of ambitious climate and environmental goals, especially in less industrialized regions. Third, institutional and procedural barriers remain a significant challenge, including the complexity of administrative processes and limited coordination between levels of public administration.

In light of the above conclusions, the following recommendations are justified. First and foremost, it is necessary to further strengthen national financing mechanisms for environmental investments to reduce excessive dependence on external funds and ensure greater sustainability of implemented projects. Furthermore, simplifying and streamlining administrative procedures is recommended, which could shorten investment implementation times and increase their efficiency. Intensifying activities supporting innovative technological solutions and developing the institutional competencies of entities responsible for implementing environmental projects is also crucial. Finally, it is essential to increase the coherence of sectoral policies and strengthen the role of long-term planning, which will allow for more effective targeting of environmental investments in Poland over the coming decades.

A significant aspect of analyzing environmental investments in Poland is their distinct spatial differentiation, visible at the level of individual counties. The scale and structure of implemented projects are largely determined by local socio-economic conditions, the level of technical infrastructure development, the availability of financial resources, and the institutional potential of local government units. As a result, significant disparities are observed between counties with high absorption capacity for investment funds and units struggling with financial and staffing constraints.

Counties with a higher level of economic development and greater experience in obtaining external funds, including European Union funds, are typically characterized by a higher intensity of environmental investments, especially in areas such as water and sewage

management, renewable energy sources, and improving energy efficiency. In peripheral and less developed counties, however, these investments are often localized and limited, which can lead to the perpetuation of spatial inequalities in environmental quality and access to modern infrastructure.

In light of the above observations, it is recommended to more closely consider the territorial dimension in the design and implementation of investment policies in the area of environmental protection. In line with the place-based approach promoted in the European Union's cohesion policy, it is reasonable to differentiate support instruments depending on the specificity and needs of individual counties. Particular attention should be paid to units with limited institutional potential by increasing the availability of advisory support, simplifying application procedures, and providing preferential financing conditions for environmental investments.

This study adds value to the literature by applying a multi-criteria approach (20 indicators) at a microregional (district) scale in the post-pandemic period. It demonstrates that the traditional approach to cohesion policy should better consider the specificity of industrial clusters as drivers of green transformation, while simultaneously strengthening support mechanisms for regions with lower income potential to prevent the phenomenon of "ecological exclusion". Although the analysis of 20 indicators provides a broad picture, future research should be expanded to include qualitative analysis (e.g., energy efficiency of achieved tangible effects) and incorporate flows of funds from the National Recovery Plan, which will allow for the assessment of the resilience of local environmental systems to external shocks.

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THE ROLE OF EUROPEAN GROUPINGS OF TERRITORIAL COOPERATION IN TRANSPORT DEVELOPMENT IN THE BALTIC SEA REGION

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Purpose: The purpose of the paper is to assess the role of European Groupings of Territorial Cooperation (EGTCs) in the development of transport in the Baltic Sea Region and to identify differences in the scope and character of their involvement in transport-related activities. The study seeks to determine whether EGTCs constitute an effective instrument for supporting territorial cooperation in transport at the macro-regional level and to indicate examples of more advanced engagement in this field

Design/methodology/approach: The research is based on a qualitative approach combining a review of the scientific literature with an analysis of European Union strategic, policy and programme documents. The study examines the EU Strategy for the Baltic Sea Region, selected European Territorial Cooperation programmes and statutory, organisational and project-related documents of EGTCs operating in the Baltic Sea Region. The analysis is complemented by a comparative review of selected EGTC case studies with a particular focus on transport-related objectives and activities.

Findings: The analysis shows that, despite the importance of transport within the EU Strategy for the Baltic Sea Region, the overall role of EGTCs in transport development remains limited. Only a small number of EGTCs operating in the Baltic Sea Region involve partners from more than one regional state, which constrains their capacity to support cooperation at the macro-regional scale. At the same time, the study identifies clear differentiation among EGTCs in terms of transport-related engagement. In this context, the Kvarken Council EGTC stands out as an example of a grouping that has implemented numerous cross-border transport projects and addressed not only accessibility and connectivity issues but also challenges related to the security and resilience of transport infrastructure in the current geopolitical context.

Research limitations/implications: A key limitation of the study is the lack of an in-depth analysis of the internal operating conditions of individual EGTCs and their formal and operational links with the EU Strategy for the Baltic Sea Region. Future research could focus on longitudinal analyses of EGTC activities, comparative studies across different macro-regions and a more detailed assessment of institutional and governance-related factors shaping EGTC performance in the transport sector.

Practical implications: The findings suggest that EGTCs may serve as a useful coordination framework for transport-related cooperation, particularly in cross-border contexts, provided that their activities are more strongly aligned with territorial cooperation programmes and macro-regional policy objectives. Strengthening the institutional role of EGTCs could enhance the effectiveness of transport initiatives in peripheral and border regions.

Social implications: Transport-related activities undertaken by EGTCs may contribute to improved accessibility of peripheral areas, enhanced territorial cohesion and greater resilience of transport systems, thereby positively affecting quality of life and regional development in the Baltic Sea Region.

Originality/value: The originality of the paper lies in its focused analysis of EGTCs as actors in transport development within a macro-regional framework and in highlighting the differentiated roles of individual groupings, with particular attention to the Kvarken Council EGTC as an example linking transport development with broader issues of cross-border cooperation and regional security.

Keywords: EGTC, Baltic Sea Region, territorial cooperation, transport.

Category of the paper: Research paper.

1. Introduction

Since its inception, the European Union has supported processes of international territorial cooperation (Toczyski, 1998; Svenson, 2015; Studzieniecki, Mazurek, 2018). Such cooperation, through the removal of border barriers, contributes to the democratisation of Europe, brings people closer together, creates platforms for mutual understanding, and helps to solve economic and social problems that transcend national borders (Kulesza, 2003). For many years, European legislation neither resolved nor defined the legal forms of territorial cooperation, recognising that these matters fell within the exclusive competence of the authorities of the Member States and lay beyond the law-making powers of the Community institutions (Studzieniecki, 2015).

The idea of territorial cooperation developed in Western Europe in the 1960s, alongside the activation of decentralisation processes that led to the growing autonomy of cross-border regions (Lechwar, 2008). Due to their peripheral location, such regions were often characterised by a low level of socio-economic development (Kasprzyk, 2004; Toczyski et al., 1998). They usually possessed less developed transport infrastructure, which stemmed from their position at the ends of communication routes (Gałuszka, 2010).

The developmental problems of border areas encouraged local and regional authorities to seek more effective systemic solutions and contributed to the growth of bottom-up international initiatives (Studzieniecki, 2015). There emerged a need to introduce new institutions and instruments that would improve the functioning of the existing Euroregions, which lacked sufficient legal status and could not directly access European Union funds (Lewkowicz, 2013; Kusiak-Winter, 2016; Perkowski, Zoń, 2017). The emergence of the European Grouping of Territorial Cooperation (EGTC) fundamentally changed this situation, creating new opportunities for the development of territorial cooperation, including cooperation in the field of transport. As the EGTC is still a relatively new instrument, the issue of its use in transport development remains underexplored. This also applies to the Baltic Sea Region (BSR),

where transport is one of the key factors of integration and development (Böhme et al., 1998; Friman et al., 2019; Studzieniecki, Palmowski, 2019). Although this is reflected in a rich body of academic literature, only a few studies address territorial cooperation in the field of transport within the BSR. Therefore, there is a need to fill this research gap by examining the use of EGTCs in territorial cooperation across the region.

2. Aims and methods

The main objective of this article is to determine whether European Groupings of Territorial Cooperation support the development of transport in the Baltic Sea Region, and if so, to what extent.

The completion of this main task required achieving two additional objectives:

1. To identify the attributes of the EGTC as an instrument of territorial cooperation capable of supporting transport development,
2. To identify the conditions of territorial cooperation in the field of transport in the BSR, with particular consideration of the EU Strategy for the Baltic Sea Region (EUSBSR).

For the purpose of the article, literature studies and analyses of secondary sources were carried out, including 15 programmes and 200 projects of European Territorial Cooperation (ETC) covering the EU programming period 2014-2020. Detailed analyses were conducted of documents and online resources of the EUSBSR and of existing European Groupings of Territorial Cooperation. The study also utilised the results of a statistical analysis of multidimensional territorial cooperation within the INTERREG Baltic Sea Region Programme 2014-2020, as well as information obtained from interviews conducted in 2023 with coordinators of the Thematic Areas “Transport” and “Shipping” operating within the EUSBSR framework.

3. Concept and development of European Groupings of Territorial Cooperation

The European Grouping of Territorial Cooperation (EGTC) is a multifaceted and multidimensional concept (Dołzbłasz, Raczyk, 2010; Kusiak-Winter, 2011; Kentnowska, 2012; Buczkowski, Żukowski, 2014; Adamczuk, 2014; Ruskowski, 2010; Lewkowicz, 2013; Jóskowiak, 2013). It is interpreted as an area of cooperation, an instrument of cooperation, a legal entity, and a participant in international relations. The regulations establishing the EGTC were introduced in 2006 (Regulation (EC) No 1082/2006). They revolutionised cross-border

cooperation (Kuligowski, 2012; Pancer-Cybulska, 2015) and accelerated the development of transnational and interregional cooperation (Salbach, 2022). The EGTC became a new actor in international relations, supporting European integration at regional and local levels (Studzieniecki, 2015).

The regulation establishing the EGTC was intended to be a legal act directly effective in all Member States, leaving them no discretion in the method of implementing the objectives of Community law (Grosse, 2011; Durand, Decoville, 2020). Nevertheless, due to the specific and sensitive nature of this form of international cooperation, a number of national provisions were adopted to complement the EU regulation. As a result, in many countries the establishment of an EGTC was made dependent on decisions of the central authorities (Studzieniecki, Mazurek, 2018).

The functioning of EGTCs is determined by a variety of factors, among which political, legal, and economic conditions at both EU and national levels play a crucial role (Fig. 1).

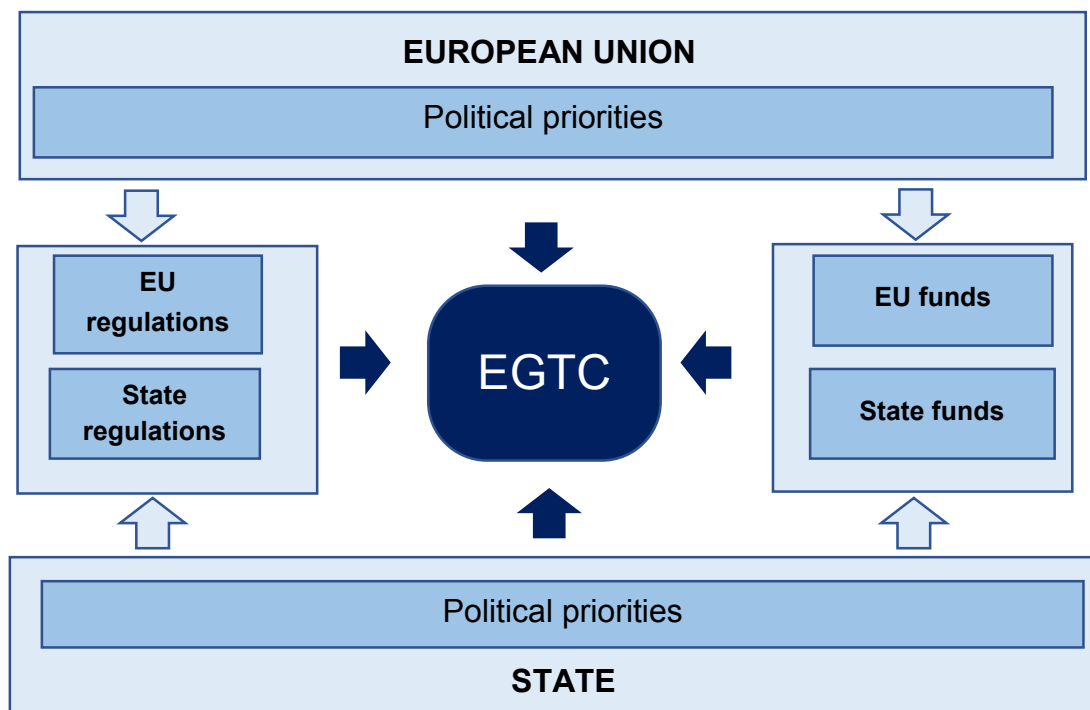


Figure 1. Determinants of the functioning of European Groups of Territorial Cooperation.

Source: own work.

The real conditions for the development, operation, and financing of EGTCs depend largely on the countries in which they operate (Studzieniecki, 2015). An EGTC operates within the scope of its assigned tasks, which involve facilitating and promoting territorial cooperation to enhance economic, social, and territorial cohesion and to overcome barriers within the internal market (Regulation (EU) No 1302/2013). The tasks of EGTCs primarily concern the implementation of cooperation programmes and operations supported by the European Union through the European Regional Development Fund (ERDF), the European Social Fund (ESF), or the Cohesion Fund (Fig. 2).

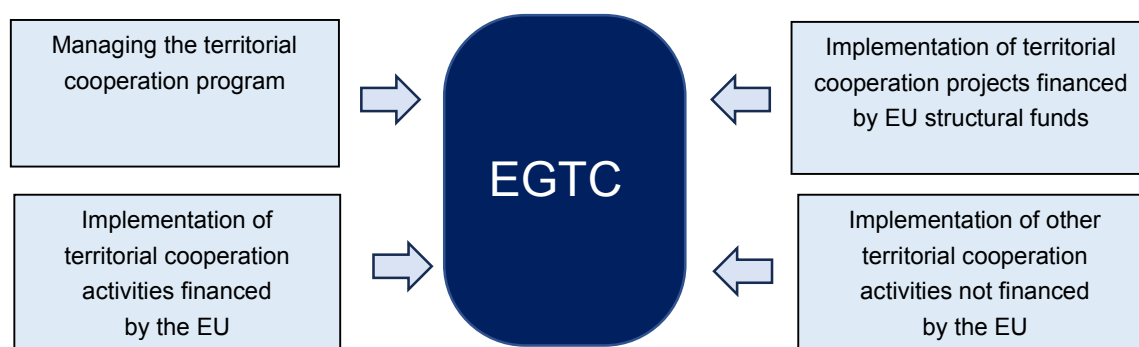


Figure 2. Tasks of European Groupings of Territorial Cooperation.

Source: own elaboration based on Regulation (EU) No 1302/2013.

Territorial cooperation is implemented in three dimensions (Fig. 3):

1. Cross-border cooperation, where entities from neighbouring border areas cooperate (e.g. Euroregions).
2. Interregional cooperation, where entities from different regions collaborate (e.g. associations of cities or regions).
3. Transnational cooperation, where cooperation covers larger areas, including entire countries (e.g. the Baltic Sea Region).

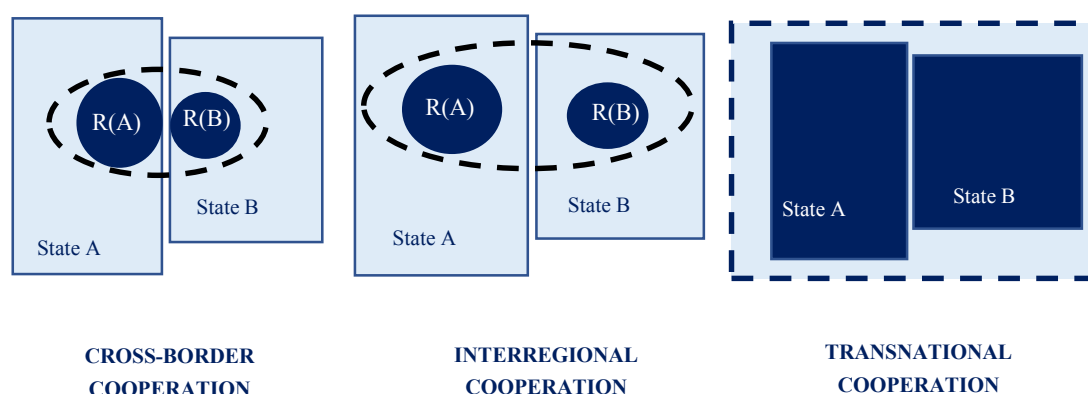


Figure 3. Dimensions of territorial cooperation.

Source: own elaboration.

Each form of cooperation is supported by dedicated European Territorial Cooperation (ETC) programmes (Table 1). During the 2014-2020 programming period, the EU allocated almost EUR 9 billion to ETC (Studzeniecki, Mazurek, 2018). The largest share (EUR 6.6 billion) was assigned to cross-border cooperation, while the smallest (EUR 0.5 billion) went to interregional cooperation. The objectives of ETC programmes proved to be highly diverse.

Table 1.
The objectives of ETC programmes

Types of cooperation	Objectives of cooperation
Cross-border cooperation	1. Solving common problems identified in border regions, such as poor accessibility (particularly concerning information and communication technologies – ICT – and transport infrastructure), declining local industries, inadequate business environments, lack of links between local and regional administrative levels, low levels of research and innovation and ICT use, environmental pollution, risk prevention, and negative attitudes towards neighbouring states' citizens. 2. Unlocking untapped growth potential in border areas (development of cross-border research infrastructure, innovation centres and clusters, integration of cross-border labour markets, cooperation between educational institutions including universities, or between healthcare institutions), while strengthening cooperation processes for the harmonious overall development of the Union.
Interregional cooperation	1. Interregional cooperation. Improving the effectiveness of cohesion policy by encouraging the exchange of experience between regions concerning thematic objectives and urban area development, including urban–rural linkages, in order to enhance the implementation of territorial cooperation programmes and related initiatives, and by supporting analyses of territorial cohesion trends through research, data collection, and other actions. 2. Exchanging experience concerning thematic objectives to improve the planning and implementation of operational programmes within the goal “Investment for Growth and Jobs” and, where appropriate, within the goal “European Territorial Cooperation”, while promoting mutually beneficial cooperation between innovative clusters with a high share of research institutions, as well as exchanges among researchers and research institutions in both developed and less developed regions, taking into account experiences from the “Regions of Knowledge” and “Research Potential” initiatives under the Seventh Framework Programme for Research.
Transnational cooperation	1. Strengthening cooperation through initiatives promoting integrated territorial development linked to the priorities of EU cohesion policy. 2. Developing maritime cross-border cooperation not covered by cross-border cooperation programmes.

Source: own elaboration based on Regulation (EU) No 1299/2013.

The members of EGTCs (Figure 4) are primarily national, regional, and local authorities. The legal framework also permits the participation of selected undertakings or public-law entities, as well as enterprises entrusted with the provision of specific services.

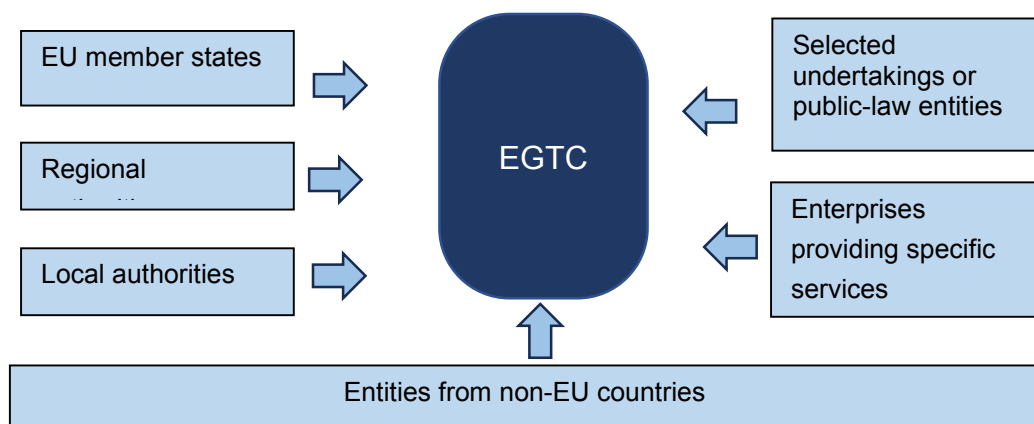


Figure 4. Types of EGTC members.

Source: own elaboration.

Since 2014, following an amendment to EU regulations, entities from non-EU countries have been allowed to join European Groupings of Territorial Cooperation (EGTCs). By 2025, total of 93 EGTCs had been established (European Committee of the Regions, 2023). However, two of them were dissolved; therefore, 91 EGTCs are currently in operation (Figure 5).

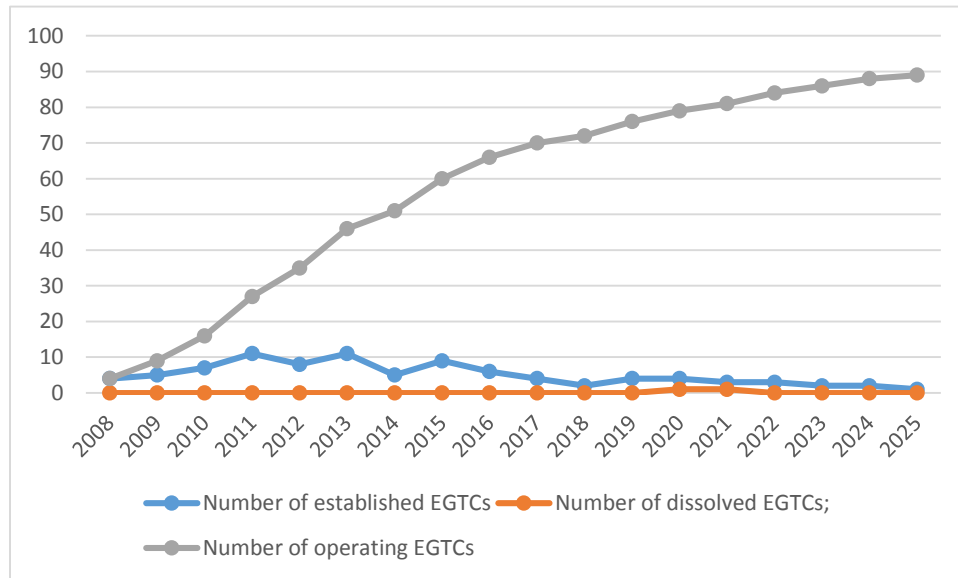


Figure 5. Development of EGTCs in Europe.

Source: own elaboration based on the European Committee of the Regions, 2025.

An analysis of EGTC statutes and conventions (Studzieniecki, 2015) indicates that tourism environmental protection, and transport are among the most frequent objectives of these institutions, with transport widely perceived as a key factor of socio-economic development. In this context, EGTC activities in the field of transport include infrastructure development, financing of transport projects, Intelligent Transport Systems (ITS), logistics and road maintenance services, rail transport, and integrated ticketing systems (Carvalho et al., 2018).

4. Transport within territorial cooperation in the Baltic Sea Region

Transport development in the Baltic Sea Region is financially supported by the European Structural and Investment Funds, in particular by the European Regional Development Fund, within the framework of European Territorial Cooperation implemented in three dimensions: cross-border, transnational, and interregional cooperation (Studzieniecki, 2015). During the 2014-2020 programming period, 15 ETC programmes operated in the region, including one interregional programme, one transnational programme, and thirteen cross-border programmes.

The interregional cooperation programme INTERREG Europe, although not directly focused on transport, indirectly supported the development of sustainable mobility through the exchange of good practices in transport policy, mobility planning, and the implementation of low-emission transport solutions (Interreg Europe, 2015).

A particularly important role in achieving transport-related objectives was played by the INTERREG Baltic Sea Region Programme, which was oriented towards the development of sustainable transport, improving the connectivity of secondary and tertiary networks with the TEN-T system, increasing the interoperability of transport systems, and enhancing the accessibility of peripheral areas affected by adverse demographic changes (Interreg Baltic Sea Region Programme 2014-2020, 2014). The specific objectives and corresponding actions of the programme are presented in Table 2.

Table 2.

Specific objectives of the main objective “Sustainable Transport” and the resulting actions in the Baltic Sea Region Programme 2014-2020

No.	Specific objective	Actions
1	Interoperability of transport modes	Increasing interoperability in freight and passenger transport along north–south and east–west connections through enhanced capacity of transport operators.
2	Accessibility of remote and demographically challenged areas	Improving accessibility of the most remote areas and regions affected by demographic change through increased capacity of transport operators.
3	Maritime safety	Enhancing safety and security at sea through advanced capacities of maritime operators.
4	Environmentally friendly shipping	Improving environmentally friendly shipping through increased capacity of entities operating in the maritime sector.
5	Environmentally friendly urban mobility	Strengthening environmentally friendly transport systems in urban areas through increased capacity of entities operating in urban transport.

Source: own elaboration based on the Interreg Baltic Sea Region Programme 2014-2020 (2014).

Transport-related issues were also addressed within cross-border cooperation programmes in the Baltic Sea Region; however, their inclusion was selective. Among the thirteen cross-border programmes implemented in the period 2014-2020, transport-related objectives and actions were included in nine programmes, with their scope varying depending on the characteristics of the area and the priorities of individual programmes (Studzieniecki, 2017). These programmes focused, inter alia, on the development of environmentally friendly mobility, the removal of infrastructure bottlenecks, and the improvement of cross-border accessibility.

As a result, territorial cooperation has become an important instrument for the implementation of the European Union Strategy for the Baltic Sea Region, in which transport is treated as a priority area (Studzieniecki, Przybyłowski, 2017). Transport-related issues are also reflected in the operational documents of the European Union Strategy for the Baltic Sea Region (SWD, 2013; SWD, 2021), which are presented in a synthetic and illustrative manner in Figure 6.

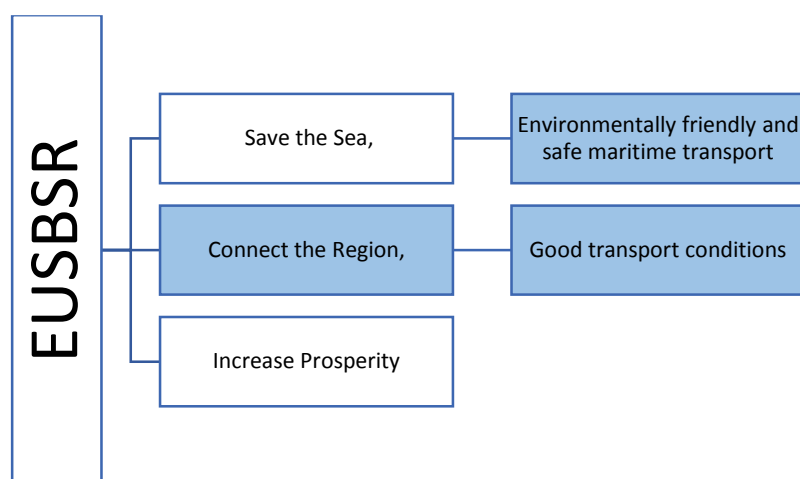


Figure 6. Transport in EUSBSR.

Source: own elaboration based on SWD (2013).

An important complement to these activities was the opportunity to disseminate good practices in transport planning and management through the INTERACT programme, which facilitated the exchange of experience among programmes and institutions involved in the implementation of macro-regional strategies (Ots, 2023).

5. Transport in the activities of European Groupings of Territorial Cooperation in the Baltic Sea Region

In the Baltic Sea Region, 21 European Groupings of Territorial Cooperation operate out of more than 90 EGTCs registered in the European Union. Their spatial distribution is uneven, with the largest number of groupings located in Germany, while only single EGTCs operate in Finland and Lithuania. No EGTCs currently function in Denmark, Estonia or Latvia. The spatial distribution of EGTCs in the Baltic Sea Region is illustrated in Figure 7, while their basic institutional characteristics are summarised in Table 3. From the perspective of macro-regional cooperation, only four EGTCs bring together members from at least two Baltic Sea Region countries, which determines their capacity to support cooperation beyond the local scale.

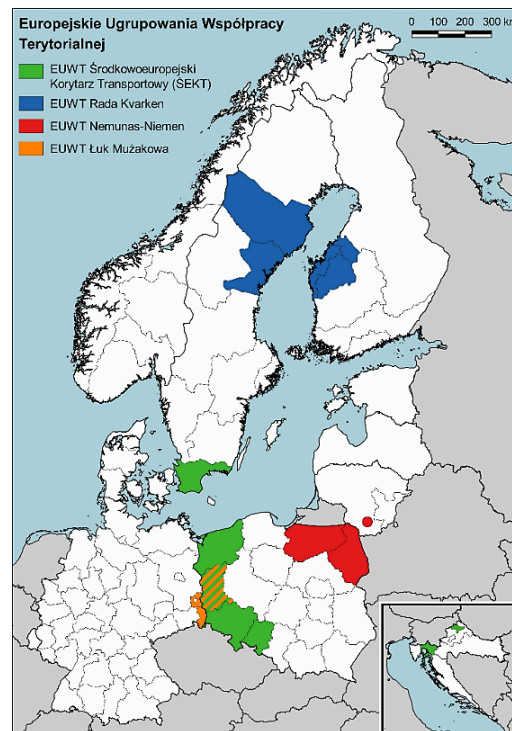


Figure 7. EGTCs involving at least two Baltic Sea Region countries.

Source: own elaboration.

The EGTCs operating in the Baltic Sea Region were established relatively recently, between 2014 and 2023, and are composed mainly of local and regional authorities or institutions established by them. The number of members ranges from two to sixteen, indicating significant differences in organisational scale and capacity. Their involvement in transport-related activities varies depending on territorial context, institutional objectives and links with European Territorial Cooperation programmes.

Table 3.
Characteristics of EGTCs operating in the Baltic Sea Region

EGTC	Year of establishment	Seat	Number of countries	Number of members	Member status	ETC programme management	Implementation of ETC projects
Kvarken Council	2020	Vaasa, Finland	2	16	Local and regional authorities	No	Yes
Polish–German Geopark Muskau Arch	2021	Klein Köllzig, Germany	2	14	Local and regional authorities	No	No
Central European Transport Corridor	2014	Szczecin, Poland	3	6	Regional authorities	No	Yes
Nemunas–Niemen	2023	Suwałki, Poland	2	2	Local authorities; association of local government units	No	No

Source: own elaboration based on EGTCs statutes.

It may be seen that the scope and nature of transport-related activities undertaken by individual groupings vary.

5.1. Polish–German Geopark Muskau Arch EGTC

The Polish–German Geopark Muskau Arch EGTC was established in 2021 to coordinate cross-border cooperation within the UNESCO Global Geopark Muskauer Faltenbogen / Łuk Mużakowa. Transport is not defined as a statutory objective of the grouping; however, due to the touristic character of the area, the EGTC is indirectly involved in transport-related activities. These include cooperation with regional public transport operators and local providers of tourist and recreational transport services, contributing to sustainable tourism development in the Polish–German border region.

5.2. Nemunas–Niemen EGTC

The Nemunas–Niemen EGTC, registered in 2023, builds on long-standing cross-border cooperation within the Euroregion Niemen. One of its declared objectives is the improvement of access to transport networks and services. The experience of its founding members includes transport-related projects concerning inland waterways and cross-border accessibility, particularly in the Polish–Lithuanian border area. These activities may provide a basis for future engagement in transport infrastructure development in a region characterised by limited accessibility.

5.3. Central European Transport Corridor EGTC

The Central European Transport Corridor EGTC was established in 2014 as an institutional framework supporting the development of an international north–south transport corridor in Central Europe. Its activities focus primarily on coordination, strategic planning and analytical work related to transport infrastructure, including the identification of missing links and bottlenecks within the corridor. The EGTC has been involved in projects promoting sustainable and rail-based transport solutions, reflecting its sectoral focus on transport and its relevance beyond the Baltic Sea Region.

5.4. Kvarken Council EGTC

A particularly prominent role among EGTCs operating in the Baltic Sea Region is played by the Kvarken Council EGTC, which institutionalised long-standing Finnish–Swedish cross-border cooperation in the Kvarken region. Transport constitutes a central element of its activities, reflecting the geographical conditions of the region and the importance of maritime connections across the Gulf of Bothnia. Ferry services between Vaasa and Umeå represent a key component of regional accessibility for both passenger and freight transport.

The Kvarken Council EGTC has been actively involved in numerous transport-related projects addressing the functioning, safety and environmental impact of maritime transport, as well as the development of low-emission and energy-efficient transport solutions. Its activities also include analytical and conceptual work related to the future development of cross-border transport connections, including discussions on the feasibility of a fixed link across the Kvarken strait.

A noteworthy example of such initiatives is the FLINC – Financing Large-scale Infrastructure – Case Nordic Connector project, which focused on analysing financing mechanisms for major cross-border transport infrastructure in the Baltic Sea Region (Kvarken, 2026). The project examined possible funding models for the development of the Nordic Connector corridor, including improved maritime and land transport links between Finland and Sweden in the Kvarken region, thereby supporting stronger cross-border connectivity and the development of a more integrated and sustainable transport system in the Baltic Sea Region.

These initiatives have increasingly incorporated considerations related to infrastructure resilience, supply security and preparedness, reflecting the growing importance of transport in the context of regional security and changing geopolitical conditions in Northern Europe. The strategic position of the Kvarken region within the system of transport connections in the Baltic Sea Region is illustrated in Figure 8, which presents the main east–west and north–south transport linkages relevant to the activities of the Kvarken Council EGTC.



Figure 8. Major transport connections in the BSR in the context of security.

Source: Kvarken (2025).

Overall, the diversity of transport-related activities undertaken by EGTCs in the Baltic Sea Region highlights the differentiated role of this instrument in cross-border cooperation, shaped by territorial context, institutional objectives and functional scope.

6. Summary

Transport constitutes an important area of territorial cooperation in the Baltic Sea Region, and the EU Strategy for the Baltic Sea Region (EUSBSR) treats it as a key element of cohesion and macro-regional integration, implemented primarily through European Territorial Cooperation programmes.

The analysis indicates that the European Groupings of Territorial Cooperation instrument functions mainly within a cross-border cooperation framework, while no EGTC of a transnational character has yet been established in the Baltic Sea Region that could directly support the objectives of the EUSBSR. At the same time, EGTCs remain a relatively young instrument that is still evolving in the region and has not yet reached full institutional maturity.

Clear differentiation can be observed among individual groupings. The Kvarken Council EGTC stands out due to the implementation of numerous cross-border transport projects addressing both accessibility and issues related to infrastructure resilience and supply security. In the longer term, the establishment of a transnational EGTC could facilitate fuller use of the potential of this instrument in achieving the objectives of the macro-regional strategy in the Baltic Sea Region, particularly in the field of transport

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DETERMINANTS OF DIGITAL NOMADS' RE-VISITING OF A DESTINATION. A QUALITATIVE RESEARCH APPROACH

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Purpose: This article aims to identify factors influencing digital nomads' return to previously visited destinations. Two research questions are analyzed in particular: (1) whether digital nomads return to the exact locations, and (2) what characteristics of destinations are key determinants of the decision to revisit a given destination.

Design/methodology/approach: A qualitative approach was applied using the structured interview method. The study was based on structured interviews conducted with an international group of ten digital nomads who lived a mobile lifestyle at the time of the study.

Findings: Each of the digital nomads surveyed returned to a previously visited location. One of the most important characteristics of a city that can influence the desire to return to a given destination is the presence of an open and friendly community. In this context, respondents referred to existing digital nomad communities, which enable establishing and maintaining contacts with similar goals. Digital and residential infrastructure facilitates mobile work and is also an important feature.

Research limitations/implications: The most significant limitations of this study include the relatively small size of the research sample, which includes a small number of interviews conducted. The study does not permit statistical analysis or generalization of the results.

Originality/value: The study's most significant finding is that digital nomads, despite being by definition a highly mobile group with a propensity for exploration and frequent relocation, tend to return to previously visited destinations. This phenomenon is groundbreaking, as it somewhat challenges the established belief in the literature that digital nomads constantly need to discover new places.

Keywords: digital nomadism, digital nomads, place marketing, city, destinations, place revisit.

Category of the paper: Research paper.

1. Introduction

Digital nomads are one of the newest social groups identified as a significant segment of potential consumers of urban offerings. However, from a city management perspective, their role goes beyond merely receiving urban services and resources. Digital nomads not only consume the city's offerings but also actively participate in shaping its image, both through

social media activities and direct recommendations, which can influence the location decisions of other members of this group (Mladenović, 2016; Bonneau, Aroles, 2021).

Despite the growing body of research on digital nomadism, including in the context of place marketing, there is still no clear answer to whether digital nomads return to previously visited locations. Although this issue has been flagged as a potential direction for future research, it has not yet received broader empirical exploration (Sztuk, 2025).

The primary goal of this article is to identify factors influencing digital nomads' return to previously visited destinations. Two research questions were analyzed in particular: (1) whether digital nomads actually return to the exact locations, and (2) what characteristics of destinations key determinants of the decision are to revisit a given destination. Furthermore, the study considers the role of recommendations from other nomads in the location decision-making process. The obtained results can provide an important source of knowledge for local government representatives and entities responsible for territorial marketing, supporting the design and promotion of offers to attract and retain this dynamically growing group of mobile professionals.

2. Digital nomadism in the light of research and practice

2.1. The rise of the digital nomadism trend

The instantaneous digital transformation observed in recent years has significantly impacted almost all areas of human life, from acquiring knowledge and maintaining social relationships, through consuming goods and services, to fulfilling professional responsibilities. The development of mobile technologies and widespread access to the internet have enabled fully remote work, which has contributed to increased geographical flexibility of employment (Lacárcel, 2025). The COVID-19 pandemic, which forced widespread isolation measures, often administrative in nature, significantly accelerated the process of workplace digitization and the widespread adoption of remote work (Hobsbawm, 2022). Researchers agree that the pandemic period and the following post-pandemic period catalyzed the growing interest in digital nomadism (Almeida et al., 2021; Cook, 2023).

Digital nomadism combines remote work with frequent relocation and is understood as a specific lifestyle (Wang et al., 2018). Digital nomadism involves a hybrid model combining professional work with leisure and exploring new destinations (Rainoldi, Buhalis, Ladkin, 2022). The average digital nomad visits five to ten countries annually, staying in each location from several weeks to several months (Tagliaferri, 2023). A characteristic feature of this group is the pursuit of temporary integration with the local community. Nomads live like locals, explore their surroundings like tourists, and simultaneously fulfill their professional

responsibilities regardless of location. Despite the apparent difficulties resulting from frequent relocations and changes in environment, digital nomads demonstrate high adaptability and flexibility in organizing their professional and personal lives (Ji, Kim, Kim, 2024). This mobility is the key feature that distinguishes them from traditional remote workers who perform their duties from a permanent place of residence (Poulaki et al., 2023).

Bibliometric research findings demonstrate increased interest in digital nomadism during the COVID-19 pandemic (Sztuk, 2024). Despite this, the research on this topic remains fragmented and dispersed, reflecting the interdisciplinary nature of digital nomadism (Miocevic, 2025). This trend can be analyzed from multiple disciplines: the labor market, urban and spatial policy, economics, sociology, territorial marketing, and tourism. This stems from the fact that the lifestyle and work of digital nomads impact various spheres of modern societies and the offering of services and products in urban spaces (Sanul, 2022).

2.2. Digital nomads from a territorial marketing perspective

Territorial marketing is a management concept for a spatial unit (city, region, country) aimed at recognizing, anticipating, and meeting the needs and expectations of various stakeholder groups using available territorial resources (Szromnik, 2017). Its primary goal is to strengthen the competitive position of a given location by creating and communicating an attractive offer from the perspective of potential recipients (Kamiński, 2011). In this approach, territorial units operate in a competitive market environment, seeking the attention and interest of residents, investors, tourists, and other customer groups by highlighting their assets and shaping a unique image (Szromnik, 2011).

One of the newest and fastest-growing target segments in destination marketing is digital nomads, individuals who combine remote work with a mobile lifestyle. By 2025, the number of digital nomads worldwide will be estimated to exceed 40 million (Kumar, 2025). Their presence generates economic benefits for cities, primarily through accommodation, food, tourism, culture, and entertainment services. Furthermore, digital nomads contribute to the development of local entrepreneurship and innovation, including through exchanging experiences and creating professional networks (Gupta, Jaiswal, Gupta, 2024). This impact may stem from the high levels of education and digital literacy that characterize most group members (Kumar, 2025).

Their contribution to shaping the destination's image is also significant. Digital nomads actively share opinions about the places they visit on social media, contributing to their global promotion (Bonneau, Aroles, 2021). The literature emphasizes that image management is a key element of place marketing strategies (Raszkowski, 2012), and a city's image is considered a strategic resource that builds its competitive advantage (Reichel, Zaćlona, 2010). In this context, digital nomads can be considered a valuable group of place ambassadors whose opinions influence the decisions of other traveling professionals.

In response to the growing importance of this group, many countries have introduced special visas for digital nomads, allowing them to stay longer and legally work remotely (Svobodová, 2022). At the same time, some cities and regions have begun to position themselves as digital nomad-friendly destinations actively, recognizing this trend's economic and image building potential (Lacárcel, 2025). One of the most frequently introduced infrastructure solutions is coworking facilities. These spaces are shared offices for short-term rentals, providing access to essential working conditions, such as high-speed internet, ergonomic equipment, air conditioning, and social facilities. Although the concept of coworking existed before, the development of digital nomadism has contributed to the rapid growth in demand and the popularization of this type of space (Bozzi, 2024). Furthermore, local governments are increasingly adapting unused urban spaces into coworking offices and supporting local entrepreneurs in establishing such initiatives through financial programs and tax breaks (Ji, Kim, Kim, 2024). Despite the growing interest in this phenomenon, there is still a lack of comprehensive empirical research on the consumption behavior of digital nomads, their interaction with the urban offer, and the impact on local tourism ecosystems (Miocevic, 2025).

In the context of place marketing, the issues of loyalty and revisit intention are critical, and have been widely analyzed in studies on tourism and consumer behavior (Zhang, Wu, Buhalis, 2018). Although well-described in the marketing literature, this issue of digital nomads has not yet been thoroughly explored (Sztuk, 2025). Given their mobile lifestyle, which involves constant exploration of new places (Lacárcel, 2025), confirming the tendency to return could be a valuable result for city authorities and place marketing practitioners. It would indicate that digital nomads form lasting relationships with places that meet their professional and social needs despite their mobility and flexibility. Conducting marketing research among digital nomads seems particularly important, as the implications for destination management and the shaping of their offerings remain insufficiently explored in the literature (Zhou et al., 2024).

3. Determinants of digital nomads' re-visiting a place

3.1. Research methodology

A qualitative approach was used to answer whether digital nomads return to previously visited locations and what location characteristics influence their decision to return. The study was based on structured interviews conducted with an international group of digital nomads who were actively mobile at the time of the study. Participants were recruited through social media platforms, such as Facebook groups and WhatsApp, dedicated to digital nomads residing in various countries. To conduct the interviews, the study's purpose and invitation to participate

were announced on various online platforms for digital nomads. Interested digital nomads applied and received a list of questions and a request for answers. The study was conducted in July 2025. Participation in the study required regular changes of residence while simultaneously working remotely. Several individuals who agreed to participate in the study did not return to the previously visited location and were therefore excluded from the remainder of the study. No age or country of origin criteria were applied to selecting respondents. However, a fundamental gender distinction was made between male and female groups.

The literature on qualitative research methods, including interviews, has no consensus on the minimum sample size necessary to draw analytical conclusions. Some authors suggest that a sample of 10 individuals may be sufficient (Atran, Medin, Ross, 2005), while others suggest a range of 10-15 (Mason, 2010). A total of 10 respondents participated in this study: three women and seven men.

Each participant answered four structured research questions:

1. Have you visited the same place more than once as a digital nomad?
2. What characteristics should a place make you consider revisiting it?
3. Have you encountered amenities specifically for digital nomads in the destinations you visit?
4. Do you use recommendations from other digital nomads?

The method used allowed for an in-depth analysis of the motivations, expectations, and behavioral patterns among digital nomads and the identification of factors influencing their loyalty to selected places.

3.2. Research results

In answering the first question, all survey respondents declared that they had visited a given location more than once as part of their digital nomad lifestyle. Three out of ten respondents indicated that they had revisited Chiang Mai, Thailand, while the remaining respondents mentioned various destinations in Europe and Asia, confirming the broad geographic diversity of the places visited.

In response to the second question, about the characteristics of a place that influence revisiting it, most respondents (8 out of 10) emphasized the importance of community, understood as the availability of a social scene that creates positive energy, the openness of residents, and the opportunity to network and establish contacts with other nomads (Table 1). For example, Respondent 1 stated: *I think the social scene is a key aspect for me.* One respondent also noted that a community is important and should be characterized by professional ambition. Respondent 6: *The place needs much energy and a community of high-quality people with a project, goals, etc.* The second most frequently cited factor was a reliable digital infrastructure, including a fast and stable Wi-Fi connection and access to coworking and coliving spaces that foster work and integration. Single, but recurring, responses referred to the attractiveness of the landscape and aesthetics of the location (e.g., the presence

of a beach), the level of safety, and additional amenities such as proximity to a gym or access to healthy food in local cafes and restaurants. Respondent 5 presented the most characteristics: *It really depends, but the first things that come to mind are a strong sense of community for digital nomads, warm weather, low prices, and walkability.*

Table 1.

Destination features that influence digital nomads to revisit

Place features that influence return visits	Number of indications
1. Community / networking / positive atmosphere among people	8
2. Stable Wi-Fi / Digital Infrastructure	5
3. Availability of coworking and coliving	5
4. Specific climate features (weather, nature, landscape)	4
5. Affordable living prices	3
6. The degree of security in a place	3
7. Amenities, access to healthy food, gym	2

Source: own elaboration.

In the third question, respondents were asked whether they had encountered amenities specifically for digital nomads in the destinations they visited. Most respondents (7 out of 10) confirmed the presence of such solutions (Table 2). The most frequently mentioned amenities included coworking spaces. Some respondents added that coworking solutions were particularly popular in Lisbon, Bali, and Chiang Mai. The digital nomads surveyed mentioned co-living and housing programs for remote workers, implemented in hostels or long-term rentals. Three respondents mentioned local events and networking events organized for the digital nomad community, e.g., Respondent 2: I think it is just the opportunity to meet and network. I know coworking spaces exist around, but I do not use them. Two respondents, however, noted local discounts and packages, including discounts on long-term accommodations. These results confirm that digital nomads recognize that destinations that actively position themselves for this user group introduce offerings specifically targeted to this group. The initiatives observed are primarily private (coworking spaces, hostels), and much less frequently, local government initiatives.

Table 2.

Elements of the city offer addressed to digital nomads in visited destinations

Type of facility	Number of indications
Coworking spaces	5
Coliving and nomad programs	3
Local events / nomad meetups	3
Local discounts/packages	2

Source: own elaboration.

In the final question, participants were asked if they use recommendations from other digital nomads. Most respondents (7 out of 10) responded affirmatively, one respondent declared that uses such sources occasionally, while two stated that they do not use them at all. Respondents who answered negatively to this question justified their lack of use of recommendations. For example, Respondent 3 stated: *I generally do not look for recommendations because*

I am enough of a traveler to know what I like and where I want to go. Respondent 7, however, said he prefers to explore and discover places alone: *I do not really read recommendations from nomads. I prefer to do basic research on places but ultimately go there and figure it out myself.*

Among those actively seeking recommendations, seven out of eight respondents cited Facebook groups (e.g., Digital Nomads in Thailand) as their primary source of information. Four respondents used travel blogs and vlogs (including those on YouTube). In this context, one respondent stated that he actively creates materials recommending places visited based on his travel experiences. Respondent 4: *When it comes to recommendations, in addition to obtaining them, I also create them, visit places, and add descriptions to our network of digital nomads.* Three respondents declared that they were obtaining recommendations directly from other nomads as part of shared stays in co-living or coworking spaces.

4. Conclusions and future research directions

The results of the study enabled to reach research objective, concluding that digital nomads often return to destinations they have previously visited. The statements provided by respondents shed light on the characteristics of a location that influence their decision to return. The study's most significant finding is that digital nomads, despite being by definition a highly mobile group with a propensity for exploration and frequent relocation, tend to return to previously visited destinations. This phenomenon can be considered groundbreaking, as it somewhat challenges the established belief in the literature about their constant need to discover new places. From a territorial governance perspective, this finding is significant, suggesting that locations that create favorable conditions for this group can count on their return visits, and thus on greater economic stability associated with the influx of this group of mobile workers.

Analysis of the respondents' responses indicates that a key feature of a place that influences the willingness to return is the presence of a community. In this context, respondents referred not only to residents perceived as open and friendly, but also to the existing community of digital nomads residing in a given location. The opportunity to function in an environment with people with similar life and professional goals and sharing similar values is an important motivating factor for returning to a location. This indicates that digital nomads demonstrate a strong need for belonging and social integration despite the individualistic nature of their work. Frequent location changes make it difficult for digital nomads to build lasting social relationships, leading to frequent feelings of loneliness (Mancinelli, 2020). Due to their nomadic lifestyle, satisfying the need for contact and face-to-face meetings with friends or people from a similar cultural background becomes crucial for this group (Lacárcel, 2025). Although being among diverse local communities enriches digital nomads' experiences, it also creates communication barriers and hinders building deeper relationships with the residents of

the places they visit (Mavragani, Kaziani, Chatzimichali, 2023). Despite attempts to integrate with the local culture and community, many digital nomads encounter difficulties establishing lasting bonds, translating into a limited sense of belonging to a given place (Beaumont, 2019). Consequently, the presence of other digital nomads in destinations who understand their lifestyle and values can be a significant factor in the destination's attractiveness. From the perspective of city managers and entities responsible for territorial marketing, communication aimed at digital nomads should emphasize the technological infrastructure and remote work conditions, as well as the local nomad community, their presence, activities, events, and initiatives that integrate them. Professionals responsible for place marketing should create opportunities or organize conferences and social gatherings specifically for digital nomads.

Later in the study, respondents also highlighted the importance of infrastructure supporting work and daily life, particularly a stable internet connection, the availability of coworking and co-living spaces, and service facilities (e.g., gyms, cafes, and healthy restaurants). Importantly, landscape features and natural beauty were less important to respondents than the atmosphere and functionality of a place. This may indicate that the attractiveness of a destination for digital nomads stems not solely from its tourist attractions, but mainly from the quality of infrastructure and the social experience a given city offers. Other researchers have previously noted this, suggesting that destinations preferred by digital nomads go beyond beautiful landscapes (Bozzi, 2024). The study results, therefore, indicate the need to develop an offer for digital nomads that includes elements of urban infrastructure, such as shared spaces.

The survey results also suggest that more places are actively developing offerings aimed at digital nomads, a fact recognized by those involved. Respondents particularly frequently cited the increasingly popular presence of coworking spaces and local events, such as conferences dedicated to this group, strengthening bonds and a sense of community.

The study also confirmed the findings of previous researchers regarding digital nomads' reliance on recommendations published in social media groups and online forums when choosing their following destinations (e.g., Sztuk, 2023). This indicates that online social and information capital, not just official city marketing communications, is significant in decision-making.

In summary, the obtained results confirm that social, infrastructural, and communication factors play a fundamental role in shaping the attractiveness of places for digital nomads, and strategically building relationships and communities around this group can bring tangible benefits to the destination.

The most significant limitation of this study is the relatively small sample size, which included a small number of interviews. This limitation impacts the scope of generalizability of conclusions and the interpretation of the obtained results. Therefore, future research would warrant supplementing the quantitative analysis with a larger sample of respondents.

Combining qualitative and quantitative methods could allow for a more comprehensive approach to the phenomenon and verification of the conclusions drawn from this study.

Furthermore, the author points to the merits of conducting a case study of selected destinations that have successfully attracted digital nomads. In this context, an interesting avenue for further analysis could be a detailed exploration of the offerings of Chiang Mai, Thailand, one of the most frequently mentioned destinations by respondents. This analysis could include identifying the infrastructure, services, and local products that significantly determine the attractiveness of this destination. The results of such a study could provide a valuable benchmark for other cities seeking to increase their competitiveness in attracting and retaining digital nomads.

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ARTIFICIAL INTELLIGENCE IN PLACE BRANDING – A LITERATURE REVIEW

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Purpose: The article aims to classify existing research on artificial intelligence in place branding and to identify emerging directions for future research.

Design/methodology/approach: The paper adopts a conceptual approach based on a systematic review of the existing literature and illustrative examples of AI applications in territorial marketing and city branding practices. A systematic literature review based on bibliometric analysis of Scopus and Web of Science databases was conducted for the study.

Findings: The review indicates that AI enables personalized marketing communication, the design of creative promotional campaigns, real-time monitoring of city image and effective stakeholder relationship management. These findings highlight the recurring trends and practical applications of AI in marketing and city and place branding identified across the literature.

Research limitations/implications: The study focuses on synthesizing insights from published research, suggesting directions for future investigation into AI's role in city branding and marketing innovation.

Social implications: AI-supported branding can improve citizen and visitor engagement, enhance communication and promote responsible use of digital tools in leveraging AI technologies to design innovative and data-driven branding strategies.

Practical implications: The findings offer guidance for city authorities and branding managers on how to leverage AI technologies to design innovative and data-driven branding strategies. They also provide insights into the challenges associated with the use of AI in city branding.

Originality/value: This paper contributes to the field by systematically mapping the role of AI in place branding and identifying key areas for application and development.

Keywords: artificial intelligence, AI, place marketing, place branding, city branding, destination branding.

Category of the paper: Literature review.

1. Introduction

In the digital era, artificial intelligence (AI) is recognized as a key technology driving business innovation (Yao et al., 2025). One of the most frequently cited definitions of AI describes it as the capability of a system to accurately interpret data from its environment, learn from it and utilize the acquired knowledge to achieve specific goals and tasks through flexible adaptation to changing conditions (Haenlein, Kaplan, 2019). AI plays a fundamental role in both transforming marketing processes and shaping the future landscape of the field (Grewal et al., 2025; Masnita et al., 2024). The rapid evolution of AI is also profoundly transforming contemporary approaches to brand image development (Hue, Hung, 2025). As emphasized by Kamkankaew et al. (Kamkankaew et al., 2025) the application of AI in online marketing strategies is expected to revolutionize the conduct of promotional activities and audience communication in the coming years. In light of data published by Semrush, AI adoption in marketing strategies has demonstrated a marked increase, highlighting its growing significance among both researchers and practitioners worldwide (Hue, Hung, 2025).

In light of data published by Semrush (Lahey, 2025), the global significance of artificial intelligence (AI) in both the economy and marketing is growing at a rapid pace. It is estimated that by 2030, AI technologies will contribute approximately USD 15.7 trillion to global GDP, while the value of the global AI market is projected to increase from USD 638.23 billion in 2024 to over USD 1.81 trillion by 2030. One of the fastest-growing segments is generative artificial intelligence (Gen AI). Its potential applications in content creation, communication and audience experience design are highly promising. Alongside technological advancement, interest in generative AI within the academic community is also increasing. Gen AI is defined as systems capable of generating novel content such as text, images, audio, video, or music, based on provided input data. Gen AI leverages advanced machine learning techniques, including, among others, large language models (LLMs) (Jang et al., 2024). This enables the generation of original materials that meet specific requirements and specifications.

In light of statistics, 88% of marketers already utilize artificial intelligence tools in their daily work, with more than half employing them for content optimization and the analysis of consumer behavior data (Lahey, 2025). Currently, its widespread application in digital marketing contributes significantly to the transformation of both content creation and user reception processes (Joshi et al., 2025). As noted by Grewal and colleagues (Grewal et al., 2025) over the coming decade, generative artificial intelligence is expected to influence how marketers interact and communicate with customers. Moreover, it will play a crucial role in supporting the creation and distribution of marketing content (including text, images, video) as well as contributing to the development of research methodologies and the design of new products and services.

From a marketing perspective, the application of generative artificial intelligence tools is associated with numerous benefits. AI-driven process automation allows for the reallocation of resources from routine tasks to strategic activities, minimizes the risk of human error, supports data protection and ensures operational continuity (Joshi et al., 2025). These technologies enable the personalization of marketing campaigns based on behavioral data, facilitate real-time decision-making and allow for the prediction of market trends. Key benefits include increased advertising process efficiency, optimized expenditures, improved profitability, precise alignment of content with individual consumer preferences and the enhancement of brand trust (Grewal et al., 2025; Islam et al., 2024; Joshi et al., 2025).

The use of artificial intelligence in marketing, as well as in business more broadly, is, however, accompanied by technological, organizational and ethical challenges (Syam, 2025). The integration of artificial intelligence systems with existing organizational structures requires systematic training and the long-term development of digital competencies (Yao et al., 2025). Striking a balance between process automation and human creative input represents one of the key priorities of contemporary communication strategies. From both a scientific and business perspective, this balance is essential for their effectiveness and innovativeness (Joshi et al., 2025).

Large language models possess advanced natural language processing capabilities and demonstrate significant potential as effective tools supporting a wide range of diverse fields (Cao et al., 2025). Researchers and practitioners recognize numerous opportunities for the application of artificial intelligence in marketing, as well as its growing significance in urban planning and management. This is particularly evident in areas such as smart cities, city management, marketing and place branding. The implementation of AI in the context of smart cities has contributed to increased efficiency, improved accessibility of services and enhanced quality of life for residents (Szarek-Orlecka, Cader, 2025; Szpilko et al., 2023). AI continuously drives innovations that enhance safety, efficiency and inclusivity, reflecting the evolving role of digitalization in shaping management processes in cities worldwide (Smart City Index 2024: How Cities Are Shaping the Future of Urban Life, 2024). The integration of branding with digital transformation and smart city initiatives enables the construction of a coherent and innovative city image, while simultaneously supporting sustainable development, citizen engagement and economic growth. A strong smart city brand enhances its attractiveness and draws residents, tourists, investors and professionals (Briana et al., 2025).

In the contemporary context, where data-driven technologies play a pivotal role across various domains, their application in place marketing and the development of cities and regions is of significant importance. This is particularly relevant for enhancing the competitiveness and attractiveness of different locations (Békési, Szöllösi, 2025). Artificial intelligence can serve as a tool supporting marketing activities and place brand management, enabling, for example, data analysis and the personalization of communication with residents and other stakeholders (Chen et al., 2024; Hakala, 2025). As evidenced in the literature, place brands are currently

undergoing significant transformations driven by artificial intelligence technologies (Chen et al., 2024).

Research on the direct application of artificial intelligence in place branding, however, remains in its early stages. The existing literature primarily consists of review-oriented studies, including hybrid-narrative analyses of the emerging field of place branding supported by human–AI collaboration (Chen et al., 2024). Concurrently, exploratory studies are emerging that highlight the potential of AI-based tools in the processes of urban creation and city identity management (e.g., Hakala, 2025). However, as noted by Corazza (Corazza, 2016), creativity evolves in tandem with profound technological transformations. In this context, artificial intelligence represents a significant shift, as it can exhibit creative capabilities either autonomously or by augmenting and supporting human creativity (Feuerriegel et al., 2024).

As with other technological tools, the effectiveness of AI deployment depends on the intentions and competencies of the entities implementing it. Place leaders and marketers should strive to identify forms and applications of AI that support their strategic activities, without replacing human creativity, reflection and interpretative capabilities. The potential of AI to support decision-making processes and enhance the coherence of place brand communication narratives is currently the subject of preliminary scholarly discussion. This underscores the need for a critical approach to integrating AI into marketing strategies, particularly in areas that require the cultivation of an authentic place brand image and stakeholder relationships.

The article aims to classify existing research on artificial intelligence in place marketing and branding and to identify emerging directions for future research. This study employs a systematic literature review to identify the most significant research on AI in place branding and indicate directions for development and uncover emerging topics for future investigation. The review highlights the extent and significance of AI applications in place marketing and branding initiatives, as well as the challenges and considerations they pose for urban stakeholders. A systematic literature review based on bibliometric analysis of Scopus and Web of Science databases was conducted for the study.

2. Literature review

Place marketing initially served as a framework for managing the attractiveness of territories, relying on marketing instruments and a market-oriented approach. With increasing competition among cities and regions, as well as the growing complexity of the needs of diverse stakeholder groups, this approach has evolved toward place branding (Boisen et al., 2018; Kumar, Panda, 2019; Zenker et al., 2017). Place branding extends place marketing by incorporating dimensions of identity, meaning and reputation. It focuses on a long-term vision and the consistent narrative of a place (Zenker et al., 2017). In the context of rapid urbanization,

city branding has evolved from a positioning tool into a strategic mechanism of urban governance and policy coordination (Le et al., 2025).

The literature indicates that branding does not replace marketing, but rather integrates and structures it at the strategic level (Boisen et al., 2018). Moreover, it increasingly influences the competitiveness and attractiveness of contemporary cities (Lemmettyinen et al., 2025). Research also emphasizes the importance of stakeholder co-creation of the brand and its embeddedness in the local social and cultural context (Eshuis, Ripoll González, 2025). According to the findings of Le et al. (Le et al., 2025) city branding is structured as a multi-phase process encompassing pre-branding, branding operationalization and post-branding stages. The authors emphasize co-creation, cross-sectoral coordination and feedback-based learning, while prioritizing alignment between strategic objectives and lived urban realities over external attractive image construction.

One of the fastest-growing areas of research is the application of artificial intelligence in marketing. This stems from its ability to analyze large datasets, automate decision-making and personalize communication in real time (Davenport et al., 2020). The literature emphasizes that AI is significantly transforming the way marketing strategies are designed, shifting them toward data-driven and behavior-prediction-based approaches (Huang, Rust, 2021). These processes can also be applied in the domains of place marketing and place branding.

As emphasized by Chen et al., (Chen et al., 2024) AI tools can assist in defining territorial brand narratives. Similarly to online marketing and corporate branding, AI can also support segmentation and the tailoring of communication to different stakeholder groups, thereby strengthening the coherence and effectiveness of place brand strategies. However, place and destination marketers often oversimplify the branding process by directly transferring mechanisms derived from corporate branding. This approach fails to account for the complexity of places and the heterogeneity of their stakeholders and, in effect, does not correspond to the specific nature of territorial brand development (Zenker et al., 2017). A similar risk is also associated with the application of generative AI tools in this domain.

The development of AI tools, however, has the potential to redefine the way cities design and manage their image. Digital platforms, municipal chatbots, intelligent service systems and personalized marketing communications now enable the creation of more personal and authentic relationships with audiences, both internal and external (Briana et al., 2025; Najah Mohammed Alrasheedi, 2025). As a result, the city brand can be understood as a set of experiences that adapt to different individuals, their needs and expectations in everyday situations. Algorithms, sentiment analysis and recommendation systems enable the continuous monitoring of social moods, multidimensional analysis of audience behavior and real-time assessment of their responses. On this basis, it becomes possible to design more coherent and adaptive communication strategies (*Bloom Consulting: Artificial Intelligence and the Future of Place Branding*, 2025; Kumar, Panda, 2019).

From a theoretical perspective, a brand can be conceptualized as a symbolic construct whose primary function is to identify and differentiate a given place from others. The brand thus serves as a carrier of cultural and social meanings embedded in its visual and verbal elements. Brand symbols, such as logos, slogans and promotional taglines constitute central points of reference. Audiences interpret these symbols by attributing specific characteristics, values and associations to the place, which in turn shapes their perceptions and decisions (Eshuis, Ripoll González, 2025).

Existing empirical studies on the use of AI in place marketing and place branding are largely exploratory in nature. One of the few examples of AI application in this domain is a study that employed the language model ChatGPT to generate city slogans for the 20 largest municipalities in Finland. In this approach, generative algorithms analyzed input data and formulated slogan proposals, which were then subjected to qualitative comparative analysis against expert-created slogans and evaluated from the perspective of place branding practitioners. The study revealed both the potential of AI tools to effectively support the creation of communication materials and the limitations related to their ability to capture the unique characteristics of local identity. The authors emphasize that, despite the widespread use of AI in marketing, its creative capabilities in the context of generating marketing slogans still require further theoretical and empirical investigation. This is particularly relevant to the linguistic and semantic dimensions of promotional content, which play a key role in building recognition and differentiating places in the competitive territorial market (Hakala, 2025). AI tools are capable of generating an almost unlimited number of proposals, which accelerates the creative process and allows for time and cost savings. Implementation examples in cities such as Pori and Vantaa (Finland) demonstrate that AI-generated slogans can ultimately be perceived as effective and valuable in terms of strategic communication. At the same time, researchers highlight the limitations of these tools: the repetitiveness of used vocabulary and the difficulty in capturing human tone and cultural context (Hakala, 2025).

According to the literature, AI enables relatively effective alignment of strategies with dynamic socio-cultural and economic contexts. It processes vast datasets from social media and global media sources, making it possible, among other things, to monitor and forecast trends in the behavior of key city stakeholders, including tourists, investors and residents. However, there is a need for in-depth research on the interaction between technologically generated intelligence and the specific identity of a place (*Bloom Consulting: Artificial Intelligence and the Future of Place Branding*, 2025).

Other approaches to defining a brand focus on perceiving it as a set of images and associations embedded in the minds of audiences, or on treating a place brand as a construct of experiences (Eshuis, Ripoll González, 2025). In the field of destination marketing and branding, as well as tourism research, artificial intelligence is increasingly recognized as a key tool for promoting and managing destination brands. AI supports tourism organizations and businesses in analyzing large datasets, creating personalized recommendations and automating

communication. It enables the management of the complexity of modern forms of tourism and economic development processes, while also revolutionizing interactions with visitors and investors. Contemporary urban marketing is increasingly moving away from one-way communication toward dialogue with city stakeholders. By leveraging artificial intelligence, cities (as well as other types of places) can respond more quickly and accurately to the needs of residents and visitors. AI-based tools, such as recommendation systems, chatbots, content generation and predictive algorithms, influence marketing strategies through dynamic capabilities to tailor messaging to consumer behaviors and preferences, while also building an attractive destination image across social media and digital channels more broadly (Najah Mohammed Alrasheedi, 2025).

In tourist destinations, AI is perceived as a multipurpose tool. Its applications encompass marketing, communication, analytical and strategic functions. AI offers a range of opportunities that have the potential to enhance the attractiveness and competitiveness of cities and regions. It enables effective information management, the creation of personalized experiences for visitors and the optimization of marketing processes. A key function of AI in destination marketing is transforming the way cities understand and communicate with their target audiences. By leveraging Big Data, AI-based systems facilitate real-time sentiment analysis. Such capabilities allow for the rapid adjustment of marketing strategies, the attraction of tourists and the improvement of a city's brand image. The implementation of AI technologies has currently created entirely new travel experiences and generated added value for tourists (Samara et al., 2020; Wang, 2025). Moreover, AI can support the creation of personalized content and travel itineraries based on visitor preferences. Generative AI also enables the delivery of one-to-one experiences, which was previously difficult to achieve in destination marketing practice. As a result, cities and regions can develop products and services through hyper-segmentation and hyper-personalization of content, adapting to the individual needs of different tourist groups (Samara et al., 2020).

An increasing number of destinations aim to promote artificial intelligence technologies with an emphasis on enabling tourists to perceive enhanced services and technological advancement within the destination, thereby fostering positive attitudes toward the place (Wang, 2025). Research indicates that a key issue is the perceived authenticity of AI-generated content, often referred to as AI thenticity. Whether AI-generated content is regarded by audiences as credible and consistent with the actual image of a place influences their trust and their intention to visit, particularly in the context of tourist destinations. The authors emphasize that maintaining the authentic character of communication remains a crucial element of effective place marketing, even when AI tools are employed (Bui et al., 2024).

Artificial intelligence can support the identification and communication of the unique identity of places (How to Future-Proof Digital Communications in Place Branding, 2024). Tools that analyze the distinctive features of a destination enable the tailoring of offerings to visitor expectations, while also facilitating collaboration between cities (e.g., by creating routes

connecting complementary locations). This approach can promote both the enhancement of tourist attractiveness and the development of a coherent place narrative.

In the realm of brand communication and creation, AI streamlines the processes of generating promotional content by offering scalability, efficiency and the automation of routine tasks (e.g., producing texts, newsletters, or marketing materials tailored to individual audience preferences). For example, AI-driven image generation allows marketers to transform abstract brand values into tangible experiences that travelers can see and share. Additionally, generative AI can be used to create unique, engaging content or to encourage users to co-create it. This adds originality to advertising campaigns and can help cities reach new audiences through creative formats and digital tools (European Travel Commission, 2025).

3. Methodology

The literature on the application of artificial intelligence in place marketing and branding was reviewed using a bibliometric analysis method. The quantitative analysis conducted enables an assessment of the current state of research and the identification of trends and changes in the number of publications within the studied area.

The literature review was planned and conducted in a phased manner to ensure systematic data collection and analysis. This approach ensures the consistency and transparency of the research process while allowing for the precise identification of trends and gaps in the existing literature (Ejdys, Szpilko, 2022; Gudanowska, 2017; Szpilko et al., 2023; Tomaszewska, Florea, 2018).

In the first stage, bibliographic databases providing access to high-quality scholarly sources were selected (I). Next, keywords enabling precise retrieval of publications related to the studied topic were identified (II), and search narrowing criteria were applied (III). The applied publication selection criteria allowed for the elimination of items not directly related to the research topic and ensured the relevance of the obtained results. Subsequently, a review and selection of data were conducted (IV). In the following step, a quantitative analysis of the selected publications was performed (V). Key research areas addressed in the literature were identified (VI), and thematic clusters were derived based on a keyword analysis (VII) (Table 1).

Table 1.
Methodology of bibliometric analysis

No.	Stage	Description
I	Database selection	Web of Science; Scopus
II	Keywords selection	“place marketing” OR “place brand*” OR “destination brand*” AND “artificial intelligence” in topic (Title-Abs-Key).
III	Criteria selection	- Document types: articles, proceedings papers, conference papers, books, book chapters, review article, editorial materials, editorial, early access. - Search period: 2010-2025.
IV	Data selection and data extraction (removal of duplicates)	Deleting duplicates: DOI, title.
V	Quantitative analysis of the results	Scope: number of publications per year, type of document, main thematic categories, total number of citations.
VI	Identification of research areas	Visualisation of the most frequent keywords.
VII	Creation of thematic clusters	Identification thematic clusters.

Source: own elaboration.

For the bibliometric analysis, the two largest publicly accessible databases were selected: Web of Science and Scopus. The analysis began with a search for publications containing the following terms: „place marketing”, „place brand*”, „city brand*”, „destination brand*”, „artificial intelligence”. The search included publications up to 2025. The initial search encompassed publications containing these phrases (in quotation marks) anywhere in the document. In subsequent steps, the search criteria were narrowed to the presence of the aforementioned keywords in the title, abstract and keywords. Certain additional limiting criteria were applied. Various types of publications were included in the further analysis. In the Scopus database, the following categories were selected: Article, Conference paper, Book chapter, Book, Editorial. In the Web of Science database, the search criteria were narrowed to: Article, Proceeding Paper, Review Article, Book Chapters, Early Access, Editorial materials, Book. The analysis period was limited to publications from 2010 to 2025.

The preliminary search for terms in both databases was conducted using a combination of the following phrases across the entire document (ALL FIELDS): “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND “artificial intelligence”. The initial selection yielded 3078 records in Web of Science and 1527 records in Scopus. However, a preliminary review of the publications revealed that a significant portion was not directly related to the studied area. To improve relevance and identify publications specifically addressing the topic, the search was narrowed to include documents containing the specified phrases in the titles, abstracts, keywords (TOPIC/TITLE-ABS-KEY: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*”) and across the entire document (AND ALL FIELDS: „artificial intelligence”). A total of 2538 publications were retrieved from Web of Science and 106 from Scopus. The search criteria were then narrowed to include all phrases only in titles, abstracts and keywords. After applying the adopted limiting criteria (document type and publication date), 2260 records remained in Web of Science and 20 publications in Scopus. The results of the successive stages of the publication search are presented in Table 2.

Table 2.
Bibliometric analysis – search results

Stage of analysis	Web of Science	Scopus
<i>1st Research query</i>	ALL FIELDS: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND “artificial intelligence”	ALL FIELDS: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND “artificial intelligence”
Number of article before inclusion criteria	3078	1527
Number of article after inclusion criteria	2677	1426
<i>2nd Research query</i>	TOPIC: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND ALL FIELDS: “artificial intelligence”	TITLE-ABS-KEY: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND ALL FIELDS: “artificial intelligence”
Number of article before inclusion criteria	2538	106
Number of article after inclusion criteria	2261	96
<i>3rd Research query</i>	TOPIC: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND “artificial intelligence”	TITLE-ABS-KEY: “place marketing” OR “place brand*” OR “city brand*” OR “destination brand*” AND “artificial intelligence”
Number of article before inclusion criteria	2537	24
Number of article after inclusion criteria	2260	20

Source: own elaboration based on the Web of Science and Scopus databases.

The bibliometric analysis was based on the results obtained from the third stage of the search. In the first step, files from both databases were downloaded and combined into a single aggregated file containing 2 280 records. Duplicates were then removed and a quantitative and qualitative analysis of the collected material was conducted. The analysis covered the number of publications during the studied period, publication types, main thematic categories and a detailed analysis of keywords. Based on this, a co-occurrence map of terms related to the application of artificial intelligence in place branding was created. The keyword co-occurrence map was generated using VOSviewer software (version 1.6.20). VOSviewer is a tool for creating and visualizing bibliometric networks. The results of the analysis allowed for the identification of thematic clusters representing the main and emerging research directions.

4. Results

In the initial phase of the literature review, an analysis of interest in the topic over the years was conducted. In the Web of Science database, the number of publications steadily increased from 2010, reaching a peak in 2020 with 224 publications. During the analyzed period, the annual number of publications ranged between 140 and 175 until 2025. In 2025,

154 publications were directly related to the studied area. In the Scopus database, relatively few publications directly addressing AI in place branding were identified, with growing interest in the topic only observed from 2020 onwards (Figure 1).

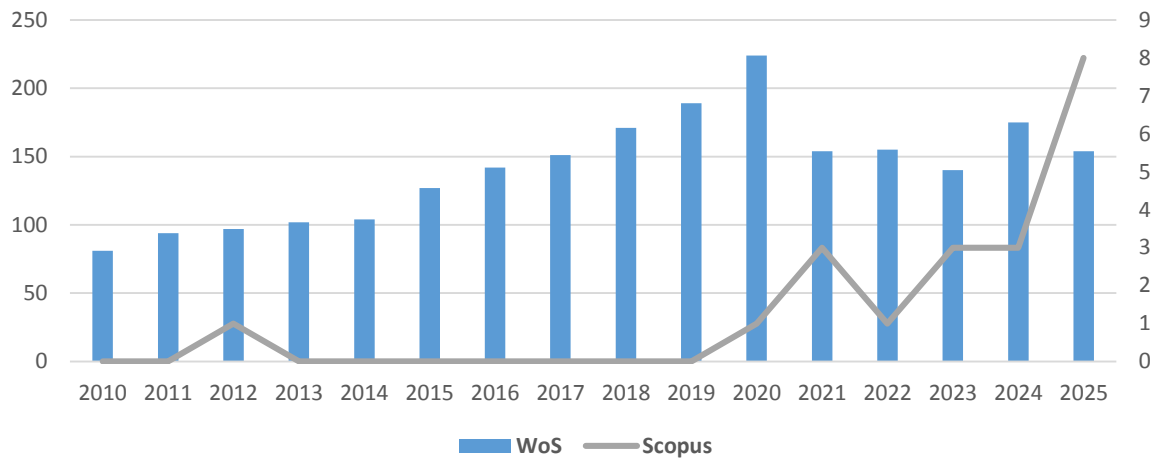


Figure 1. Number of publications in the field of artificial intelligence in place branding in the Web of Science and Scopus databases.

Source: own elaboration based on the Web of Science and Scopus databases.

The total number of citations for publications indexed in Web of Science amounted to 35,995, whereas in Scopus it was 241. In both Web of Science and Scopus, the majority of publications were articles (83.6% and 45%, respectively). A smaller portion consisted of editorial articles, book chapters and books. The distribution of publications by document type is presented in Figure 2.

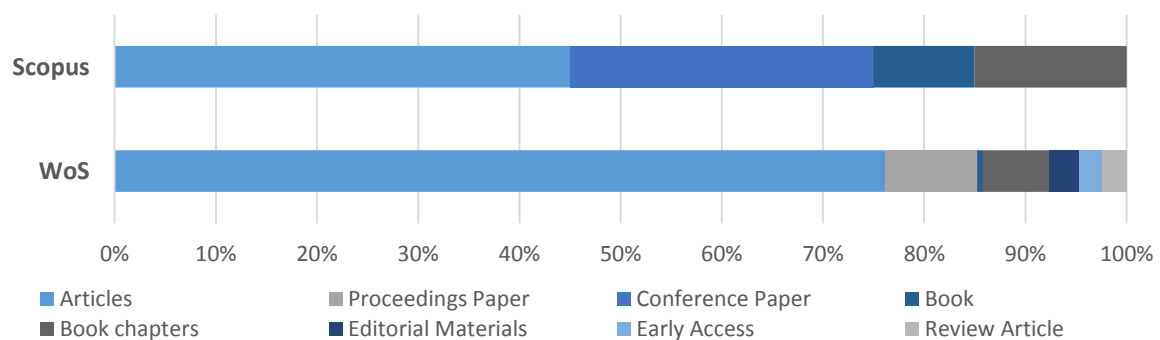


Figure 2. Type of documents of publications in the field of artificial intelligence in place branding in the Scopus and Web of Science databases (indexed from 2010 to 2025).

Source: own elaboration based on the Web of Science and Scopus databases.

The main thematic areas of publications in the Scopus and Web of Science databases were also identified. Initially, publications on artificial intelligence in place marketing and branding were scarce, classifying this area as an “emerging topic.” The majority of publications in the Web of Science database were assigned to the following WoS categories: Hospitality Leisure Sport Tourism (31%), Business (18%), Management (12%) oraz Urban Studies (12%). In the Scopus database, the largest number of publications were assigned to three areas, namely:

Business, Management and Accounting (18,8%), Social Sciences (16,7%) oraz Computer Science (12,5%).

As part of the bibliometric analysis, the most frequently occurring keywords related to artificial intelligence in place branding were identified. For this purpose, VOSviewer software was used. A co-occurrence analysis type was applied, employing the full counting method. The generated dataset initially contained a total of 221 keywords. Phrases used in the search and their abbreviations (e.g., AI), terms unrelated to the subject of analysis or irrelevant (e.g., analysis, method, country names), as well as synonymous terms and unrelated expressions, were subsequently removed. The final set comprised 101 keywords. For visualization, a minimum cluster size of 10 and the association strength method were applied. The keywords and the relationships between them are presented in Figure 3.

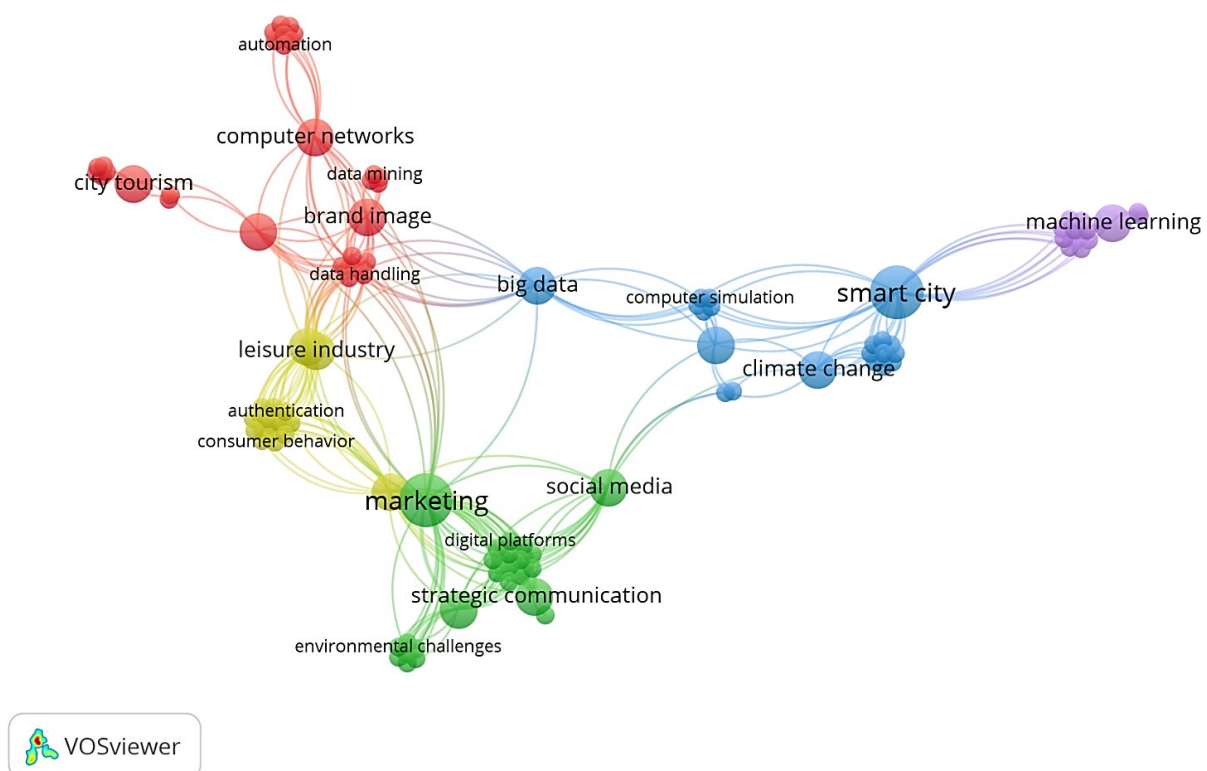


Figure 3. Keyword co-occurrence map of artificial intelligence in place branding.

Source: author's work using VOSviewer software.

Among the keywords related to AI in place branding, the following terms were identified: *marketing, social media, strategic communication, brand image, computer networks, city tourism, smart city, machine learning* and *Big Data*. It should be noted that these terms also exhibit the most connections with other keywords. Among the keywords most frequently appearing in publications from 2025 were: *digital platforms, digital technologies, digital marketing* oraz *sustainable city, environmental challenges, environmental technology, sustainable development*, as well as *authentication, consumer attitudes, data mining* and *local marketing* (Figure 4).

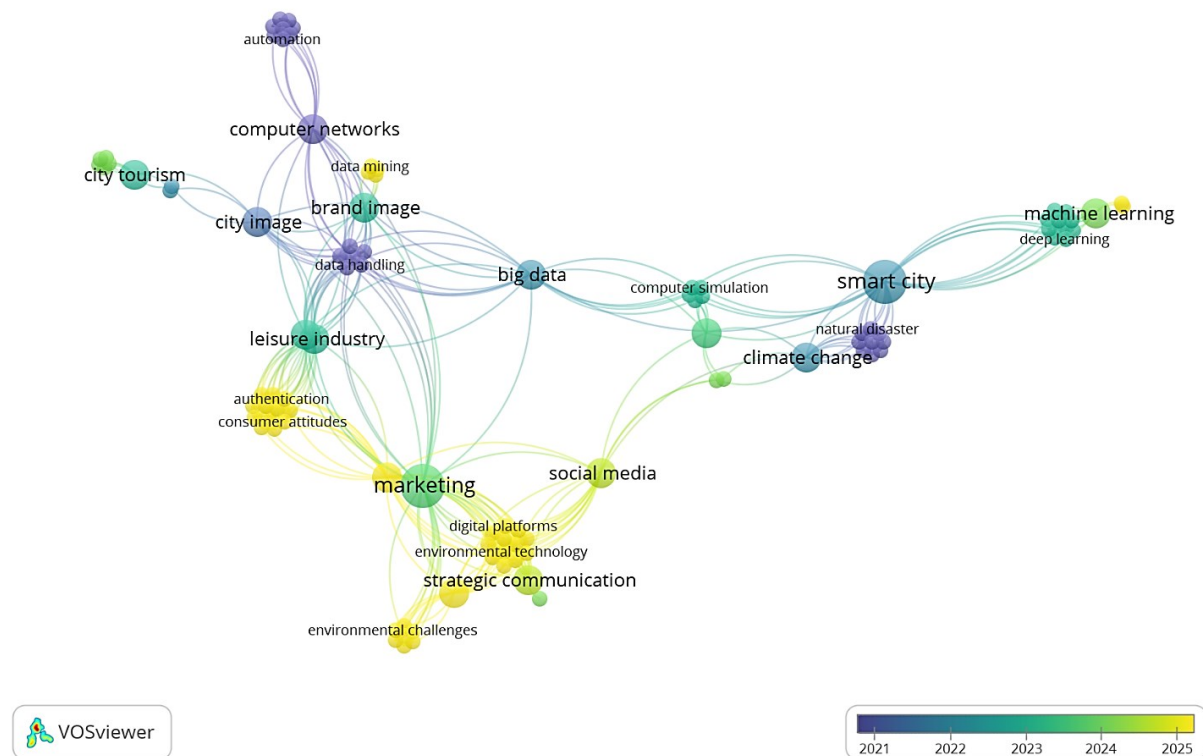


Figure 4. Keyword co-occurrence map of artificial intelligence in place branding.

Source: author's work using VOSviewer software.

The keyword analysis allowed for the identification of five thematic clusters (Table 6).

Table 3.

Thematic clusters of artificial intelligence in place branding

No.	Cluster	Characteristic	Keywords	Examples of publications
1.	<i>Perception of city image and the management of its development in the era of artificial intelligence</i>	The use of AI and data analytics for monitoring the urban environment, detecting emotions and sentiments, analyzing the behavior of residents and tourists and managing the image of cities.	automation, brand image, city image, city of the future and city history, city storytelling, city tourism, computer networks, data handling, data mining, emotion recognition, image evaluation, intelligent monitoring, intelligent robots, living environment, location algorithm, marathon events, multi-source sensing technology, municipal economic development, national fitness, passenger flows, prevention and controls, sensing technology, sentiment analysis, sports, tourist intention, travel motivations, urban construction, urban myth, urban policy and urban development	(Cao et al., 2025; Chen et al., 2024; Klijn et al., 2012)
2.	<i>AI in digital communication and sustainable place branding</i>	The application of digital technologies and AI in place marketing and digital communication on social media, with an emphasis on building place identity, promoting sustainable development, fostering social cohesion	digital diplomacy, digital marketing, digital platforms, digital technologies, electronic commerce, environmental challenges, environmental sustainability, environmental technology, immersive, integrated marketing, marketing, marketing communication, place identity, sense of belonging, social and environmental, social challenges, social	(Alhaddar, Kummitha, 2025; Briana et al., 2025)

		and leveraging digital platforms.	cohesion, social media, strategic communication, sustainability, sustainable city, sustainable development, technology transfer, technology-driven	
3.	<i>Data and artificial intelligence in building the brand of a smart city</i>	The development of global cities and smart cities using big data, computer simulations and AI in urban planning, crisis management, climate change adaptation and the analysis of social perception.	artificially intelligent city, big data, cities, climate change, computer simulation, database, global city, globalization, humans, natural disaster, perception, public perceptions, smart city, smart urban technology, social implication, sustainable urban development, urban informatics, urban planning	(Albayrak Fakioglu, Oguztimur, 2025; AlShaaan, Durugbo, 2025; Lu, 2024)
4.	<i>Virtual and immersive experiences in destination branding</i>	The role of AI, digital avatars and virtual reality in shaping tourist experiences, consumer behavior, the sense of authenticity, as well as social and parasocial relationships.	authentication, consumer attitudes, consumer behavior, cultural authenticity perception, digital humans, economic and social effects, human computer interaction, human engineering, leisure industry, para-social interaction, social interactions, tourism, tourism consumption, tourism industry, virtual reality	(Liu, Andriano-Moore, 2023; Wang, 2025)
5.	<i>Data-driven AI in place marketing and branding</i>	Technological foundations of AI: algorithms, machine learning, neural networks, IoT and networked systems supporting analytics, decision automation and place marketing strategies.	algorithms, artificial neural network, cognitive learning, data-driven decision making, deep learning, distributed networks, electricity design, internet, internet of things, local marketing, machine learning, natural language, networking	(Békési, Szöllősi, 2025; Kamkankaew et al., 2025; Syam, 2025)

Source: author's work using VOSviewer software.

The first cluster “Perception of city image and management of its development in the AI era” focuses on the use of artificial intelligence and advanced data analysis methods for monitoring and interpreting phenomena occurring in urban spaces. It encompasses topics such as emotion recognition, sentiment analysis, city image assessment and the study of resident and tourist behavior based on multi-source data. This cluster integrates sensor technologies, intelligent monitoring systems and data mining tools with the concept of urban narrative management, development policy and urban tourism. It constitutes a key pillar of research on city brand management in the digital environment.

The second cluster “AI in digital communication and sustainable place branding”, relates to the use of digital technologies and AI-based tools in marketing communication processes and place identity building. It emphasizes the role of digital platforms, social media and diplomacy in shaping city image, while simultaneously addressing environmental, social and cultural challenges. This cluster strongly highlights the integration of marketing strategies with the concept of sustainable development and the fostering of a sense of belonging and social cohesion.

The third cluster “Data and artificial intelligence in building the brand of a smart city”, covers topics related to the development of smart cities and global metropolises using big data, computer simulations and AI tools. It focuses on the application of data in urban planning, crisis management, climate change adaptation and social perception analysis. This cluster illustrates how advanced information and analytical systems form the foundation of modern city branding, positioning cities as intelligent, innovative and sustainable entities.

The fourth cluster “Virtual and immersive experiences in destination branding”, concerns the role of artificial intelligence, digital avatars and virtual reality technologies in creating tourist experiences. It encompasses research on tourist behavior, the perception of cultural authenticity, parasocial relationships and human–computer interactions. This cluster points to the growing importance of immersive technologies as tools for building an emotional connection with a place and enhancing the competitiveness of destinations.

The fifth cluster “Data-driven AI in place marketing and branding”, serves as the technological backbone of the entire research area. It focuses on algorithms, machine learning, neural networks, natural language processing and Internet of Things solutions that enable the automation of decision-making and analytical processes in place marketing. This cluster underscores the significance of digital infrastructure and data-driven systems as the foundation for modern, intelligent place marketing strategies.

The role of artificial intelligence in place marketing and branding encompasses supporting management and communication strategies, particularly through digital communication, the implementation of intelligent systems, data analytics and immersive technologies.

5. Discussion and conclusion

Digital place branding concepts focus on promoting the unique identity and attractiveness of a place through a variety of digital marketing tools. The strategic use of digital platforms allows for increasing place recognition, building a positive long-term image and engaging the community (Briana, Malindretos, 2025). Nowadays, digital technologies such as artificial intelligence, augmented and virtual reality (AR/VR), big data analytics, as well as social media and other digital marketing tools, enable the creation of immersive place-related experiences, the personalization of interactions with audiences and the co-creation of a place’s identity. In the context of digital place branding, both increasing visibility and actively engaging the community are considered crucial. This contributes to shaping a positive place image and to building and strengthening relationships with stakeholders based on narrative and authentic communication (Briana, Malindretos, 2025).

Despite growing interdisciplinary interest in the marketing literature, research on the direct application of artificial intelligence in the field of place branding remains insufficiently explored. The integration of artificial intelligence within place branding still constitutes a new, “emerging” research topic and direction, raising a number of questions, particularly regarding the emotional dimension of a place brand.

To date, research has primarily focused on the general applications of generative AI in marketing, while its specific implications for different types of branding, including place branding, remain largely underexplored. According to Davenport et al. (Davenport et al., 2020), in the future, artificial intelligence is likely to significantly transform both marketing strategies and customer behavior. The introduction of generative AI into place marketing and branding therefore presents a range of new challenges that require further in-depth analysis and an interdisciplinary approach. This concerns multiple aspects, such as creativity, alignment with brand identity and the development of long-term stakeholder relationships. As emphasized by Govers, artificial intelligence and social media currently exert a significant influence on the perception of places through the dynamic shaping of opinions. However, according to the researcher, a place brand strategy must remain rooted in the long-term identity and narrative of the place, with all digital technologies serving to express, rather than replace, that identity (How to Future-Proof Digital Communications in Place Branding, 2024).

Artificial intelligence is playing an increasingly important role, particularly in tourism research and practice, leading to changes in traditional methods of data analysis. The applications of AI therefore offer significant potential for strengthening destination branding (Al Balushi et al., 2024). Despite the increasing practical adoption of these technologies, there remains a notable scarcity of empirical studies that directly investigate their influence on destination brand image formation. The existing body of literature highlights the need for more comprehensive and longitudinal analyses of the implications of artificial intelligence for long-term place reputation and identity (Al Balushi et al., 2024). Destination branding should not be approached superficially as a collection of promotional slogans or marketing activities targeted exclusively at tourists. Instead, it should be understood as a strategic process that entails embedding local values, historical narratives and lived experiences within the urban fabric, thereby fostering an authentic brand image rooted in the distinctive identity of a place (Boisen et al., 2018; Briana et al., 2025; Lessa et al., 2025).

Global trends in tourism and place branding are evolving dynamically under the influence of changing consumer preferences, technological advancement and a growing awareness of the importance of sustainable development. A detailed review of the literature indicates an increasing interest in, among other factors, artificial intelligence-driven smart destinations. (ang. *AI-Powered Destination Intelligence*). According to experts, the application of artificial intelligence enables the generation of highly personalized visitor experiences as well as the execution of precise real-time demand forecasting. As a result, destinations can achieve

a significant competitive advantage in the management of tourist flows (Lisa Barrett on Rethinking Tourism at Destination Canada, 2025).

The literature on the future of digital communication in place branding is dominated by the view that artificial intelligence is redefining communication tools and currently underpins fundamental transformations in place brand-building strategies. Experts consistently emphasize that AI-based technologies are already becoming and will continue to be, crucial for the effective personalization of communication, the analysis of audience behavior and the integration of multichannel communication across diverse stakeholder segments, ranging from tourists to investors and residents (How to Future-Proof Digital Communications in Place Branding, 2024).

From the perspective of future directions in the development of artificial intelligence in place branding, several key areas can be identified. First, generative AI enables hyper-personalization and the automated adaptation of content to the individual needs and expectations of audiences. The literature identifies this capability as a critical mechanism for increasing message relevance and enhancing stakeholder engagement. Second, immersive experiences represent a significant and increasingly important domain. The integration of AI with technologies such as virtual reality (VR) and augmented reality (AR) creates new opportunities for presenting places to potential visitors. Through the application of advanced technologies and AI, the attractiveness of place brands is enhanced; for example, tourists may virtually explore destinations prior to making visitation decisions. Third, advanced AI tools facilitate data analysis and trend forecasting, including the modeling of future audience behaviors, thereby enabling proactive adjustments to marketing strategies. The literature further emphasizes that the growing deployment of AI must be accompanied by the preservation of the authenticity of place narratives and the ethical use of data. Failure to maintain this balance may result in the erosion of a place's unique identity and, potentially, its reputation (How to Future-Proof Digital Communications in Place Branding, 2024).

Ultimately, artificial intelligence in place branding holds significant potential to support both precise targeting and the narrative coherence of place brands within a complex digital environment (How to Future-Proof Digital Communications in Place Branding, 2024; Kavaratzis, 2024). In the context of destination brand building, artificial intelligence can support, for instance, the generation of insights, the personalization of communication, the analysis of audience perceptions and the examination of strategic data (Al Balushi et al., 2024). Despite its numerous advantages, experts emphasize that artificial intelligence in place branding remains a supportive tool rather than a substitute for human creative input (Hakala, 2025; Kavaratzis, 2024). While algorithms can generate multiple options, it is ultimately human actors who shape the final form of place branding strategies and brand narratives (*Bloom Consulting: Artificial Intelligence and the Future of Place Branding*, 2025). Artificial intelligence continues to face certain limitations in capturing human tone, historical depth and contemporary cultural context. This underscores the necessity of maintaining a balance between

automation and human interaction in the creative process. The future of place brand building will be determined by the extent to which data-driven artificial intelligence is integrated with authenticity and human sensibility. By leveraging AI-based tools, cities may strengthen their brand image while simultaneously building global reputation and a distinctive local identity (*Bloom Consulting: Artificial Intelligence and the Future of Place Branding*, 2025).

As indicated by Lessa et al. (Lessa et al., 2025) future research directions in place branding should encompass the expansion of methodological approaches, including the application of new technologies, artificial intelligence and big data analytics, which enable the creation of even more personalized and engaging experiences. Chen et al. (Chen et al., 2024) in turn, emphasize that in assessing urban competitiveness, effective AI-driven analytics requires a structured and systematic approach. Chotisarn i Phuthong (Chotisarn, Phuthong, 2025) argue that, in advancing the understanding of contemporary dynamics in place branding, further progress is increasingly associated with the implementation of artificial intelligence tools. An expanding body of research further suggests that effective planning and evaluation of place branding strategies require the integration of qualitative and quantitative data with AI-based analytical instruments. Such an approach has the potential to enhance analytical precision and to provide a methodological framework for adaptive place marketing strategies grounded in empirical data and responsive to the dynamic changes of the urban context (Békési, Szöllősi, 2025). In turn, Kavaratzis (Kavaratzis, 2024), drawing on content generated by ChatGPT, indicates that the application of artificial intelligence and data analytics in the development of personalized place branding strategies requires maintaining a balance between technological efficiency and the preservation of the human and authentic character of communication.

The literature review identified five key thematic areas shaping the current academic discourse on the application of artificial intelligence in place and city branding. First, research increasingly focuses on the perception of city image and its management through AI-based analytics, including sentiment analysis, monitoring of digital narratives and behavioral analysis of residents and tourists. Future studies should examine the reliability of AI-driven perception analysis and its long-term implications for city brand management.

Second, the literature highlights the role of AI in digital communication and sustainable place branding, where AI-supported tools enhance stakeholder engagement and personalized communication across digital platforms. Future research may explore how AI-driven communication strategies influence trust, civic participation and the promotion of sustainable urban narratives.

Third, studies on AI and data in smart city branding emphasize the integration of big data and AI in urban governance, planning, and crisis management, contributing to the positioning of cities as innovative and technologically advanced. Further research should investigate the relationship between smart city development and city brand competitiveness.

Fourth, the growing importance of virtual and immersive experiences in destination branding is evident, as technologies such as virtual reality and AI-generated environments shape tourist engagement and perceptions of authenticity. Future studies could explore how immersive technologies influence emotional connections with destinations and visitor behavior.

Finally, research highlights the technological foundations of data-driven AI in place marketing, including machine learning and IoT systems supporting advanced analytics and decision-making. Future research should address issues of transparency, algorithmic bias and ethical governance in AI-driven place branding.

Based on the findings of this review, further research is needed to conduct a more in-depth investigation of generative artificial intelligence applications in shaping and managing the brands of various categories of places. Additionally, there is a need to develop analytical frameworks to assess AI's impact on the coherence and authenticity of place brand communication, as well as on brand image perception among key stakeholders. From a practical perspective, these findings offer guidance for city authorities and branding managers on how to leverage AI technologies to design innovative, data-driven city branding strategies.

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ENTREPRENEURIAL COMPETENCIES OF GENERATION ALPHA: AN EXPLORATORY MIXED-METHODS STUDY OF STUDENT SELF-ASSESSMENTS AND EDUCATOR PERSPECTIVES

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Purpose: To pilot-test an age-appropriate diagnostic instrument for the quantitative self-assessment of entrepreneurial competencies among Generation Alpha students, in order to improve quality assurance in primary and lower secondary schools (ISCED levels 1 and 2).

Design/methodology/approach: We used a convergent mixed-methods design, integrating three data streams: (1) a random-sample, regionally representative student survey ($N = 247$), (2) a purposive teacher rating study ($N = 28$), and (3) qualitative focus group interviews with educator-experts ($N = 5$). The core analytical strategy was rank-profile concordance (Spearman's ρ , Kendall's τ -b) comparing within-source patterns and avoiding invalid cross-group mean comparisons.

Findings: First, the study provides evidence of a curricular imbalance in pedagogical focus in the studied region: competencies related to resource management rank highest, those related to value creation rank lowest. Second, student self-assessment yields internally consistent and diagnostically informative rank patterns. High rank-profile convergence (Spearman's $\rho = 0.910$) was found between student and teacher data. Differences in absolute means reflect a "Criteria Gap" rather than simple inflation (students rate self-efficacy; educators rate observed performance).

Research limitations/implications: The educator rating study ($N = 28$) is purposive and not representative. Student and educator samples were unmatched by design, enabling independent system-level triangulation through rank-profile comparison rather than individual-level linkage.

Practical implications: The findings indicate a need to rebalance curricula at ISCED levels 1 and 2. Policymakers and educators should shift from a dominant focus on resource management toward integrating modules for value creation to address the identified weaknesses.

Social implications: The study provides an evidence-based diagnostic approach that separates systemic failures from methodological artifacts and supports data-driven reforms cultivating the entrepreneurial mindset in Generation Alpha.

Originality/value: We present an initial baseline profile of Generation Alpha's entrepreneurial competencies in one Polish region, analyze variation across socio-demographic subgroups, and propose a method addressing the "Assessment Gap" in entrepreneurship education, offering triangulated evidence of the pedagogical imbalance between "Resource Management" and "Value Creation" at ISCED levels 1 and 2.

Keywords: entrepreneurial education, entrepreneurial competencies, generation alpha, self-assessment reliability, assessment gap.

Category of the paper: Research paper.

1. Introduction

The long-standing debate over whether entrepreneurs are born or made has converged on a clear policy position: entrepreneurial competencies can and should be developed through entrepreneurial education (EE). At ISCED levels 1 and 2, policy frameworks define entrepreneurship as acting on opportunities and ideas to create value for others, which broadens the objective beyond venture creation to transversal competencies and an entrepreneurial mindset (Bacigalupo et al., 2016; Council of the European Union, 2018; Joint Research Centre, 2024; Eurydice, 2025).

This shift coincides with the rise of Generation Alpha (born 2010 or later). Extrapolations from older cohorts are unsafe because their formative experiences and learning ecologies differ from those of today's ISCED levels 1 and 2 students (Dimock, 2019; McCrindle, Fell, 2020; Höfrová, Balidemaj, Small, 2024). Evidence on learning preferences and early platform immersion has implications for how EE is designed and delivered to this cohort (Burlacu, Coman, Bularca, 2023; Ofcom, 2024).

Practice in schools has bifurcated into two approaches competing for scarce curricular time. One emphasizes resource management (financial literacy, stewardship, sustainability). The other emphasizes value creation (opportunity recognition, innovation, problem finding and solving to generate social, cultural or economic value). Reviews indicate that resource management content is often over-represented relative to value creation despite the holistic scope of the EntreComp framework (Bacigalupo et al., 2016; Eurydice, 2025; Morris, Liguori, 2016). Without a cohort-specific baseline for Generation Alpha and a valid diagnostic strategy, policymakers cannot tell whether observed weaknesses are systemic or artifacts of measurement.

This study targets two connected gaps. First, the thematic gap: we provide a baseline profile of Generation Alpha's self-perceived entrepreneurial competencies at ISCED levels 1 and 2 in Poland's West Pomeranian Voivodeship. Second, the diagnostic gap: we implement a convergent mixed-methods design triangulating student self-assessments with educator ratings and educator focus groups and evaluate whether rank-profile patterns replicate across sources. This design separates curricular problems from differences in rating criteria and yields actionable implications for rebalancing EE at ISCED levels 1 and 2.

2. Literature review

The integration of entrepreneurial education (EE) into compulsory schooling has become a sustained policy priority for international bodies (Carvalho et al., 2022; Lackéus, 2015). Within the European Union, the competence of initiative and entrepreneurship is included among the eight key competences for lifelong learning (Council of the European Union, 2018), reflecting the view that EE develops transversal abilities such as creativity and adaptability (Eurydice, 2025; Lackéus, 2020).

At the primary and lower-secondary stages (ISCED levels 1 and 2), the literature identifies a substantive shift in emphasis (Fidan, Arıç, 2022; Moberg, 2014). The target has shifted away from venture creation or technical instruction on how to found a firm and toward cultivating an entrepreneurial mindset (European Commission, 2016), including dispositions such as initiative, self-efficacy and resilience (Council of the European Union, 2018).

The central reference for this broader conception is the European Entrepreneurship Competence Framework (EntreComp) (Bacigalupo et al., 2016). In this framework, entrepreneurship is understood as acting on opportunities and ideas to create value for others (Joint Research Centre, 2024). By recognizing financial, cultural and social forms of value, EntreComp positions EE beyond narrow commercial aims and aligns it with pro-social educational goals (OECD, 2021; Bisanz et al., 2019).

Despite convergence on aims and definitions, implementation remains uneven (OECD, 2021). Cross-national reviews continue to note a policy-practice gap, with practical entrepreneurial experiences frequently treated as optional or placed outside the core timetable (Eurydice, 2025). This incomplete transition toward mindset-oriented EE at ISCED levels 1 and 2 coincides with the emergence of a new cohort in schools: Generation Alpha.

2.1. Cohort specificity at ISCED levels 1 and 2: Generation Alpha versus Generation Z

A significant limitation in the current entrepreneurial education literature is the reliance on data extrapolated from older cohorts, primarily Generation Z (born c. 1997-2012) (Dimock, 2019). It is methodologically unsound to apply findings from Generation Z to the cohort now populating ISCED levels 1 and 2. Generation Alpha requires a new baseline profile (McCrindle, Fell, 2020), since this cohort was born entirely within the 21st century and lacks a pre-digital frame of reference. While Generation Z are often described as digitally native, Generation Alpha has experienced continuous exposure to touchscreens and voice assistants from early childhood (GWI, 2023).

The formative life events for these cohorts differ in substantive ways. Generation Z's views were shaped by the 2008 economic recession, whereas Generation Alpha's experience is defined by the COVID-19 pandemic (World Bank, UNESCO, UNICEF, 2021). The pandemic normalized technology-mediated education and social interaction, reinforcing distinct

preferences for highly visual, interactive, gamified and micro-content formats (Burlacu, Coman, Bularca, 2023).

Generation Alpha is also the first AI-native cohort, engaging with generative AI as part of the everyday environment rather than as a discrete tool (Ofcom, 2024; Cassandra Report, 2022). This profile has implications for entrepreneurial competencies such as opportunity recognition. Recent evidence points to high digital literacy alongside early interest in entrepreneurial activities (Tassin, Briggs, 2025). Industry reporting suggests this interest is reinforced by creator-economy dynamics in which digital influencers function as entrepreneurial role models (Visa, 2023; GoHenry, 2024). This combination of characteristics supports a revision of curriculum content and sets up the subsequent debate on curricular emphasis.

2.2. Thematic imbalance in curricula: resource management vs. value creation

While EntreComp promotes a holistic set of 15 competencies, reviews of implementation point to a thematic split. In practice, two camps compete for limited space in the ISCED levels 1 and 2 curriculum, reflecting an unresolved debate about the primary purpose of entrepreneurial education.

Camp 1, Resource Management, treats EE as a set of prudential life skills for stewarding existing assets. It is dominated by financial literacy initiatives and sustainability themes that stress responsible management of ecological resources. These strands are often mandated and align with established assessment traditions (Brookings Institution, 2022; Consumer Financial Protection Bureau, 2019). The practical outcome is preparation for responsible management within existing systems.

Camp 2, Value Creation, aligns with EntreComp's generative orientation and presents EE as a transformative mindset aimed at producing new value. Curricular emphasis falls on opportunity recognition and innovation, alongside creating social, cultural or environmental value rather than focusing solely on profit (Morris, Liguori, 2016; Tapsell, Woods, 2010; Joint Research Centre, 2024). This approach positions students as proactive agents who identify problems and deliver solutions for others.

The 2025 Eurydice report offers comparative evidence of imbalance between these camps. Knowledge-oriented abilities, such as financial and economic literacy associated with Camp 1, are widely represented, whereas skill- and attitude-oriented abilities central to Camp 2, including vision and coping with uncertainty, are comparatively underrepresented. This pattern is consistent with path-dependent systems that favor instruction and testing of concrete knowledge while struggling to assess abstract, non-linear competencies. Policy analyses similarly point to structural constraints that impede adoption of such competencies at ISCED levels 1 and 2 (Eurydice, 2025; OECD, 2021). This diagnosis motivates a careful reconsideration of how imbalance is measured and which assessment approaches should be trusted.

2.3. Assessment approaches and validity threats in entrepreneurial education

Assessment remains a persistent challenge in entrepreneurial education (OECD, 2021). Beyond the general difficulty of assessing abstract competencies such as creativity (Bacigalupo et al., 2016), the field is divided over which source to privilege: student self-perception or educator observation.

Approach A, student self-assessment (QUAN-S), dominates quantitative work. It is grounded in social cognitive theory and the theory of planned behavior (Bandura, 1986; Ajzen, 1991). Evidence consistently links entrepreneurial self-efficacy to entrepreneurial intention (Krueger, Reilly, Carsrud, 2000; Wu et al., 2022; Zhao, Seibert, Hills, 2005). Subsequent models corroborate this link, and self-assessment instruments are widely used to forecast intentions (Lüthje, Franke, 2003; Liñán, Chen, 2009; López-Núñez et al., 2022).

Approach B underscores a fundamental limitation of self-reports. While suitable for intentions, self-ratings are weak proxies for actual competence. Studies document a perception gap between student and educator assessments (QUAN-T), with systematic overestimation by students, frequently interpreted via the Dunning-Kruger effect (Kruger, Dunning, 1999).

This divergence has clear methodological implications. Direct mean comparisons across sources are inappropriate without establishing construct equivalence; otherwise, results may be misleading. Recommended practice is to adopt designs that move beyond mean differences and respect the distinct criteria used by each source (Linn, McLaughlin, Thissen, 2009; Jones, Thissen, 2006).

2.4. Synthesis and research gaps: thematic and diagnostic gaps motivating the design

The reviewed literature combines strong policy and theoretical foundations with two interlinked gaps that demand a specific empirical response.

The first is the Thematic Gap. A persistent two-camps debate is accompanied by comparative evidence of imbalance in European curricula, where Resource Management (for example, financial literacy) tends to dominate over Value Creation (for example, vision) (Eurydice, 2025; Lackeus, 2015). For the cohort now in ISCED levels 1 and 2, a cohort-specific baseline of entrepreneurial competencies is still missing. It remains unclear how Generation Alpha's characteristics – including early interest in entrepreneurial activities and informal creator-economy learning – relate to this pattern (Visa, 2023).

The second is the Diagnostic Gap. Studies repeatedly show a misalignment between student self-perceptions (QUAN-S) and educator assessments (QUAN-T), with consistent evidence of self-report inflation. Existing designs rarely reconcile the two sources to determine whether observed gaps reflect genuine weaknesses or measurement artifacts.

A targeted mixed-methods design follows logically. To address the Thematic Gap, surveys of Generation Alpha students (QUAN-S) using age-appropriate instruments can build the first baseline profile. To address the Diagnostic Gap, their data should be triangulated with educator

ratings (QUAN-T). Because direct mean comparisons are inappropriate without establishing construct equivalence, analysis should rely on rank-based concordance to test whether both sources share the same competency pattern even when levels differ (Linn, McLaughlin, Thissen, 2009; Jones, Thissen, 2006). Qualitative educator insights (QUAL-T) then complete the triangulation by explaining why the observed patterns emerge (Krueger, Casey, 2014; Hennink, Kaiser, Weber, 2019).

In sum, the literature supports a mixed-methods study that (a) establishes a baseline for Generation Alpha's entrepreneurial competencies, (b) diagnoses the two-camps curricular imbalance in practice, and (c) reconciles the assessment gap through rank-based comparisons combined with qualitative educator evidence.

3. Research methodology

We employed a convergent mixed-methods design for diagnostic triangulation (Creswell, Plano Clark, 2018; Fetters, Curry, Creswell, 2013), integrating three independent evidence streams collected in the 2022/2023 academic year in Poland's West Pomeranian Voivodeship, providing an early post-pandemic baseline for regional entrepreneurship education: a random-sample, regionally representative student survey of primary and lower secondary school pupils (QUAN-S), a purposive teacher rating study (QUAN-T), and educator focus-group interviews (QUAL-T). Across components, educator data were treated as contextual and explanatory. Samples were independent and unmatched. Therefore, we did not perform cross-group tests of level differences. Cross-source alignment was examined only as within-source rank profiles rather than through level comparisons.

3.1. Student survey (QUAN-S)

The student survey used a structured questionnaire administered in 2022 to primary-school pupils from Generation Alpha (born 2010 or later). The overall survey examined three domains of entrepreneurial education among direct recipients of educational services: (1) satisfaction with the quality of entrepreneurial education, (2) entrepreneurial attitudes and intentions, and (3) entrepreneurial competencies. The present article reports results for domain (3), entrepreneurial competencies. This article forms part of a broader research programme, with complementary analyses of entrepreneurial attitudes and intentions reported elsewhere (Tsimayeu, Michalcewicz-Kaniowska, Mickiewicz, 2025; Tsimayeu, 2023).

The questionnaire included 24 items, with 18 core items and six sociodemographic variables. To ensure construct validity and alignment with European standards, the survey items were adapted from the field-tested YouthStart framework, pedagogically grounded in the TRIO model (Bisanz et al., 2019), and aligned with EntreComp (Bacigalupo et al., 2016).

The target population consisted of students aged 7 to 12 enrolled in grades 2 to 6. A simple random sampling method was applied. Inclusion criteria were residence in the study region and attendance at the same school for at least 12 months. In total, $N = 259$ students participated, with valid competency data for $n = 247$ (response rate 95.4%).

Data were collected via paper-and-pencil interviewing (PAPI) under the supervision of trained researchers. Items used age-appropriate phrasing, simplified syntax and accessible vocabulary. To support engagement and reduce stress, response options were presented with a star-based visual scale mapped to numeric values 1-7.

Each of the 18 items assessing entrepreneurial competence and knowledge was rated on a 7-point Likert-type scale with item-specific anchors aligned to the stem. Depending on the item, anchors ranged from “definitely cannot” to “definitely can”, “definitely do not know how” to “definitely know how”, or “definitely not” to “definitely yes”. All items were keyed in the positive direction so that higher values indicate greater self-assessed competence or knowledge.

A pilot study with 26 students assessed clarity and usability. Minor wording adjustments were implemented. Internal consistency for the competencies scale in the main study was high, Cronbach’s alpha, $\alpha = 0.90$.

3.2. Teacher rating study (QUAN-T)

In the same academic year, a parallel teacher questionnaire was administered to a purposive (convenience-based) case sample of primary-school teachers in the West Pomeranian Voivodeship ($N = 28$; five schools). Recruitment proceeded through collaborating schools. Reachable and willing teachers participated. The instrument replicated the 18 student items with wording adapted for teachers to rate observed pupil competence on the same 1-7 anchors, ensuring construct alignment while reflecting a different rater perspective (Creswell, Plano Clark, 2018). The teacher component is non-representative by design and serves a diagnostic function: to check rank-profile replication and to provide quantitative context for themes identified qualitatively.

3.3. Focus group interviews with educators (QUAL-T)

To explain quantitative profiles and illuminate mechanisms, focus group interviews were conducted with five primary-education practitioners from the region, including a school principal and classroom teachers. This small, purposive sample was designed to provide illustrative contextual insights rather than statistically generalizable evidence. Discussion blocks covered assessment of pupils’ entrepreneurial competencies and satisfaction, integration of entrepreneurship across subjects, availability and relevance of teaching materials, constraints and change levers, examples of good practice, and a structured brainstorm that included problem formulation, idea generation and deliberation. Excerpts and synthesized statements in joint displays are tagged as explicit support or analytic inference.

3.4. Analytical strategy and integration

Rank-profile alignment. Item means were converted to within-source ranks (1 = strongest). Alignment between independent sources was summarized with Spearman's ρ and Kendall's τ -b, both computed from the 18 paired mean scores using standard tie-corrected mid-ranks for ties, as descriptive profile-alignment metrics for all 18 items. These coefficients assess convergence of patterns rather than equality of levels. Accordingly, no cross-source t tests, ANOVA or regressions were conducted on unmatched samples (Jones, Thissen, 2006).

Joint display integration. A rank-only joint display was constructed using a pre-specified rule to select five focal themes: two High-high, two Low-low, and one Divergence defined as the largest absolute rank difference. For each theme, the display juxtaposes the student rank, the teacher rank, a concise focus-group excerpt or synthesis, and a one-line curricular implication. This integrates QUAN-S, QUAN-T and QUAL-T and informs the Discussion (Creswell, Plano Clark, 2018; Fetters, Curry, Creswell, 2013).

4. Empirical results

The sample of 247 primary-school students was balanced by gender and covered all targeted age and grade groups, including both urban and rural areas of varying sizes (Table 1). For reporting, respondents are grouped into four grade-level cohorts (grades 2-3, 4, 5, 6) and four age cohorts (7-9, 10, 11, 12 years). Older students constituted the largest proportion of the sample, which is consistent with regional demographic patterns (Statistics Poland, 2022).

Table 1.
Demographic profile of the student sample (N = 247)

Indicator	Options	Frequency (%)
Gender	Girl	48.58
	Boy	51.42
Age	7-9 years	20.65
	10 years	19.03
	11 years	27.53
	12 years	32.79
Place of Residence	Village	23.08
	Small town ($\leq 50k$)	30.77
	Medium city (51k-300k)	23.48
	Large city ($\geq 300k$)	22.67
Grade	2-3 grade	16.60
	4th grade	23.89
	5th grade	22.67
	6th grade	36.84

Note. Percentages are based on valid responses.

Source: Own study.

Table 2 reports item-level self-perceived entrepreneurial competencies across three domains. The overall mean across all 18 items was 4.89. Domain means were 4.72 for Developing ideas, 4.86 for Implementing ideas, and 5.29 for Thinking sustainability. The highest item means were 3.1.1 “I understand the importance of environmental protection” (5.58) and 3.2.2 “I can plan how to spend my pocket money” (5.53). The lowest item means were 1.2.1 “I can identify social problems and develop ideas to solve them” (4.31), 1.1.3 “I can explain what determines the price level of products in a shop” (4.32), and 1.2.2 “I can collect a set of ideas and record them in a notebook” (4.40). Subdomain means followed the same pattern, with higher scores for 3.1 Acting as a visionary (5.44) and 3.2 Financial literacy (5.15), and lower for 1.2 Identifying opportunities (4.63).

Table 2.

Entrepreneurial competencies of students (N = 247)

Area	Chapter	Code	Competency /Skill	Mean
1. Developing ideas	1.1 Attitude	1.1.1	I can identify areas in which I am good.	5.27
		1.1.2	I can focus on successfully completing my task.	4.98
		1.1.3	I can explain what determines the price level of products in a shop.	4.32
		1.1.4	I can reflect on my future education and future job.	4.69
	1.2 Identifying opportunities	1.2.1	I can identify social problems and develop ideas to solve them.	4.31
		1.2.2	I can collect a set of ideas and record them in a notebook.	4.40
		1.2.3	I can present my own ideas.	4.79
		1.2.4	I can recognize risks in everyday life and think about how to avoid them.	5.02
2. Implementing ideas	2.1 Organising	2.1.1	I can plan my time during the day.	5.04
		2.1.2	I can give examples of limited materials that we should save.	4.64
		2.1.3	I can plan goals and make decisions about how to achieve them.	4.59
		2.1.4	I can create a new useful object from available materials (such as "useless" waste or leftover materials).	4.63
	2.2 Working together	2.2.1	I can work with others as part of a team.	5.33
		2.2.2	I can negotiate responsibilities and solve potential problems when cooperating with others.	4.92
3. Thinking sustainability	3.1 Acting as a visionary	3.1.1	I understand the importance of environmental protection for our lives.	5.58
		3.1.2	I am aware of issues related to energy saving, protection of animals and plants, and I reflect on how I can contribute to solving these problems.	5.29
	3.2 Financial literacy	3.2.1	I can explain and compare the prices of products in a shop.	4.76
		3.2.2	I can plan how to spend my pocket money.	5.53

Note. Items were rated on a 1-7 Likert-type scale. Higher values indicate greater self-assessed competence or knowledge.

Source: Own study.

Table 3 summarises mean self-perceived competencies across key socio-demographic groups. In most groups, domain means follow the ordering: Thinking sustainability > Implementing ideas > Developing ideas; two exceptions are noted (Grade 6 and “Parents have higher education: No”). Gender differences are small. The overall mean is M = 4.85 for girls

and $M = 4.93$ for boys ($\Delta = 0.08$). By place of residence, the lowest overall mean appears in large cities $\geq 300k$ (4.70) and the highest in medium cities 51k-300k (5.00). Villages and small towns lie between at 4.95 and 4.92. Grade-level patterns are non-monotonic. Grades 2-3 have the highest overall mean (5.11). Scores dip in grade 4 (4.65) and recover by grade 6 (5.03). Family background aligns with clear gradients. Students reporting parental entrepreneurship average 5.07 compared with 4.90 among those reporting no such background, with the lowest values in the “I don't know” group (4.59). For parental education, overall means are 5.11 for “Yes, both”, 5.06 for “Yes, one”, 5.05 for “No”, and 4.57 for “I don't know”.

Table 3.

Entrepreneurial competencies by socio-demographic group (N = 247)

Indicator	Options	Developing ideas	Implementing ideas	Thinking sustainability	Overall mean
Gender	Girl	4.66	4.78	5.35	4.85
	Boy	4.78	4.93	5.24	4.93
Place of Residence	Village	4.78	4.91	5.38	4.95
	Small town ($\leq 50k$)	4.77	4.84	5.33	4.92
	Medium city (51k-300k)	4.87	4.96	5.31	5.00
	Large city ($\geq 300k$)	4.46	4.73	5.13	4.70
Grade	2-3 grade	4.94	5.10	5.48	5.11
	4th grade	4.40	4.71	5.05	4.65
	5th grade	4.58	4.71	5.29	4.78
	6th grade	4.93	4.93	5.38	5.03
Parents started a company?	No	4.73	4.89	5.27	4.90
	I don't know	4.38	4.54	5.08	4.59
	Yes	4.92	5.00	5.47	5.07
Parents have higher education	No	4.89	4.88	5.60	5.05
	I don't know	4.33	4.53	5.09	4.57
	Yes, one	4.93	5.04	5.36	5.06
	Yes, both	4.99	5.09	5.40	5.11

Note. Entries are item means. Items were rated on a 1-7 Likert-type scale. Higher values indicate greater self-assessed competency or knowledge. Overall mean is computed across all 18 items.

Source: Own study.

Table 4 summarizes rank-order profiles for the 18 competency items from two independent sources: the student self-perception survey (QUAN-S, $N = 247$) and the teacher ratings (QUAN-T, $N = 28$). Within each source, item means were converted to ranks with 1 as the highest. The table reports the paired ranks and the absolute rank difference. Concordance is strong (Spearman's $\rho = 0.910$; Kendall's $\tau-b = 0.779$). The mean absolute rank difference is 1.61 and the median is 1. These results indicate close agreement in relative ordering rather than equality of levels and prepare the ground for the focused comparison in Table 5.

Table 5 provides the central diagnostic integration for this study, integrating the quantitative ranks from the student self-assessment (QUAN-S, $N = 247$) and the educator ratings (QUAN-T, $N = 28$) with a single qualitative synthesis column derived from the educator focus groups (QUAL-T, $N = 5$). This joint display structures the findings by selecting five focal themes based on rank concordance: the two competencies with the highest shared ranks (high-

high), the two with the lowest shared ranks (low-low), and the single competency demonstrating the largest absolute rank difference (divergence).

The high-high category captures shared strengths, for example in “pocket-money planning” (3.2.2) and “environmental protection” (3.1.1). Conversely, the low-low category records shared weaknesses, for example in “identifying social problems” (1.2.1) and “price formation” (1.1.3). The divergence theme isolates “time planning” (2.1.1), where students rank the skill higher than teachers (for example, students rank 6; teachers rank 11). These specific rank pairings (for example, ranks 2 vs 1 for 3.2.2; ranks 18 vs 18 for 1.2.1) represent the strongest points of consensus at the top and bottom of the 18-item profile. This 5-rank gap for “time planning” (2.1.1) is also the maximum absolute divergence observed across all items, pinpointing it as the primary area of non-consensus.

Table 4.

Rank-order profile of entrepreneurial competencies: students vs teachers

Code	Skill/Competency	Students		Teachers		Δrank
		Mean	Rank	Mean	Rank	
3.1.1	I understand the importance of environmental protection for our lives.	5.58	1	4.61	3	2
3.2.2	I can plan how to spend my pocket money.	5.53	2	4.64	1	1
2.2.1	I can work with others as part of a team.	5.33	3	4.46	4	1
3.1.2	I am aware of issues related to energy saving, protection of animals and plants, and I reflect on how I can contribute to solving these problems.	5.29	4	4.46	4	0
1.1.1	I can identify areas in which I am good.	5.27	5	4.64	1	4
2.1.1	I can plan my time during the day.	5.04	6	3.86	11	5
1.2.4	I can recognize risks in everyday life and think about how to avoid them.	5.02	7	4.29	7	0
1.1.2	I can focus on successfully completing my task.	4.98	8	4.43	6	2
2.2.2	I can negotiate responsibilities and solve potential problems when cooperating with others.	4.92	9	3.79	13	4
1.2.3	I can present my own ideas.	4.79	10	4.14	8	2
3.2.1	I can explain and compare prices of products in a shop.	4.76	11	4.11	9	2
1.1.4	I can reflect on my future education and future job.	4.69	12	3.82	12	0
2.1.2	I can give examples of limited materials that we should save.	4.64	13	3.96	10	3
2.1.4	I can create a new useful object from available materials (such as “useless” waste or leftover materials).	4.63	14	3.79	13	1
2.1.3	I can plan goals and make decisions about how to achieve them.	4.59	15	3.71	15	0
1.2.2	I can collect a set of ideas and record them in a notebook.	4.40	16	3.46	17	1
1.1.3	I can explain what determines the price level of products in a shop.	4.32	17	3.61	16	1
1.2.1	I can identify social problems and develop ideas to solve them.	4.31	18	3.04	18	0

Note. Items were rated on a 1-7 Likert-type scale. Ranks are computed within each source with 1 as the highest rank and use standard competition ranking for ties (identical integer rank for tied means) for ease of presentation; Spearman's ρ and Kendall's τ -b are based on tie-corrected mid-ranks. Descriptive concordance across 18 items: Spearman's $\rho = 0.910$, Kendall's τ -b = 0.779, median |Δrank| = 1, mean 1.61, maximum 5. Concordance refers to relative ordering, not absolute levels. Teachers' data are diagnostic and are not used for inferential cross-group comparisons.

Source: Own study.

The final column, Qualitative synthesis, operationalizes the triangulation by tagging educator evidence as Explicit (direct statements or data) or Analytic (convergent inference by the researchers), as noted in the table note. It also distils educator insights into one-sentence, practice-focused implications. The display confirms alignment at the top and bottom of the competency profile and highlights one discrepancy in ratings.

Table 5.

Joint display of focal themes across sources (students $N = 247$; teachers $N = 28$)

Code	Theme	Rank (students)	Rank (teachers)	Rank profile category	Qualitative synthesis (QUAL-T; focus group interviews)
3.2.2	Pocket-money planning	2	1	high-high	Explicit: Financial-literacy routines at home and school, supported by savings and banking programs, make budgeting easy to practise. Implication: Extend from budgeting to comparison shopping and opportunity-cost tasks.
3.1.1	Environmental protection	1	3	high-high	Explicit: environmental awareness leads in teacher ratings. Analytic: cross-subject sustainability activities sustain frequent practice. Implication: use this platform for local value-creation projects.
1.2.1	Identifying social problems	18	18	low-low	Explicit: Lowest teacher score for spotting social problems and developing solutions. Analytic: Students need scaffolds to turn issues into projects. Implication: add problem-framing and idea-to-prototype steps.
1.1.3	Price formation	17	16	low-low	Explicit: Near-bottom ratings for understanding price drivers. Analytic: Abstract mechanisms are seldom practised due to material gaps. Implication: start from concrete receipt and shop simulations.
2.1.1	Time planning	6	11	divergence	Explicit: Goal-setting is weak in teacher ratings within Organising while students self-rate time planning higher. Analytic: Educators suggested that rigid school routines may be conflated with active planning skills.

Note. Ranks are computed within each source (1 = highest). The table integrates QUAN-S (students $N = 247$), QUAN-T (teachers $N = 28$) and QUAL-T (focus group interviews, $N = 5$). Evidence tags: Explicit = direct teacher data or interview statements; Analytic = convergent inference. Teacher data are diagnostic and not used for cross-group inference.

Source: Own study.

5. Discussion and conclusions

The quantitative and qualitative results of this study provide clear insights into the entrepreneurial competency profile of Generation Alpha, and they offer empirical answers to the central debates identified in the literature.

5.1. The curricular imbalance: resource management vs. value creation

This study provides empirical evidence that contributes to the two-camps debate. Our findings offer convergent, yet preliminary, mixed-methods indications that, in the studied region, the current pedagogical approach at ISCED levels 1 and 2 tends to emphasise competencies associated with Camp 1: Resource Management but gives comparatively less systematic attention to those central to Camp 2: Value Creation.

The competencies representing Camp 1 – namely, sustainability-related and personal financial literacy competencies (for example, 3.1.1 Environmental protection, 3.2.2 Pocket-money planning) – were consistently ranked as the strongest competencies by both students and teachers (Tables 4 and 5). This convergence suggests that the curricular emphasis on these topics, widely documented in policy and reviews (Council of the European Union, 2018; Brookings Institution, 2022), is being effectively translated into perceived student competence. The high ranking of these skills aligns with the traditional structure of primary education, which is well suited to delivering concrete, knowledge-based content such as household budgeting and ecological stewardship.

In stark contrast, competencies central to Camp 2 – the generative skills of identifying opportunities and understanding market mechanisms (for example, 1.2.1 Identifying social problems, 1.1.3 Price formation) – were consistently ranked at the bottom of the profile by both groups. This finding is critical. It empirically confirms the concerns raised by cross-national reports that abstract, skill- and attitude-based abilities such as vision are underrepresented in practice (Eurydice, 2025; Lackéus, 2015). The failure in these areas suggests that impeding educational structures have not yet adapted to teach the proactive, problem-finding mindset advocated by the EntreComp framework (Bacigalupo et al., 2016).

5.2. Reinterpreting the Assessment Gap: Rank Convergence and the Criteria Gap

Beyond the thematic imbalance, this study engages with the debated "Assessment Gap" between student self-assessments and educator judgements. While the literature often attributes higher student scores to self-assessment inflation or Dunning-Kruger-type miscalibration (Kruger, Dunning, 1999; Wisniewski et al., 2022), our findings are consistent with a more nuanced interpretation. Despite independent student ($N = 247$) and educator ($N = 28$) samples, their ratings yield highly congruent rank profiles across the 18 items (Spearman's $\rho = 0.910$; Kendall's $\tau\text{-b} = 0.779$; see Tables 4 and 5). This convergence can be read as being consistent with the idea that discrepancies in absolute levels may, at least in part, reflect a "Criteria Gap" rather than mere measurement noise, although inflation effects cannot be definitively ruled out.

We posit that the two groups assess related but partly distinct constructs: pupils primarily rate their perceived self-efficacy ("I feel I can"), consistent with social cognitive theory (Bandura, 1986) and intention-focused models of entrepreneurship (Lüthje, Franke, 2003; Liñán, Chen, 2009), whereas educators rate observable applied performance ("I see them do").

The divergence in "time planning" (Rank 6 vs. 11) exemplifies this pattern: students are likely to draw on their experience of managing daily routines, while teachers focus on curriculum-based goal setting and sequencing. Thus, rather than being reducible to overconfidence, the observed gaps suggest partially overlapping assessment criteria. We therefore refer to this as the "Criteria Gap" working hypothesis, used here as an exploratory interpretive lens rather than as a statistically tested effect. In this reading, the pattern tentatively points to curricular weaknesses in "Value Creation" in the studied region rather than to mere methodological artefacts, but remains a provisional interpretation that requires verification in future studies using matched student–teacher pairs and designs explicitly contrasting inflation-based and criteria-based explanations (Jones, Thissen, 2006).

5.3. Implications for policy and practice, limitations, and future research

The triangulated findings, which support the interpretation of a curricular imbalance in the studied context and the diagnostic value of the observed gaps, have direct implications for educational policy and practice. A primary policy implication is the need to rebalance the curriculum at ISCED levels 1 and 2, moving away from an exclusive focus on Camp 1: Resource Management and toward the explicit integration of Camp 2: Value Creation skills in line with EntreComp and recent European evidence (Eurydice, 2025). The consensus finding that students are weakest in "identifying social problems" and "price formation" is not an abstract problem, but an actionable diagnostic. It calls for the immediate development and deployment of practical, project-based modules in which students engage in identifying problems and modeling value, extending beyond static ecological and financial literacy content.

However, simply calling for new modules is insufficient if we do not also address the root cause of the imbalance. Our qualitative findings show the imbalance persists because educators lack both (1) reliable diagnostics and (2) a "compendium of solutions" (materials) for specific gaps. Generic calls for project-based modules are insufficient. Policy should prioritise creating a dynamic repository in which specific, age-appropriate (ISCED levels 1 and 2) teaching materials are explicitly mapped to validated competency diagnostics, particularly those aligned with the EntreComp framework exemplified by the instrument piloted in this study.

Several limitations must be acknowledged to properly frame these findings. First, the teacher sample (QUAN-T, $N = 28$) was purposive, non-representative, and intended to diagnose curricular priorities rather than to provide generalisable estimates or to evaluate individual teacher performance. Second, the student ($N = 247$) and teacher samples were independent and unmatched. This methodological choice avoided cross-group mean comparisons on unmatched samples, which restricts the analysis to robust rank-profile comparisons.

These limitations naturally inform a clear agenda for future research. A priority next step is to replicate this study using matched-pair samples, with teachers rating their own specific students, to allow for more granular, multilevel analysis of the criteria gap. Second, a longitudinal study is necessary to track how these competency profiles evolve as Generation Alpha progresses through ISCED levels 1 and 2. Finally, future research should move from diagnostics to solutions by first developing and validating the compendium of solutions and then using quasi-experimental designs to test the efficacy of providing teachers with this integrated system, targeting the Camp 2 priority areas identified in this study.

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SUSTAINABLE FARM MANAGEMENT IN THE CONTEXT OF THE SOCIETY 5.0 CONCEPT – CHALLENGES AND DEVELOPMENT PERSPECTIVES

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Purpose: The purpose of this article is to demonstrate how the ideas of Society 5.0 can be translated into the everyday management of a crop farm and what real benefits and limitations accompany this transformation. The focus is on linking digital tools with the environmental, economic, and social objectives of sustainable development, viewed from the perspective of on-farm practice.

Design/methodology/approach: The study adopts a qualitative–quantitative approach in the form of a case study of a single anonymous crop farm located in the Kujawsko-pomorskie Province of Poland. The analysis is based on the farm’s operational data (crop structure, yields, records of purchases and usage of production means) as well as a structured interview with the farm owner. The research is complemented by a review of the literature and reports on digital agriculture, Society 5.0, and data governance.

Findings: The case study shows that the gradual implementation of digital tools, which is focused on areas generating the greatest losses, makes it possible to achieve measurable environmental and cost-related effects without full farm automation. The greatest benefits resulted from the organization of treatment records (FMIS), the reduction of overlapping passes through the use of GNSS, and better adjustment of fertilization and crop protection to field conditions. Key barriers included costs, user competencies, and the integration and accessibility of data from machines and systems, including the risk of dependence on a single provider.

Research limitations/implications: The findings relate to a single farm and are not representative of the entire sector. The observed effects may have been influenced by external factors such as weather conditions, changes in crop structure, or production means prices. The value of the study lies in illustrating a practical chain: data – decision – implementation – result, which is relevant for further research on the digitalization of agriculture.

Practical implications: The most important solutions are those that shorten decision-making time and reduce losses that are difficult to detect in the short term, such as overlapping passes, repeated treatments, or incomplete records of field operations. In practice, the key issue is not “more technology” but better control of the production process.

Social implications: Within the logic of Society 5.0, technology is intended to serve people by facilitating work, reducing time pressure and the risk of errors, and ordering documentation. The social dimension of sustainability thus translates into greater predictability of work and a reduced administrative burden.

Originality/value: The article links the concept of Society 5.0 with the practice of crop farm management, demonstrating an implementation pathway from data, through decision-making, to measurable environmental, economic, and organizational effects.

Keywords: sustainable agriculture, Society 5.0, digital agriculture, precision agriculture, crop production, data management.

Category of the paper: Empirical research (case study).

Introduction

Sustainable development is one of the key paradigms of the contemporary economy, integrating economic, social, and environmental aspects in order to ensure long-lasting well-being for present and future generations. In agriculture, sustainable farm management is increasingly rarely understood as “environmental protection.” In practice, it means operating in a way that simultaneously maintains economic viability (profitability and liquidity), reduces pressure on natural resources (soil, water, and biodiversity), and ensures social sustainability (work safety, generational continuity, and the stability of rural life) (Wielewska, 2014, pp. 186-195).

In the realities of farm management, these three dimensions often generate decision-making tensions, as cost-effective actions are not always environmentally neutral, and reducing chemical use requires investment and changes in work organization. For this reason, sustainability is not a single figure, but rather a way of “reading” the farm through the lens of data (which can be measured, recorded, and compared) and the consequences of decisions. The better the records of treatments, fertilization, and energy use, the easier it is to reduce losses and risks while maintaining economic viability. Therefore, farm assessment should primarily be based on measures that reflect actual management outcomes, and only in the absence of such data should simplified indicators describing practices or declared objectives be used (FAO, 2013, pp. 3-4, 71). The subject literature identifies as many as 101 indicators of agricultural sustainability, grouped into several thematic categories, which shows that their selection is not neutral and always entails decisions that are important for farm assessment (Bathaei, Štreimikienė, 2023, pp. 1-2). Some Polish studies additionally emphasize that environmental investments (e.g. solutions reducing environmental pressure or investments in renewable energy sources) serve not only an ecological function but also a stabilizing and organizing role in the operation of farms (Wielewska, 2013, pp. 141-150; 2014, pp. 186-195; 2016, pp. 199-206; 2019, p. 105).

In recent years, the classical understanding of sustainability has been increasingly complemented by digital transformation, described, among others, in terms of Society 5.0. In Japanese strategic documents, Society 5.0 is presented as a society that integrates digital and physical spaces in a human-centered manner, in which technology supports the solving of social

and environmental problems (Cabinet Office, Government of Japan, 2021, p. 11). The essence of this concept is not the amount of data, but how it is used in the decision-making process while maintaining the primacy of the human role (Narvaez Rojas et al., 2021, pp. 1-2). In agriculture, digitalization makes sense when it shortens decision-making time, reduces losses and uncertainty, and supports farmers in balancing economic, environmental, and social objectives. In a crop farm, this means that data from fields, machinery, and weather are not an end in themselves, but a tool for improving decision quality – when to enter the field, what rate to apply, where to respond first, and how to document operations without adding unnecessary bureaucracy. This process is accompanied by growing pressure from public policies and the market in Europe. The “Farm to Fork” strategy sets targets for 2030, including a 50% reduction in the overall use and risk of chemical pesticides and at least a 50% reduction in nutrient losses, while also reducing fertilizer use by at least 20% (European Commission, 2020, pp. 7-8). These goals imply a change in management practices for crop farms. Better control of application rates, timing, and treatment outcomes is required – hence better data and a more efficient decision-making process.

It should also be noted that the digitalization of agriculture is not developing evenly. JRC research indicates that although 93% of EU farms use basic digital tools (a computer, the internet, general software), technologies directly related to crop production are implemented much less frequently and to a highly varied extent (from a few to several dozen percent) (Cardona et al., 2025, p. 5). In practice, farmers rarely implement a full package of solutions; more often, they select those that most quickly streamline decision-making and costs.

In summary, Society 5.0 in agriculture makes sense when technologies and data genuinely help farmers run their farms in a way that is simultaneously economically viable, less burdensome to the environment, and more organizationally stable (Breque et al., 2021, p. 9; Whelan, 2007, p. 2).

In this article, it is assumed that the meaning of Society 5.0 in a crop farm is expressed not in the number of technologies used, but in whether or not technology improves decision quality and facilitates the integration of the three pillars of sustainability. The aim of the article is therefore to show how the ideas of Society 5.0 can be translated into the everyday management of a crop farm and what real benefits and limitations accompany such a transformation in the conditions of a farm located in the Kujawsko-pomorskie Province of Poland.

2. Methodology of the case study

The article is based on a case study of a single anonymous crop farm located in the Kujawsko-pomorskie Province of Poland. The empirical material covered data from the 2024/2025 farming year, including crop structure, yield levels, and basic records of purchases

and use of selected production inputs (e.g. mineral fertilizers, plant protection products, fuel/energy). Quantitative analysis of operational data was complemented by a structured interview with the farm owner, addressing farm characteristics, the level of digitalization, decision-making processes, and the assessment of benefits and barriers associated with solutions linked to Agriculture 5.0. The interpretation of results was embedded in a review of current literature on Society 5.0 and Industry 5.0, adopting a “human-centred” perspective in which digital technologies are intended to support farmers in making faster and more accurate decisions, improving work organization, and reducing losses and risks on the farm, rather than increasing administrative burdens (Cabinet Office, Government of Japan, 2021, p. 11).

The selection of measures was purposeful. It was assumed that the indicators analyzed should be based on data that can be collected within the framework of day-to-day farm operations and should primarily reflect the actual effects of actions undertaken, rather than declarations or planning assumptions.

To ensure the transparency and comparability of results, the following principles were adopted:

- mineral nitrogen use (kg N/ha) was calculated as the total amount of nitrogen resulting from mineral fertilizers applied during a given season, related to the area of arable land; the calculations were based on fertilization records and purchase documents, with adjustments for changes in stock levels where applicable,
- the use of plant protection products was expressed as kilograms of active substance per hectare (kg a.s./ha), based on treatment records (product, dose, area); in the case of multi-component products, active substances were summed according to the product label,
- the costs of mineral fertilizers and plant protection products (PLN/ha) were calculated as purchase costs attributed to the analyzed season and related to the cultivated area; only variable costs associated with the purchase of production means were included in the analysis,
- the costs of digital solutions (e.g. system subscriptions, GNSS services) were treated as organizational and technical costs and analyzed qualitatively, rather than as elements of variable production costs.

The reference point for changes in the use of production inputs and costs was the values derived from farm records from the period immediately preceding the analyzed season, which made it possible to assess the direction and scale of changes while maintaining interpretative caution.

At the same time, it was assumed that the observed effects are multi-factorial in nature, and their interpretation focuses primarily on mechanisms for reducing operational and organizational losses (e.g. overlapping passes, repeated treatments, delayed decisions), rather than on fully isolating the impact of digital technologies from other production-related conditions.

3. Characteristics of the studied farm

The studied crop farm operates on 112 ha of agricultural land. It is located in the central part of the Kujawsko-pomorskie Province region, in an area with moderately favourable climatic conditions for crop production and a predominance of medium and good-quality soils typical of the Kujawy region. According to the soil valuation classification, soils of classes IIIa, IIIb, and IVa dominate, which supports intensive, market-oriented crop production while also implying sensitivity to agrotechnical errors and excessive chemical pressure.

The terrain is predominantly flat or slightly undulating, which facilitates the mechanization of field operations. At the same time, fields of irregular shapes and varying sizes occur, which has significant implications for the organization of machinery passes and the risk of overlapping treatments.

The crop structure (Figure 1) was designed to combine crop rotation stability with market flexibility. In the 2024/2025 season, winter wheat dominated with 42 ha (37.5%), followed by winter rapeseed with 18 ha (16.1%) and grain maize with 20 ha (17.9%). These were complemented by sugar beet—12 ha (10.7%), barley—10 ha (8.9%), legumes (pea)—6 ha (5.4%), and catch crops/technological fallow—4 ha (3.6%). Such a structure reduces the risk of monoculture and allows fieldwork and costs to be spread over time, which in practice enhances the farm's organizational stability.

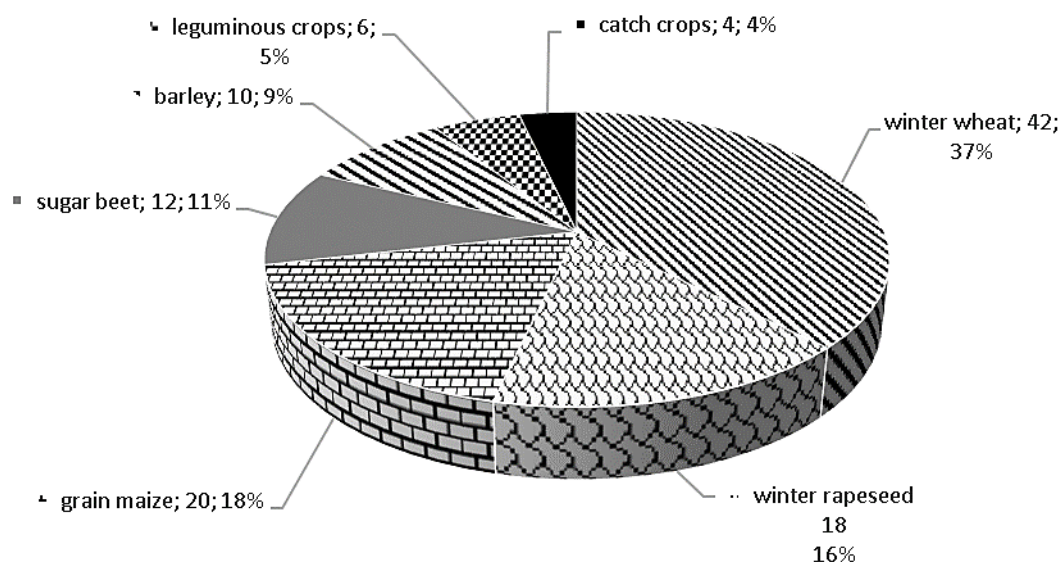


Figure 1. Crop structure in the studied farm [ha].

Source: own study.

The farm has a family character and is managed by the owner together with family members – his wife and son. The owner acts as the main decision-maker, machinery operator, and the person responsible for documentation and contacts with external institutions.

During periods of the highest intensity of fieldwork (sowing and harvesting), the farm seasonally employs two additional workers, with no permanent employment, however.

The total number of people involved in the farm's day-to-day operations over the year is three (the owner, his wife and son), and during peak periods this workforce is supplemented by two seasonal workers. This results in a high concentration of decision-making and operational responsibilities in the hands of the owner. This kind of organizational structure increases the importance of tools that support planning, coordination of work, and the reduction of errors arising from time pressure.

The farm's machinery park is typical for medium-sized crop farms in the region and includes, among others, agricultural tractors of varying power, a field sprayer, a mineral fertilizer spreader, seed drills, and tillage equipment. Some of the machines are equipped with terminals enabling GNSS-based parallel guidance and automatic section control, which constitute an important foundation for the further digitalization of production processes.

Work organization on the farm can be described by strong seasonality. During periods of intensive fieldwork decisions must be made quickly, often under conditions of incomplete information and weather pressure. In such circumstances, the lack of well-organized treatment records and an up-to-date picture of field conditions increases the risk of repeated operations, delays, and operational losses. For this reason, the farm represents a good example of a unit in which digitalization is not an end in itself, but a response to organizational and time constraints.

In this case study, the key issue was not so much what to cultivate, but how to make decisions under pressure to reduce chemical use and meet growing documentation requirements. It is precisely in this context that digitalization began to play a structuring role – not as a one-off investment, but as a gradual process of building better information about fields, treatments, and costs.

4. Digitalization in the spirit of Society 5.0 – from data to decisions in the field

In the studied farm, digitalization was not implemented as a “big project,” but rather as a series of practical steps introduced gradually where the lack of data most strongly hindered management and generated the greatest losses (time-related, cost-related, or organizational). This approach was consistent with the logic of Society 5.0, in which technology plays a role that supports people rather than imposing rigid organizational solutions.

The digitalization process began with organizing information that had previously existed in the form of scattered notes, loose sheets of paper, calendar entries, and the farm owner's memory regarding when and where agrotechnical operations had been carried out. Earlier, this information was often reconstructed after the season had ended, which increased

the risk of errors and inaccuracies, especially in situations involving inspections, planning for the next season, or comparing costs between fields.

At this stage, an FMIS (Farm Management Information System) was implemented – an information system for farm management designed to collect, process, store, and share data needed to conduct ongoing field operations (Tummers, Kassahun, Tekinerdogan, 2019, pp. 1-2). In practice, the FMIS became the place where the farm began to consolidate information about fields and operations in chronological order. In other words, it served as a central repository of operational data rather than merely an electronic equivalent of a notebook.

First, a field database was created, including plot boundaries, field names, areas, and the crops grown in a given season. Next, templates for the most frequently performed operations were prepared (e.g. pre-sowing fertilization, herbicide and fungicide protection), which reduced the need to enter data from scratch each time. During the season, only variable elements were updated: the date of the operation, the applied rate, weather conditions, and the person performing the work.

A key organizational change was shifting the moment of record-keeping from the “after the season” stage to “at work” stage. Records of fertilization, crop protection, and passes began to be created immediately after an operation was performed, most often using a mobile device. As a result, the farm stopped reconstructing the season’s history from memory and instead began building it continuously – field by field and day by day.

Only on this basis did the FMIS start to function as a decision-support tool rather than solely a record-keeping tool. The farmer could quickly check which operations had already been carried out, on which fields, and at what rates, which reduced the risk of repetition and enabled comparisons of input use between plots. The system was also used for planning the next season and assessing the effectiveness of implemented solutions.

Within the logic of Society 5.0, this way of implementing technology is fundamental, because technology should facilitate decision-making and relieve farmers of the burden of memorization and bureaucratic reconstruction of data, rather than creating an additional layer of administrative duties (Cabinet Office, Government of Japan, 2021, p. 11). At the same time, the subject literature emphasizes that modern FMIS solutions are expected to support managerial decisions and organize farm business processes precisely in order to reduce costs and facilitate compliance with quality requirements and standards (Tummers et al., 2019, p. 2).

The second stage of digitalization focused on reducing losses resulting from field geometry – primarily overlapping passes, repeated treatments on headlands, and unnecessary traffic lanes on irregularly shaped plots. For this purpose, the farm introduced GNSS (Global Navigation Satellite System) in key field operations such as tillage, sowing, and spraying. The machinery driving route ceased to depend solely on the operator’s experience and visible wheel tracks and, instead, began to follow guidance lines displayed on the in-cab terminal screen. Meanwhile, where most justified in terms of cost and environmental impact, automatic sprayer section

control was implemented. This enabled individual boom sections to be switched on and off depending on the area of the field that had actually been covered. In practice, this eliminated double application of spray solution on headlands and field wedges.

Studies indicate that automatic section control can reduce overlap on average by about 9% for sprayers and about 6% for seeders, although the magnitude of benefits depends on field size and shape (Shockley et al., 2012, pp. 413-414). In the studied farm, the effect was less spectacular, but still sufficiently important to be reflected in the records of plant protection product use. The key was not achieving the maximum possible reduction, but the systematic elimination of operational errors.

The third area of digitalization involved better matching of fertilization and crop protection to field conditions, without assuming full automation of the process. The farm began combining simple data – such as the history of operations, field structure, and crop observations – with weather information and a short-term work plan. This enabled the more accurate selection of treatment windows and a decrease in situations where operations were repeated due to haste or an incorrect assessment of conditions.

This approach aligns with the assumptions of Society 5.0, in which digital technologies are meant to support people in making decisions at the right time, rather than replacing their knowledge and experience. Thus, in the studied farm, the key was not increasing the number of technologies, but minimizing losses resulting from repeated operations, overlapping passes, and decisions made too late or on the basis of incomplete information.

5. Results – measurable effects from the perspective of the three pillars of sustainability

The assessment of the effects of the implemented digital solutions was conducted from the perspective of the three pillars of sustainable development: environmental, economic, and socio-organizational. It was assumed that the key importance does not lie in individual technologies, but in the combined effect of data organization, improved decision-making processes, and the reduction of operational losses in the crop farm.

5.1. Environmental and resource-related effects

In the studied farm, the greatest environmental potential emerged in areas where losses were difficult to capture: excessive application rates, repeated treatments on headlands, and operations carried out “just in case” due to a lack of complete information. The reduction of pressure on resources did not result from a radical change in cultivation technology, but rather from greater data discipline and improved work organization.

Table 1.*Selected indicators before and after the implementation of digital solutions*

Indicator	Before implementation	After implementation	Difference
Mineral nitrogen use (kg N/ha)	160	145	-9.4%
Plant protection product use (kg active substance/ha)	2.9	2.6	-10.3%

Source: author's own study.

In the analyzed year, the farm recorded a decrease in mineral nitrogen use (calculated per arable land area) from 160 kg N/ha to 145 kg N/ha, which represents a reduction of 15 kg N/ha (−9.4%). This change resulted from several minor adjustments: better temporal planning of application rates, reduced overlap of passes, and more accurate selection of treatment timing in relation to weather conditions and crop growth stages. A similar trend was observed in the use of plant protection products. The average active substance use for major crops declined from 2.9 kg a.s./ha to 2.6 kg a.s./ha (−0.3 kg; −10.3%). This reduction was mainly due to fewer repeated treatments on headlands and field edges, as well as more consistent timing of applications.

The obtained results are directionally consistent with the objectives of the “Farm to Fork” strategy, which aims, among others, to reduce nutrient losses and decrease the use of fertilizers and pesticides. At the same time, they fall within the range of effects reported in synthetic studies on precision agriculture, which indicate improvements in nitrogen use efficiency and reductions in pesticide application. In the studied farm, these changes were achieved without a declared decrease in production levels.

5.2. Economic effects: variable costs and process control

In a crop farm, the “economics of sustainability” becomes evident when reducing inputs does not lead to yield losses or delays in field operations. A key factor was the integration of treatment records with on-field control of their execution. When the farmer can see which operations were actually carried out and where, it is easier to maintain discipline in application rates and eliminate unnecessary repetitions.

Table 2.*Selected indicators before and after the implementation of digital solutions*

Indicator	Before implementation	After implementation	Difference
Costs of mineral fertilizers (PLN/ha)	1800	1520	-280
Costs of plant protection products (PLN/ha)	900	780	-120

Source: author's own study.

Farm records show that the costs of mineral fertilizers per hectare decreased by approximately PLN 280/ha (−5.8%), while the costs of plant protection products decreased by about PLN 120/ha (−7.5%). The cost reduction did not take the form of a one-off “technological gain,” but rather resulted from the systematic limitation of operational losses, such as duplicated

passes, corrective treatments, or the purchase of production inputs at less favourable price moments.

At the same time, it should be emphasized that in the studied farm the implementation of digital tools was associated with additional organizational and technical costs, including software, maintenance of GNSS solutions, and the time required for implementation and learning. From a managerial perspective, however, it was important that these costs were predictable and could be planned, in contrast to earlier operational inefficiencies that generated losses difficult to estimate during the season. In this sense, the farm improved not only its cost level but also the degree of control over the production process, which is particularly important under conditions of weather variability and time pressure characteristic of crop production.

5.3. Social and organizational effects: the human at the center of the process

The social effects of the implemented solutions are not easy to capture using a single indicator; however, they are clearly reflected in work organization and decision-making processes. Within the logic of Society 5.0, technology should improve the quality of work and decision security, rather than merely increase production efficiency.

In the studied farm, the most noticeable effect of technology implementation was a reduction in time pressure and a shortening of the time spent reconstructing documentation after the end of the season. Keeping records on an ongoing basis enabled calmer planning of operations and earlier responses to deviations from the plan. Decisions ceased to be made in a “last-minute” mode and became more repeatable and less cognitively burdensome.

Organizing data related to fertilization and crop protection and providing a clear picture of field conditions within a single system reduced information chaos and limited the risk of errors resulting from reliance solely on memory, scattered notes, or photos stored on a phone. As a result, technology did not “produce yield” itself, but strengthened the farmer’s agency by facilitating planning, monitoring the execution of operations, and maintaining consistent documentation required by the market and regulations.

These effects align with the human-centred character of Society 5.0, in which digitalization is intended to support people in decision-making and work organization, thus contributing to greater predictability of actions and a reduction in the time-related and psychological costs of farm management.

6. Barriers and risks: why not everything can be “automated”

The analysis of the case study indicates that despite noticeable environmental, economic, and organizational benefits, the digitalization process in a crop farm encounters significant barriers and risks that limit both the pace and scope of implementing more advanced solutions.

These barriers do not stem solely from the availability of technology, but are largely the result of integration, competency, and institutional challenges characteristic of medium-sized crop farms.

6.1. Technical and integration barriers

One of the key barriers identified in the studied farm was the low level of interoperability between the digital solutions in use. Data on treatment records collected in the FMIS, files generated by GNSS terminals, and machine work reports largely functioned as separate “information islands.” Obtaining a coherent picture of the production season (e.g. linking actual passes with the applied rate, cost, and treatment effect on a specific field) required manual data export, format conversion, unification of field and operation names, and mapping the same fields across different systems. In practice, this meant that part of the potential benefits of digitalization was limited not by a lack of technology, but by the time-consuming nature of data organization and the absence of uniform data exchange standards. This phenomenon is consistent with findings from studies conducted at the European Union level, which indicate that farm data are still often collected and processed in a fragmented manner, increasing the administrative burden on farmers and limiting their analytical use (Tur Cardona et al., 2025, pp. 4-6).

An additional technical constraint was the quality of ICT infrastructure. Even the most advanced applications lose their usefulness in the absence of stable internet access. Limited connectivity in some locations hindered real-time data synchronization and encouraged the selection of offline solutions, at the expense of systems requiring constant connectivity, updates, and technical support. Within the European Union, 85% of surveyed farms declare adequate internet coverage, yet 15% still report insufficient connectivity (Tur Cardona et al., 2025, p. 6). Under such conditions, farmers are more likely to choose proven and easy-to-use solutions, even if their integration and analytical potential is limited.

6.2. Organizational and competency barriers

The second important group of barriers included organizational and competency constraints. In a farm where most decision-making, operational, and administrative responsibilities rest with a single person, any new technology must be not only functional but also easy to implement and operate under conditions of time pressure and strong seasonality of work.

The process of learning to use digital systems, configuring devices, and interpreting generated data involved additional time costs that were not always offset by immediate economic benefits. In practice, this favoured the selective adoption of only those tools that most quickly organized the decision-making process and documentation, as well as caution toward more advanced solutions requiring greater organizational commitment.

An important factor was also the perceived risk of error. When systems are seen as overly complex or unintuitive, farmers fear losing control over the production process and prefer solutions that leave decision-making in human hands. In this sense, full automation is not always perceived as a desirable direction of development, especially in medium-sized crop farms.

6.3. Institutional risks and data governance

The third group of barriers consists of risks related to data governance and the relationship between farmers and technology providers. Data generated by machines, sensors, and information systems are gaining increasing economic value, as they directly influence production decisions, costs, and farm performance. At the same time, farmers often lack full certainty regarding the rules of access to, portability of, and further use of these data.

The risk of dependence on a single technology provider (vendor lock-in) limits the willingness to integrate systems and invest in solutions that may prove to be technologically closed. In the studied farm, these concerns related primarily to long-term access to historical data and the possibility of using them in other systems in the future.

In this context, the Data Act regulation is of particular importance. It entered into force on 11 January 2024 and will apply from 12 September 2025. This act regulates, among other things, the rules of access to data generated by connected products and the conditions for data sharing (Regulation (EU) 2023/2854, 2023, recital 117, p. 30). From the perspective of a farm, this regulation represents a potential factor in building trust in investments in digital technologies over the long term, as it strengthens the position of data users versus technology providers (Regulation (EU) 2023/2854).

However, it should be emphasized that legal regulation alone does not guarantee practical system interoperability or easy use of data in everyday farm management. If digital solutions are to function over many years, farmers must have a sense of maintaining control over their data. Whether such control will be possible in practice will ultimately depend on the adopted technical standards and applied business models.

6.4. Limits of automation in a crop farm

The case study shows that not all processes in a crop farm can be effectively automated. Decisions concerning the timing of treatments, responses to changing weather conditions, or the interpretation of crop status still require the farmer's knowledge and experience. Digitalization can support these decisions by providing better information, but it does not replace human decision-making responsibility.

In the studied farm, the most effective solutions were those that reduced operational errors and organized the work process, rather than those aiming at full automation. Thus, the boundary for technology implementation was not the level of its sophistication, but its ability to genuinely

support the decision-making process without increasing organizational complexity or operational risk.

7. Conclusions

The conducted case study shows that sustainable management of a crop farm in the spirit of Society 5.0 does not require full automation or the implementation of comprehensive, costly technological systems. What matters most is a logical sequence of actions in which digitalization serves as a tool that structures the decision-making process, reduces operational losses, and strengthens control over the course of production.

In the studied farm, the starting point proved to be the organization of operational data and treatment records. Only the creation of a coherent, up-to-date information base on fields, passes, and applied rates enabled further organizational improvements. Shifting documentation from the “after the season” stage to the “at work” stage was important not only for data quality, but also for improving decision security and reducing time pressure.

On this foundation, it became possible to effectively reduce field-level operational losses, such as overlapping passes, repeated treatments on headlands, or unintended double applications of inputs. The use of GNSS parallel guidance and automatic section control did not change the biology of production, but it eliminated operational errors that, in practice, generate a significant share of excess costs and environmental pressure.

The achieved environmental effects – reduced use of mineral nitrogen and plant protection products – were not the result of a radical change in cultivation technology, but rather a consequence of better work organization and more timely, better-targeted decisions. Similarly, in economic terms, the key was the reduction of hidden cost losses resulting from repetitions and inefficient operations, rather than a one-off increase in production efficiency.

An important outcome of the implemented solutions were also the social and organizational effects. Digitalization contributed to a reduced administrative burden, greater predictability of seasonal work, and less information chaos. In this sense, technology did not replace the farmer but strengthened the farmer’s agency, fitting the human-centred character of Society 5.0.

At the same time, the case study reveals clear barriers to further digitalization, which are related primarily to data integration, user competencies, and the risk of dependence on closed technological ecosystems. This means that the further development of digital agriculture should not focus exclusively on delivering more tools, but rather on improving interoperability, ease of use, and building trust in data governance principles.

The conclusions drawn from the study are application-oriented and should not be treated as representative of the entire agricultural sector. They do show, however, that even in a single medium-sized crop farm, it is possible to gradually strengthen sustainability through the

conscious use of data and decision-support technologies. The most rational development path appears to be an incremental approach, starting with organizing information and controlling the process, and only subsequently reaching for more advanced technical solutions.

In this perspective, Society 5.0 in agriculture does not mean “more technology”, but a better use of available tools in a way that simultaneously strengthens economic efficiency, reduces environmental pressure, and improves the working conditions of people in crop farming.

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**TOURIST ATTRACTIVENESS IN SMART CITIES:
PERCEPTION OF RESIDENTS AND COMPANIES**

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Purpose: This paper aims to identify the differences in how citizens and companies perceive tourist attractiveness of two cities - Szczecin and Koszalin - and offer a broader perspective on the role of tourist attractiveness within the concept of a smart city.

Design/methodology/approach: The study was quantitative and based on survey data from residents and businesses in Szczecin and Koszalin. The data were collected using a survey research method with mixed-mode data collection techniques. The results related to tourist attractiveness were analysed using Student's t-test for independent samples, after verifying normality and equality of variances. The paper raises the following research question: What are the differences in how residents and businesses in the surveyed cities perceive tourist attractiveness?

Findings: The tourist attractiveness of cities was rated on a scale from 0 to 100, where 0 indicates no tourist attractiveness, and 100 signifies definite tourist attractiveness. Residents of Szczecin and Koszalin perceive their cities' tourist appeal similarly, but companies show notable differences. Entrepreneurs in Szczecin rate the tourist attractiveness higher than those in Koszalin. In Koszalin, there is also a gap between residents' and businesses' assessments, emphasising the importance of collaborative efforts among diverse stakeholder groups to enhance tourist attractiveness.

Research limitations/implications: The study is constrained by its pilot nature and focus on only two medium-sized cities, which limits the potential for broader generalisation of the results. Additionally, enterprises were analysed without sectoral division, and the data is purely declarative, which may impact its objectivity.

Practical implications: The study's findings offer practical guidance for city managers, demonstrating how to consider the perspectives of two key stakeholder groups with different needs and expectations. This can support more informed decision-making when developing tourist attractions, particularly in smaller urban centres.

Social implications: These include strengthening citizens' roles in co-creating urban space and enhancing the quality of life through a more sustainable and inclusive approach to tourism development.

Originality/value: The study offers broader insights into how residents and businesses perceive tourist attractiveness within the context of Smart Cities and perceptions of the tourist appeal of medium-sized cities.

Keywords: smart city, citizens, company, tourist attraction.

Category of the paper: research paper.

1. Introduction

The concept of a Smart City as a research context is currently linked not only with technological solutions (Albino et al., 2015; Fernandez-Anez et al., 2018), but also with quality of life, sustainable areas, inclusiveness for residents and businesses, including the achievement of social goals. The modern definition of a city refers to management methods and operations driven by implementing various objectives (Hämäläinen, 2020). Therefore, smart cities must be innovative solutions to urban issues, people-oriented, and beneficial to all users (Hollands, 2020).

Nowadays, the idea of a Smart City involves attracting human capital and mobilising it through modern technologies in collaboration with various city stakeholders (Meijer, Bolívar, 2016). Therefore, a Smart City mainly involves changing and modernising relationships within and between people, communities, and local government. As a result, the urban environment is enhanced, the city's competitiveness and prestige are elevated, which improves its residents' well-being (Kong, Woods, 2018).

Transforming a city into a Smart City requires a broad and critical perspective. This is due to the fact that the concept itself is subject to ongoing debate. Some researchers emphasise that a Smart City is sometimes instrumentalised and used to achieve corporate goals, and technological development may worsen socio-economic inequalities (Vanolo, 2013). This instrumental approach, viewing residents as customers, will reinforce the neoliberal concept of citizenship (Cardullo, Kitchin, 2019), where citizens become mainly consumers of technological services rather than co-creators of urban communities. Consequently, this could deepen inequalities and weaken the social aspect of the Smart City. Therefore, this study highlights inclusiveness and diverse perspectives—of residents and businesses—as essential to understanding the attractiveness of a city in the context of Smart City (Vanolo, 2013).

It is crucial to take a critical approach when implementing Smart City initiatives to ensure they follow the principles of sustainability, inclusiveness, and fairness, and their results are beneficial not only to the economy but also to the well-being of all city residents (Albino et al., 2015). It is worth noting that integrating the economy with an innovative environment and, further, with a smart office or smart mobility for residents will create a comprehensive urban ecosystem that addresses the needs of inclusiveness, sustainability, and efficiency within the city. For example, integrating the economy with an innovative environment and, further,

with a smart office or smart mobility for residents will create a comprehensive urban ecosystem that addresses the needs of inclusiveness, sustainability, and efficiency within the city (Hollands, 2020).

In recent years, there has been a noticeable rise in interest in enhancing the attractiveness of a place. This concept extends well beyond just the city's infrastructure or the availability of related services. It includes factors such as quality of life, a sense of community, and residents' opportunities to shape urban spaces (Lee et al., 2020; Meijer, Bolívar, 2016; Romão et al., 2018). Smart living, social activation, and inclusion are increasingly important for residents. Smart living is described as a lifestyle where technology and the urban environment interact to improve quality of life, highlighting the importance of integrating modern solutions with the needs of the local community (Chen, Chan, 2022).

In the literature, the attractiveness of a city is also linked to the quality of life, which is increasingly considered a core component of the definition of a Smart City, replacing an approach focused solely on technology and management efficiency (Caragliu et al., 2011; Ismagilova et al., 2019; Mora et al., 2019). This shift in focus indicates that the development of a smart city must be viewed within the context of its residents' social and cultural experiences, which also directly influences its perceived tourist attractiveness.

As part of the development of the concept of tourist attractiveness within a smart city, the notion of smart tourism has emerged. According to this idea, it is possible to co-create experiences (Gretzel et al., 2015). Therefore, residents and businesses can be considered co-creators of a smart city's tourist attractiveness.

Nevertheless, detailed analyses of other key stakeholder groups, such as residents and businesses, who influence both the quality of life in the city and its appeal to tourists, remain lacking. This paper aims to identify differences in how citizens and companies perceive the tourist attractiveness of two cities, Szczecin and Koszalin, to address a research gap and emphasise the need for further investigation in this field.

2. Methods

The data were collected using a survey research method with mixed-mode data collection techniques. The sampling frame was based on a database of companies provided by the Flow Research Centre. In 2021, a pilot survey was carried out on a random sample of 221 companies and 427 citizens from the West Pomeranian region in Poland using CATI (computer-assisted telephone interviewing) and CAWI (computer-assisted web interviewing) techniques. The sample comprises 221 companies: 120 from Szczecin and 101 from Koszalin. Of 427 citizens, 225 from Szczecin and 202 from Koszalin constitute the sample. The final sample comprised 221 companies. Among the surveyed entities, sole proprietorships

constituted the largest group ($n = 130$), followed by micro-enterprises ($n = 61$) and small firms ($n = 20$). Medium-sized and large companies were represented to a lesser extent, with five entities in each category. In terms of respondent characteristics, women accounted for 58% of the sample ($n = 247$), while men represented 42% ($n = 180$). Most respondents reported either tertiary education (52%) or secondary education (40%). With regard to marital status, half of the participants were married (50%), whereas 26% declared being single.

This study aims to identify whether there are significant differences in the perceived tourist attractiveness between citizens and companies in two urban contexts (Szczecin and Koszalin), both across cities and between stakeholder groups within each city. The paper raises the following research question: What are the differences in how residents and businesses in the surveyed cities perceive tourist attractiveness? The tourist attractiveness of cities was rated on a scale from 0 to 100, where 0 indicates no tourist attractiveness, and 100 signifies definite tourist attractiveness.

The study adopted a quantitative approach, with the independent two-sample t-test used as the primary statistical technique to test the null hypothesis. Moreover, the normality test - Shapiro-Wilk normality test ($\text{Alpha} = 0.05$) and the F-test for equal variances ($\text{Alpha} = 0.05$) were also conducted as preliminary procedures for the t-test. The tourist attractiveness scores were collected from the four mentioned samples under the ratio scale question. The scale ranges from 0 to 100, where 0 means no tourist attractiveness at all, and 100 means the maximum tourist attractiveness. RStudio and Microsoft Excel were used to analyse the primary data, and results were reported according to the APA standards.

Research hypotheses

- H_{01} : The population means of citizens' tourist attractiveness scores in Szczecin and Koszalin are equal.
- H_{a1} : The population means of citizens' tourist attractiveness scores for Szczecin and Koszalin are unequal.
- H_{02} : The population means companies' tourist attractiveness scores in Szczecin and Koszalin are equal.
- H_{a2} : The population means of the companies' tourist attractiveness scores for Szczecin and Koszalin are unequal.
- H_{03} : The population mean scores for companies' tourist attractiveness are equal to the population mean scores for citizens' tourist attractiveness in Szczecin.
- H_{a3} : The population mean scores for companies' tourist attractiveness are not equal to the population mean scores for citizens' tourist attractiveness in Szczecin.
- H_{04} : The population mean scores for companies' tourist attractiveness are equal to the population mean scores for citizens' tourist attractiveness in Koszalin.
- H_{a4} : The population mean scores for companies' tourist attractiveness are not equal to those for citizens' tourist attractiveness in Koszalin.

3. Results

Statistical analyses enabled a comparison of perceptions of tourist attractiveness in two urban centres – Szczecin and Koszalin – considering the perspectives of residents and businesses. The Shapiro-Wilk normality test was employed to ensure reliable and credible differences in stakeholder perceptions (Table 1).

Table 1.

Normality test - Shapiro-Wilk normality test (Alpha = 0.05)

Sample distribution	W	p-value	Decision
Citizens' tourist attractiveness scores in Szczecin	.95	.000	Data not coming from a normally distributed population
Citizens' tourist attractiveness scores in Koszalin	.95	.000	Data not coming from a normally distributed population
Companies' tourist attractiveness scores in Szczecin	.97	.010	Data not coming from a normally distributed population
Companies' tourist attractiveness scores in Koszalin	.95	.000	Data not coming from a normally distributed population

Source: Field data 2021.

A Shapiro-Wilk test was conducted to assess the normality of citizens' tourist attractiveness scores in Szczecin, $W(n = 225) = .95$, $p < .005$, the normality of citizens' tourist attractiveness scores in Koszalin, $W(n = 202) = .95$, $p < .005$, the normality of companies' tourist attractiveness scores in Szczecin, $W(n = 120) = .97$, $p < .005$, the normality of companies' tourist attractiveness scores in Koszalin, $W(n = 101) = .95$, $p < .005$. The results indicated a significant deviation from normality. However, for $n > 30$, the t-test is robust even though it violates normality due to the Central Limit Theorem (Table 1).

The F-test was used to assess the homogeneity of variance between stakeholder groups and cities (Table 2).

Table 2.

F test for the equal variance (Alpha = 0.05)

Sample distribution I	Sample distribution II	F	p-value	Decision
Citizens' tourist attractiveness scores in Szczecin	Citizens' tourist attractiveness scores in Koszalin	.88	.356	Sample variances are equal
Companies' tourist attractiveness scores in Szczecin	Companies' tourist attractiveness scores in Koszalin	.74	.121	Sample variances are equal
Citizens' tourist attractiveness scores in Szczecin	Companies' tourist attractiveness scores in Szczecin	1.01	.952	Sample variances are equal
Citizens' tourist attractiveness scores in Koszalin	Companies' tourist attractiveness scores in Koszalin	.85	.349	Sample variances are equal

Source: Field data 2021.

An F-test was conducted to compare the variances of citizens' tourist attractiveness scores in Szczecin and Koszalin: $F(224, 201) = 0.88$, $p = .357$, 95% CI [0.67, 1.15], companies' tourist attractiveness scores in Szczecin and Koszalin: $F(119, 100) = 0.74$, $p = .121$, 95% CI [0.50, 1.08], citizens' tourist attractiveness scores and companies' tourist attractiveness scores in

Szczecin: $F(224, 119) = 1.01, p = .952, 95\% \text{ CI } [0.73, 1.37]$, and citizens' tourist attractiveness scores and companies' tourist attractiveness scores in Koszalin: $F(201, 100) = 1.85, p = .349, 95\% \text{ CI } [0.60, 1.18]$. The F tests confirmed no significant differences in the variability between the stakeholder groups and cities studied. This indicates that the spread of tourist attractiveness ratings was similar among residents of Szczecin and Koszalin and between company representatives and citizens. In other words, the average levels of attractiveness and the stability and consistency of the ratings were comparable. From a methodological standpoint, this permitted the use of Student's t-tests assuming homogeneity of variance (Table 2).

Testing hypothesis H₀₁

An independent samples t-test was conducted to compare the tourist attractiveness scores between citizens of Szczecin and Koszalin. There was no significant difference in scores between citizens of Szczecin ($M = 62.82, SD = 24.96, n = 225$) and citizens of Koszalin ($M = 60.60, SD = 26.58, n = 202$); $t(425) = 0.88, p = .37, \text{Cohen's } d = 0.08$.

Testing hypothesis H₀₂

An independent samples t-test was conducted to compare the tourist attractiveness scores of companies from Szczecin and Koszalin. There was a significant difference in scores between companies from Szczecin ($M = 62.25, SD = 24.80, n = 120$) and companies from Koszalin ($M = 47.7, SD = 28.76, n = 101$); $t(219) = 3.46, p = .000, \text{Cohen's } d = 0.46$. The 95% confidence interval for the mean difference ranged from 5.38 to 19.58. It can be also concluded that companies from Szczecin rate the tourist attractiveness of their city higher than those from Koszalin.

Testing hypothesis H₀₃

An independent samples t-test was conducted to compare the tourist attractiveness scores of citizens and companies from Szczecin. There was no significant difference in scores between citizens of Szczecin ($M = 62.82, SD = 24.96, n = 225$) and companies from Szczecin ($M = 60.25, SD = 24.80, n = 120$); $t(343) = 0.910, p = .36, \text{Cohen's } d = 0.10$.

Testing hypothesis H₀₄

An independent samples t-test was conducted to compare the tourist attractiveness scores of citizens and companies from Koszalin. There was a significant difference in scores between citizens of Koszalin ($M = 60.60, SD = 26.58, n = 202$) and companies from Koszalin ($M = 47.7, SD = 28.76, n = 301$); $t(219) = 3.85, p = .000, \text{Cohen's } d = 0.49$. The 95% confidence interval for the mean difference ranged from 6.27 to 19.38. It can be concluded that citizens of Koszalin rate the tourist attractiveness of their city higher than companies from Koszalin.

T-test summary

An independent samples t-test was conducted to compare tourist attractiveness scores across various groups. There was no significant difference between citizens of Szczecin ($M = 62.82, SD = 24.96, n = 225$) and citizens of Koszalin ($M = 60.60, SD = 26.58, n = 202$); $t(425) = 0.88, p = .37, \text{Cohen's } d = 0.08$. However, a significant difference was observed

between companies in Szczecin ($M = 62.25$, $SD = 24.80$, $n = 120$) and companies in Koszalin ($M = 47.7$, $SD = 28.76$, $n = 101$); $t(219) = 3.46$, $p < .001$, *Cohen's d* = 0.46, with a 95% confidence interval for the mean difference ranging from 5.38 to 19.58. There was no significant difference in scores between citizens of Szczecin ($M = 62.82$, $SD = 24.96$, $n = 225$) and companies from Szczecin ($M = 60.25$, $SD = 24.80$, $n = 120$); $t(343) = 0.91$, $p = .36$, *Cohen's d* = 0.10. In contrast, a significant difference was found between citizens of Koszalin ($M = 60.60$, $SD = 26.58$, $n = 202$) and companies from Koszalin ($M = 47.7$, $SD = 28.76$, $n = 301$); $t(219) = 3.85$, $p < .001$, *Cohen's d* = 0.49, with a 95% confidence interval for the mean difference ranging from 6.27 to 19.38.

4. Discussion

Assessing the tourist attractiveness of a city from both residents' and local companies' perspectives supports the Smart City concept by including stakeholder-driven knowledge in urban development. Smart cities prioritise participatory governance, co-creation, and evidence-based decision-making, where local actors serve not only as users but also as contributors to city development. Residents offer insights on quality of life, place identity, and the usability of urban spaces, while companies provide assessments based on economic viability, service quality, and infrastructure performance. Combining these viewpoints allows local authorities to create tourism and urban policies that are more responsive, inclusive, and aligned with actual stakeholder needs, thereby enhancing smart governance and fostering sustainable urban growth. It should also be highlighted that a smart city's tourist attractiveness largely depends on innovative factors, such as infrastructure or sustainable development practices, which influence the creation of urban value (Romão et al., 2018). The focus on co-creating smart urban spaces encourages community involvement, boosts residents' self-esteem, and enhances the area's tourist attractiveness (Lee et al., 2020).

In Szczecin, perceptions of tourist attractiveness were similar among citizens and businesses, indicating consistency across key stakeholders and suggesting potential for coordinated planning. The residents' assessments were fairly consistent and showed no significant difference between the two cities. This aligns with prior research showing that citizens often assess urban attractiveness comparably regardless of city size or specific characteristics (Cassia et al., 2018). From a management perspective, the similarity in perceptions between citizens and companies suggests a high level of stakeholder alignment regarding the tourist attractiveness of the cities. Such convergence may facilitate coordinated planning and implementation of urban development strategies, as shared assessments reduce the risk of conflicting expectations among key actors.

However, Koszalin showed a significant difference between citizens' and companies' assessments. This divergence may reflect differing priorities or expectations that a Smart City should meet for various stakeholders (Bokhari, Seunghwan, 2024; Chong et al., 2023). A comparison of the two cities reveals marked differences in the evaluation of companies, with Szczecin receiving a higher rating than Koszalin. This discrepancy is indicative of their divergent economic and promotional potential. This phenomenon may be attributed to the perception of entrepreneurs in larger cities that they are able to identify more opportunities and benefits for tourism, such as superior infrastructure, a more extensive market, and the potential for smart services (Azevedo Guedes et al., 2018). The size of a city may also influence its level of attractiveness and, consequently, its ratings (Müller-Eie, Kosmidis, 2023).

A difference in assessment between companies and residents was also noted in the perception of stakeholder engagement (Fernando et al., 2025). In the West Pomeranian region, citizens rated stakeholder engagement higher than companies. Evidence from stakeholder engagement research also shows that trust in government is closely connected to the way the benefits of smart city initiatives are perceived (Hamamurad et al., 2022).

Findings highlight that residents' perceptions of a city's attractiveness directly impact their willingness to support and engage with tourism, creating a feedback loop that enhances the city's overall appeal for both residents and tourists (Romão et al., 2018). In turn, Liu and Li's research sheds light on how local residents perceive the impact of tourism on their communities (Liu, Li, 2018). Their study found that, despite some environmental concerns, local residents generally have a positive attitude towards tourism due to its economic and socio-cultural benefits. When local companies use smart technologies to improve service delivery and foster greater engagement, residents often see the local tourism sector as more vibrant and attractive. This enhances their sense of pride in their city (Torabi et al., 2022).

The literature on the subject often emphasises the relationship not only between tourism and the smart city, but also its specific dimension, which relates to sustainable development and inclusivity (Jayasinghe et al., 2024; Szabó-Szentgróti et al., 2025; Tundys, Wiśniewski, 2024). Findings presented in this paper highlight the importance of recognising multiple stakeholder perspectives when assessing tourist attractiveness, a key element in developing Smart City strategies. The observed discrepancies in Koszalin suggest that smaller urban centres may require more targeted engagement and dialogue between citizens and companies to support coherent planning and policy implementation.

Summary

This paper aimed to identify the differences in how citizens and companies perceive the tourist attractiveness of two urban cities of the West Pomeranian region, Szczecin and Koszalin, and offer broader insights into the role of tourist attractiveness within the Smart City concept.

Based on the analysis, the authors have enough evidence not to reject the formulated hypotheses H_{01} and H_{03} . The results indicate that there is no significant difference in the perception of tourist attractiveness between the citizens of Szczecin and Koszalin. Furthermore, there is no significant difference in the perception of tourist attractiveness between companies and citizens of Szczecin.

Based on the analysis, the authors have enough evidence to reject the formulated hypotheses H_{02} and H_{04} . The results indicate that there is a significant difference in the perception of tourist attractiveness between the companies from Szczecin and Koszalin. Companies from Szczecin rate the tourist attractiveness of their city higher, and those from Koszalin. Furthermore, there is a significant difference in the perception of tourist attractiveness between companies and citizens of Koszalin. It should be noted that citizens rate tourist attractiveness higher than companies. The observed differences in how tourist attractiveness is perceived may originate from the varying roles and experiences of the analysed stakeholder groups. Companies tend to evaluate tourist attractiveness from an economic and operational perspective, considering factors such as demand stability, seasonality, infrastructure quality, and the local business environment, while citizens might base their views more on everyday experiences, emotional ties to the place, and symbolic or identity-related elements of the city. The higher ratings given by companies in Szczecin could reflect the city's stronger economic position and more extensive tourism infrastructure compared to Koszalin. For policymakers, these results emphasise the importance of tailoring urban development and tourism policies to the perspectives of different stakeholders. Specifically, the disparity between citizens' and companies' perceptions in Koszalin indicates a need for increased dialogue with the business community to better align tourism strategies with economic expectations and to foster greater involvement of local businesses in tourism development initiatives.

Despite the sizeable samples, this study has limitations. It was a pilot study conducted in only two cities within a specific region of Poland, which may limit the generalisability of the results. Moreover, data were based on self-reported perceptions, and the business sample was not analysed by sector. Future research could expand the scope to include additional urban centres, consider sectoral differences among businesses, and further explore the relationship between stakeholder perceptions and strategic urban planning. When indicating future research directions, it would also be necessary to take into account the perspective of the tourists themselves and their perception of the cities under study.

Overall, the companies' and citizens' responses provide a valuable initial overview of tourist attractiveness in the context of Smart Cities, offering insights for both theory and urban management practice.

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COMPANIES' ENGAGEMENT IN THE CO-CREATION OF SMART CITY – AN EMPIRICAL STUDY

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Purpose: This article aims to present an empirical analysis of companies' attitudes towards co-creation within the Smart City concept, with particular attention to the role of managers' gender in the regional context of Western Pomerania.

Design/methodology/approach: The survey was conducted using CATI and CAWI methods among companies operating in two cities of the West Pomeranian region, Szczecin and Koszalin. The aim of the analysis was to assess business entities' willingness to co-create the smart city concept in the West Pomeranian Voivodeship. Ten Smart City dimensions were evaluated, and two hypotheses were formulated: (H01) there is no difference between female and male decision-makers in the combined importance ratings of willingness to co-create Smart City variables (A–J), and (H02) there is no difference between female and male decision-makers in the combined importance ratings of co-creation experience variables (A–J). Quantitative data were analysed using Cronbach's alpha, MANOVA, post hoc ANOVA, and Pearson's chi-squared test.

Findings: The results indicate that managers' gender does not influence firms' willingness or experience in smart city co-creation in the West Pomeranian region. Accordingly, hypotheses H01 and H02 were not rejected.

Research limitations/implications: The main limitation is that only the two largest cities in the West Pomeranian region were analysed, and the research was pilot in nature. Regional specificity also limits the ability to generalise the results.

Practical implications: The study's results, gathered from the surveyed companies, may be helpful for managers as they show that cooperation between municipal institutions and local entrepreneurs does not need to depend on gender. Municipal institutions can also plan collaborations with companies without considering gender, based on the company's size and industry.

Social implications: Considering gender perspectives in Smart City planning can support more inclusive and informed decision-making, build public trust, and ensure that innovation and co-creation initiatives are grounded in skills rather than gender stereotypes. Although gender was not a differentiating factor in this study, acknowledging gender perspectives remains essential for fostering inclusivity in urban development.

Originality/value: This study contributes to the smart city literature by providing empirical evidence on companies' engagement in smart city co-creation, with a particular focus on the role of gender as an explanatory variable. By analysing firms operating in the West Pomeranian region, the study offers a regional perspective that is rarely examined in existing research.

The findings indicate that gender does not significantly influence firms' willingness or experience in co-creation, thereby challenging common assumptions about gender-based differences in business engagement with smart city initiatives.

Keywords: Smart City, co-creation, company, gender, business engagement, urban innovation.

Category of the paper: Research paper.

1. Introduction

The concept of Smart City, which has been discussed since the 1980s, has evolved from viewing the city as a technological system to seeing it as a space co-created by residents, businesses, government, and science. The absence of a universally accepted definition means that Smart Cities are understood differently across technological, urban, managerial, and social perspectives (Albino et al., 2015; Mora et al., 2017).

This evolution is visible across generations, from City 1.0 to City 5.0. Each new generation has been influenced by digital and technological transformations and major trends like globalisation, urbanisation, climate change, and sustainable development (Höjer, Wangel, 2015; Masik, Studzińska, 2018). It is worth noting that future Smart City concepts focus less on technology and more on building relationships and cooperation with stakeholders. Therefore, the city management model is shifting from a passive to an active approach, where residents and businesses are not only recipients of services but also creators of new solutions. The role of residents in the Smart City concept is well explained, especially in improving their quality of life. However, the role of companies remains less explored. There is a lack of studies highlighting the role of companies not only as users of Smart City services, but also as co-creators of Smart City solutions and services. Special attention will be given to companies and their dual roles in Smart Cities. The Polish context is fascinating because the development of the Smart City concept here involves strong participation of local authorities, while the role of companies is not sufficiently recognised.

Previous studies have mainly focused on residents and their quality of life, while the role of businesses in co-creating smart cities remains underrecognised. Meanwhile, as infrastructure users and innovative solutions providers, companies significantly influence shaping the urban ecosystem and its adaptation capacity. Addressing this gap is crucial to understanding how the Smart City development works (Letkiewicz et al., 2024).

Participation in the co-creation process presents a new challenge for city managers and companies. The core of co-creation has evolved since the early 2000s, when it was recognised that engaging customers in the development of products and services is vital to enhancing a company's value (Prahalad, Ramaswamy, 2000, 2004). By becoming an active participant in the creation process, the customer establishes a new link in communication and knowledge exchange. The Dialogue – Access – Risk assessment – Transparency model (DART) proposed

by Prahalad and Ramaswamy, which emphasises dialogue, accessibility, risk assessment, and transparency, has started to be implemented in various business sectors, including city management (Popescul et al., 2024; Rodríguez Bolívar, 2018; Schulders, 2022).

It is worth noting that co-creation involves not only value but also the co-creation of the product and the experience. A significant trend in integrating co-creation into Smart City development was the movement toward individualisation and mass personalisation that emerged in business (Cardullo, Kitchin, 2019; Cohen, Karatzimas, 2022; Preston et al., 2020). The concepts of co-creation, developed in business literature, were later adopted by urban research, where cooperation among various stakeholders became a crucial element in the development of Smart Cities.

The idea of co-creation originated in business literature and was subsequently transferred to urban research, where collaboration among stakeholders became a central part of developing Smart Cities. Today, a key focus in Smart City development is not solely on technology and rankings but also on various aspects of quality of life, including stakeholder experiences and how social needs are addressed within the city.

Today, an essential aspect of Smart City development is not just technology and rankings, but also various dimensions of quality of life, including stakeholder experiences and ways to meet social needs in the city. The Quadruple Helix Innovation Model demonstrates the stakeholder cooperation, emphasising four main actor groups: government, civil society, business, and academic institutions (Carayannis et al., 2012). This model stresses the importance of collaboration and participation among diverse stakeholders in developing the Smart City concept, highlighting the core social needs and sustainable urban growth (Cai, Lattu, 2021).

The innovation ecosystem perspective can further enrich the Quadruple Helix concept by emphasising the actors involved, their relationships, and value exchanges. In ecosystem terms, the city acts as a complex network of interdependencies where companies play a crucial role—both as recipients of public services and as creators of innovative solutions (Jacobides et al., 2018).

In the context of Smart Cities, companies serve a dual role. They benefit from city solutions, such as digitised administrative services, data access, infrastructure, and improved business processes. On the other hand, they develop innovative solutions, such as mobile apps, IoT systems, or smart energy networks, that can be implemented city-wide or across different organisations.

Given this dual role, it is essential to refer to the concept of Public Value Co-Creation, which suggests that public value is generated not only through residents' involvement but also through the active participation of local businesses (Bryson et al., 2014, 2017). The core idea of this concept is the joint creation of social value and innovation that influences residents' quality of life. One institutional mechanism supporting co-creation is Public-Private Partnership (PPP) (Cohen, Karatzimas, 2022).

Understanding how companies co-create within Smart Cities requires examining their attitudes and experiences within a specific urban context. This article aims to present an empirical analysis of companies' attitudes and experiences related to collaboration in the Smart City concept, considering the gender of the decision-maker. The aim of the analysis was to assess business entities' willingness to co-create the smart city concept in the West Pomeranian Voivodeship. The study provides insights into the potential and limitations of cooperation in the two most significant urban centres in the West Pomeranian region.

2. Methods

In 2021, a pilot survey was conducted using CATI (computer-assisted telephone interviewing) and CAWI (computer-assisted web interviewing) techniques on a random sample of 221 companies from the West Pomeranian region in Poland. The study was based on self-reported data collected through a cross-sectional survey approach. Consequently, the results reflect respondents' subjective evaluations at a single moment and do not permit causal inference or analysis of changes in firms' engagement over time.

The study adopted a quantitative approach, employing descriptive statistics, Cronbach's alpha, MANOVA, post-hoc ANOVA, and Pearson's Chi-squared test to analyse the primary data. The research questionnaire consists of two main sections. The first section addressed collecting ratio-scale data from 0 to 100, where 0 indicates no willingness to co-create Smart Cities related to the company, and 100 indicates maximum willingness to co-create. The second section focused on collecting ratio scale data from 0 to 100, where 0 signifies no experience in co-creation by the company, and 100 represents maximum expertise in co-creating Smart Cities by the company. Cronbach's alpha was calculated to assess the internal consistency of the company's scale for willingness to co-create Smart Cities, which includes 10 items: attractiveness of infrastructure (A), cultural events (B), green areas (C), e-office (D), healthcare (E), education (F), environmental protection (G), local labour market (H), safe city (I), and attractiveness of the property (J). It also evaluated the company's co-creation experience with the same 10 items: attractiveness of infrastructure (A), cultural events (B), green areas (C), e-office (D), healthcare (E), education (F), environmental protection (G), local labour market (H), safe city (I), and attractiveness of the property (J) (table 1).

Table 1.*Description of the variables and symbolic representations*

Name of the variable	Symbolic representation	Measurement scale
Attractiveness of infrastructure	A	Ratio scale (0-100, 0 means no willingness or no experience in co-creation, 100 means maximum willingness or maximum experience in the co-creation of smart cities)
Cultural events	B	
Green areas	C	
E-office	D	
Healthcare	E	
Education	F	
Environmental protection	G	
Local labour market	H	
Safe City	I	
Attractiveness of the property	J	

Source: own.

The selection of the ten Smart City dimensions (A–J) was guided by established smart city frameworks and aimed at capturing areas that are particularly relevant from the perspective of companies as both users of urban services and active partners in urban development processes. The dimensions reflect key domains identified in widely recognised models, including the Smart City Wheel (Cohen, 2012, 2015), which emphasises the interconnectedness of governance, economy, environment, mobility, and quality of life, as well as Giffinger's smart city model, which offers a structured classification of urban functions linked to economic performance, innovation, and labour markets (Giffinger et al., 2007).

Additionally, the selection was guided by models that explicitly incorporate sustainability, governance capacity, and stakeholder collaboration, such as IBM's Smarter Cities framework and the Smart Cities Maturity Model developed by the Scottish Cities Alliance. These approaches broaden the smart city concept beyond technological infrastructure by emphasising the importance of digital public services, data-driven governance, environmental responsibility, and cross-sector cooperation in improving urban management and citizen participation (Harrison et al., 2010; Scottish Cities Alliance, 2021).

Taken together, these frameworks support including dimensions related to infrastructure attractiveness, digital public services, environmental protection, labour markets, safety, and the quality of the urban environment. These are areas where companies directly interact with cities and contribute to value creation, making them particularly relevant for analysing business engagement in smart city co-creation. This operationalisation allows an empirical examination of smart city development focused on business participation and collaborative governance rather than only on technological solutions.

The study used self-reported data collected via a cross-sectional survey. As a result, the findings reflect respondents' subjective assessments at a single point in time and do not permit causal inference or the analysis of changes in firms' engagement over time. A reliability analysis indicated the ten-item company's willingness to co-create smart cities scale had acceptable internal consistency, Cronbach's $\alpha = .773$, 95% BCa CI [.698, .825] with a sample of 122 companies (Table 2), and the ten-item the company's co-creation experience of the Smart

Cities scale had good internal consistency, Cronbach's $\alpha = .828$, 95% BCa CI [.740, .887], with a sample of 66 companies (Table 3). RStudio and Microsoft Excel were used to analyse the primary data, and the results were reported in accordance with APA standards.

The conceptual framework of this study comprises a classification variable, specifically gender. The classification or treatment levels indicate whether women or men made decisions. Additionally, the model identifies dependent variables, encompassing ten areas of Smart Cities (A-J) (see Table 1). These ten variables were evaluated under two scenarios: willingness to participate in co-creating a Smart City and experience in co-creating one (Figure 1).

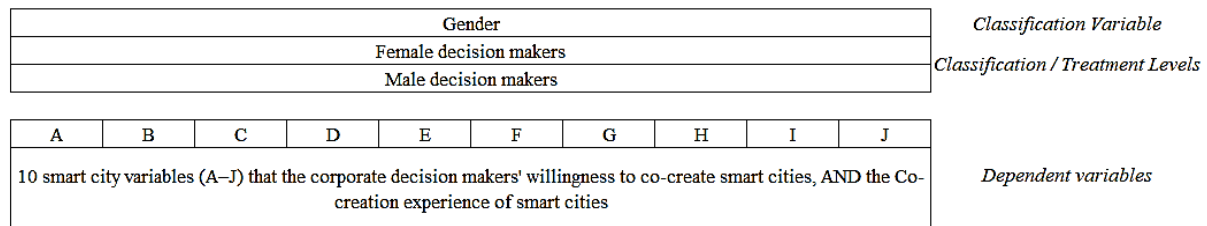


Figure 1. Conceptual framework of the study.

Source: own study.

The research objective

RO1: The first research objective was to test whether female and male decision-makers differ in how they rate willingness to co-create smart cities across 10 Smart City variables (A–J).

RO2: The second research objective was to test whether female and male decision-makers differ in how they rate the co-creation experience of Smart Cities across 10 Smart City variables (A–J).

Main research hypotheses

(H01): There is no difference between female and male decision-makers in the combined importance ratings of willingness to co-create Smart Cities variables (A to J).

(H02): There is no difference between female and male decision-makers in the combined importance ratings of the co-creation experience of Smart Cities variables (A to J).

Post-hoc ANOVA hypotheses (willingness to co-create Smart Cities variables A-J)

Ha10: Mean willingness to co-create Smart Cities variable rating of variable A is equal across females and males.

Hb10: Mean willingness to co-create Smart Cities variable rating of variable B is equal across females and males.

Hc10: Mean willingness to co-create Smart Cities variable rating of variable C is equal across females and males.

Hd10: Mean willingness to co-create Smart Cities variable rating of variable D is equal across females and males.

He10: Mean willingness to co-create Smart Cities variable rating of variable E is equal across females and males.

Hf10: Mean willingness to co-create Smart Cities variable rating of variable F is equal across females and males.

Hg10: Mean willingness to co-create Smart Cities variable rating of variable G is equal across females and males.

Hh10: Mean willingness to co-create Smart Cities variable rating of variable H is equal across females and males.

Hi10: Mean willingness to co-create Smart Cities variable rating of variable I is equal across females and males.

Hj10: Mean willingness to co-create Smart Cities variable rating of variable J is equal across females and males.

Post-hoc ANOVA hypotheses (Co-creation experience of Smart Cities variables A-J)

Ha20: Mean co-creation experience of Smart Cities variable rating of variable A is equal across females and males.

Hb20: Mean co-creation experience of Smart Cities variable rating of variable B is equal across females and males.

Hc20: Mean co-creation experience of Smart Cities variable rating of variable C is equal across females and males.

Hd20: Mean co-creation experience of Smart Cities variable rating of variable D is equal across females and males.

He20: Mean co-creation experience of Smart Cities variable rating of variable E is equal across females and males.

Hf20: Mean co-creation experience of Smart Cities variable rating of variable F is equal across females and males.

Hg20: Mean co-creation experience of Smart Cities variable rating of variable G is equal across females and males.

Hh20: Mean co-creation experience of Smart Cities variable rating of variable H is equal across females and males.

Hi20: Mean co-creation experience of Smart Cities variable rating of variable I is equal across females and males.

Hj20: Mean co-creation experience of Smart Cities variable rating of variable J is equal across females and males.

3. Results

The research was a pilot study and was conducted in companies from the two largest cities in the West Pomeranian Province, Szczecin and Koszalin. The sample included 120 companies from Szczecin and 101 from Koszalin. The regional study focused on companies in the West

Pomeranian Province to ensure the sample accurately represented the structure of companies in the area. Carefully selected sampling criteria were applied to improve the results' reliability and enable generalisations about the population of companies operating in the province. This approach is essential for accurately understanding the opinions and experiences of companies in this specific region (Bazarnik et al., 1992).

Table 2.

Chi-square test of independence - willingness to co-create Smart Cities

Gender	Willing to co-create	
	Yes	No
Female	47 / 21%	43 / 19%
Male	75 / 34%	56 / 25%

Source: field data 2021.

The contingency table shows the distribution of responses across two groups: women and men. The results show that 21% of women and 34% of men expressed willingness to co-create a Smart City (Table 2).

A Chi-square test of independence was conducted to examine the association between the decision maker's gender (female vs. male) and responses (Willing to co-create—Yes vs. Willing to co-create—No). The association was not statistically significant, $\chi^2 (1, N = 221) = 0.36$, $p = .548$, indicating that yes/no responses did not differ by the company's decision-maker's gender.

Table 3.

Chi-square test of independence - experience to co-create Smart Cities

Gender	Co-creation experience	
	Yes	No
Female	23 / 10%	67 / 30%
Male	43 / 19%	88 / 40%

Source: field data 2021.

The contingency table presents the distribution of responses between two respondent groups: women and men. The results show that 30% of women and 40% of men reported having no co-creation experience (Table 3). A chi-square test of independence was conducted to examine the association between the decision maker's gender (female vs. male) and responses (Co-creation experience of smart cities = Yes vs. Co-creation experience of smart cities = No). The findings indicated that the association was not statistically significant, $\chi^2 (1, N = 221) = 1.02$, $p = .312$, indicating that the yes/no responses did not vary according to the company's decision-maker's gender.

MANOVA analysis of the effect of the gender of the decision maker on willingness to co-create Smart Cities. A one-way multivariate analysis of variance was conducted to examine whether the decision-maker's gender (female vs. male) influenced willingness to co-create across 10 dimensions of smart cities (A–J). The results of the multivariate tests were not statistically significant. Specifically, **Pillai's Trace was .13, $F(10, 111) = 1.65$, $p = .102$;**

Wilks' Lambda was .87, $F(10, 111) = 1.65$, $p = .102$; **Hotelling–Lawley trace** was .15, $F(10, 111) = 1.65$, $p = .102$, and **Roy's Largest Root** was .15, $F(10, 111) = 1.65$, $p = .102$. These results indicate that, when considered jointly, there were no statistically significant differences between female and male decision makers in their willingness to co-create across the ten measured Smart City dimensions (A-J) (Table 4).

Table 4.

Multivariate test summary of the gender on willingness to co-create Smart Cities

Test Statistic	Value	F	Hypothesis df	Error df	p value
Pillai's Trace	.13	1.65	10	111	.102
Wilks' Lambda	.87	1.65	10	111	.102
Hotelling–Lawley	.15	1.65	10	111	.102
Roy's Largest Root	.15	1.65	10	111	.102

Note: The independent variable is the decision maker's gender (female or male). The dependent variables are A-J (willingness to co-create dimension of smart cities).

Source: Field data 2021.

Accordingly, none of the dependent variables from A-J (willing to co-create smart cities) show a statistically significant difference between female and male decision-makers.

Analysis - MANOVA - the effect of gender on experience in co-creating Smart Cities. MANOVA was conducted to examine whether the gender of the decision maker (female vs. male) influenced experience in co-creating Smart City dimensions (A–J) (Table 5).

Table 5.

Analysis - Post-hoc ANOVAs (Univariate tests summary of the gender on willingness to co-create smart cities)

Variable	F-value	p-value	Interpretation
A	3.11	.080	Not significant
B	1.40	.287	Not significant
C	1.04	.309	Not significant
D	0	.995	Not significant
E	1	.139	Not significant
F	.68	.410	Not significant
G	1.33	.250	Not significant
H	.47	.491	Not significant
I	3.85	.060	Not significant
J	.08	.771	Not significant

Source: Field data 2021.

The multivariate effect of gender was not statistically significant. Specifically, **Pillai's Trace** = .12, $F(10, 55) = 0.77$, $p = .660$; **Wilks' Lambda** = .88, $F(10, 55) = 0.77$, $p = .660$; **Hotelling–Lawley trace** = .14, $F(10, 55) = 0.77$, $p = .660$; and **Roy's Largest Root** = .14, $F(10, 55) = 0.77$, $p = .660$. These results indicate that female and male decision makers did not differ significantly in their co-creation experience when considering the ten dimensions jointly (Table 6).

Table 6.*Multivariate test summary of the gender on the co-creation experience of Smart Cities*

Test Statistic	Value	F	Hypothesis df	Error df	p value
Pillai's Trace	.12	.77	10	55	.660
Wilks' Lambda	.88	.77	10	55	.660
Hotelling–Lawley	.14	.77	10	55	.660
Roy's Largest Root	.14	.77	10	55	.660

Note: The independent variable is the gender of the decision maker (female or male). Dependent variables: A–J (Co-creation experience of Smart Cities).

Source: Field data 2021,

Based on the results presented in Table 7, none of the variables examined (A–J) differentiate participants' experiences in Smart City projects.

Table 7.*Analysis - Post-hoc ANOVAs (Univariate tests summary of the experience in co-creation of Smart Cities)*

Variable	F-value	p-value	Interpretation
A	.01	.920	Not significant
B	1.13	.291	Not significant
C	.00	.948	Not significant
D	.010	.917	Not significant
E	.79	.377	Not significant
F	.57	.451	Not significant
G	.16	.685	Not significant
H	.51	.474	Not significant
I	1.24	.269	Not significant
J	.10	.749	Not significant

Source: Field data 2021.

Accordingly, none of the dependent variables from A–J (Experience in co-creating Smart Cities) show a statistically significant difference between female and male decision-makers.

4. Discussion

The analyses conducted show that in none of the areas studied was there a significant correlation between the gender of managers and their attitude towards co-creating a Smart City. The areas examined included: attractiveness of infrastructure (A), cultural events (B), green areas (C), e-office (D), healthcare (E), education (F), environmental protection (G), local labour market (H), safe city (I), and attractiveness of the property (J). The findings may suggest that gender does not play a significant role in the willingness to innovate, including in co-creating a Smart City (Expósito et al., 2023). However, when it comes to issues of security or trust in modern solutions, emotions are correlated with gender. However, these issues were not the subject of the research results presented in the article (Walczak et al., 2025).

Regarding experience in co-creating Smart City areas, no correlation was found between the manager's gender and their self-reported experience. This is different from research on CSR implementation and gender differences in attitudes (Lu et al., 2020).

However, studies in other markets indicate that gender issues should be taken into account at the planning stage. This is particularly true in regions where women play a lesser role in management, such as Asian countries (Wahyudi, Elanda, 2023).

Companies' gender does not seem to differentiate either willingness or experience in co-creating Smart City areas. Consequently, this may mean that in practice, when engaging companies from the West Pomeranian region, the willingness to participate in Smart City projects is independent of the gender of the management staff. This may suggest that, in the region under study, companies' approach to smart cities is shaped more by sectoral, technological, or economic factors than by managers' socio-demographic characteristics.

Some limitations may have influenced the research results. First, it is important to note that the study was pilot in nature. The relatively small sample size might not have identified subtle differences between gender groups across the examined variables. It should also be recognised that the sample included companies from a region with a specific sectoral structure, which may limit the broader applicability of the findings. Additionally, as the concept of co-creation is not yet widely integrated into the development of Smart Cities, this may have influenced respondents' assessments of both willingness to participate and actual experience.

The data were based on self-reported assessments, which may be affected by respondents' subjective perceptions and social desirability bias. Additionally, the cross-sectional design of the study does not permit tracking changes in firms' engagement over time or establishing causal links between gender and co-creation attitudes. Finally, the use of aggregated indicators may have restricted the ability to observe more detailed differences across specific dimensions of smart city co-creation.

Despite these limitations, the findings add to the existing literature, as empirical studies exploring business engagement in smart city co-creation within the Polish context remain limited, and gender does not appear as a major differentiating factor. In practice, this indicates that local governments planning collaboration with companies do not need to tailor their strategies for engaging firms based on the gender of the individual in charge. Therefore, the researcher recommends conducting similar studies with a larger sample covering the entire country of Poland as a future research direction. Additionally, future research could be designed to analyse the same phenomena across various sectors and industries to identify potential differences.

In summary, the literature on this topic shows mixed results. Some studies find no gender differences in the overall perception of Smart City co-creation. Conversely, others indicate that differences exist regarding specific aspects, such as trust in technology or environmental values.

5. Summary

The aim of the empirical analysis in this article was to evaluate business entities' willingness to participate in the co-creation of the smart city concept in the West Pomeranian Voivodeship, based on companies' attitudes and experiences, with gender as a factor explaining differences. The results indicate that managers' gender does not differentiate between companies' willingness to co-create Smart Cities or their experiences in this area. This means that, in practice, business involvement in such initiatives in the West Pomeranian region is gender-neutral.

These results significantly contribute to the discussion on co-creating Smart Cities, as they indicate that demographic factors - such as gender - do not necessarily determine business engagement. This suggests that other factors, such as industry, company size, level of innovation, or a company's degree of integration into the local ecosystem, may play a more significant role in shaping urban policies.

From a practical perspective, the results show that strategies for involving businesses in Smart City projects can be designed more universally without differentiating activities based on the management staff's gender. This allows local governments to focus on building cooperation platforms, making project access easier, and creating sectoral incentives that appeal to companies regardless of their demographic makeup.

However, it should be emphasised that the study was a pilot study and its scope was limited to the two largest urban centres in the West Pomeranian region. The small sample size might not have revealed subtle relationships that would be visible in a larger-scale study. Additionally, each region has its own sector-specific characteristics, which makes it difficult to generalise the results to other areas. Future analyses should consider the industry and size of companies, as well as cultural, technological, and organisational factors that may influence their readiness to co-create a Smart City.

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AI IMPACT AND SOCIAL BEHAVIOR IN LEARNING ENVIRONMENTS: A PROXEMICS-BASED APPROACH TO EDUCATION 5.0 (PAE 5.0)

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Purpose: The purpose of this paper is to theoretically consider how proxemics (Hall, 1966)—the study of interpersonal spatial relationships—can be applied as an analytical and design-oriented approach for structuring contemporary learning environments. The research addresses the growing need to integrate human-centered spatial design with adaptive technologies in line with the principles of Education 5.0.

Design/methodology/approach: The paper adopts a conceptual and design-informed research approach. It synthesizes architectural theory, environmental psychology, and proxemics theory, drawing on the works of Edward T. Hall, Bryan Lawson, and William H.

Whyte. Visual and behavioral analysis of archival material from pre-digital era *The Social Life of Small Urban Spaces* is combined with hypothetical spatial organization concept based on PAE 5.0 framework to develop a structured vision to educational environments redevelopment strategies. The framework is illustrated through a hypothetical and conceptual design model referred to as the Co-Learning Space.

Findings: The paper demonstrates that proxemics principles can be translated into measurable spatial parameters and recurring patterns that support interaction, observation, collaboration, and reflection (IOCR) in educational environments. It clarifies how spatial distance, visibility, and thresholds mediate social behavior and learning processes. These principles are illustrated through a conceptual case study—the Co-Learning Space—which integrates Education 5.0 spatial assumptions (PAE 5.0) with an AI-driven proxemics loop (AIPL) to enhance pedagogical outcomes.

Research limitations/implications: The research is conceptual and does not include empirical testing in implemented learning environments. The paper is intentionally framed as a conceptual and analytical contribution, aimed at developing a transferable framework rather than reporting results from an implemented project. Further research should involve pilot projects, longitudinal observation, and mixed-method evaluation, combining sensor data with qualitative methods or behavioral studies to assess learning and organizational outcomes.

Practical implications: The proposed proxemics approach provides decision-support guidance for architects, educational managers, and education planners. It can inform spatial programming, campus redevelopment strategies, and governance frameworks for adaptive learning environments, particularly where AI-supported systems are introduced.

Social implications: By reinforcing physical co-presence, observation, and collective engagement, the proxemics approach contributes to improved social cohesion, and inclusive

learning cultures. It supports responsible technology adoption by framing AI as an assistive rather than determinative component of educational space.

Originality/value: The paper contributes an original integration of proxemics theory with Education 5.0 and adaptive spatial systems, positioning proxemics as a strategic analytical approach relevant to architecture design, education space organisation, and management studies. Its value lies in bridging human-centered design, technological mediation, and organizational governance within learning environments.

Keywords: spatial communication; Education 5.0 environments design; proxemics; human-centered AI design; AI impact on sociability.

Category of the paper: Conceptual paper; Hypothetical Case Study.

1. Introduction

This paper examines spatial communication in educational environments through the lens of proxemics, focusing on how interpersonal distance, spatial configuration, and embodied perception influence social interaction and learning processes in AI-mediated contexts. Grounded in architectural theory and environmental psychology, the study positions proxemics as an analytical approach for interpreting human–space relations within contemporary educational settings shaped by adaptive and data-informed technologies. The paper addresses current challenges in designing educational environments that sustain collective presence, social empathy, and human-centered values while accommodating the increasing role of artificial intelligence in spatial mediation contexts. Sustaining sociability is one of the core principles of Education 5.0 and in wider context Society 5.0 (Government of Japan, 2016).

In contemporary learning environments, digital tools and adaptive technologies increasingly influence how space is used and managed. „The transition from Education 4.0 to Education 5.0 thus represents a move from digital to pedagogical transformation, from re-digitalizing education to re-humanizing it” (Komló, 2025). Education 5.0 foregrounds human flourishing, creative collaboration, and the purposeful integration of technological instruments in support of social and emotional development. Realizing these objectives extends beyond curricular reform and digital infrastructure; it necessitates a reconsideration of the spatial conditions that enable IOCR (interaction, observation, collaboration and reflection) to increase co-presence and collective engagement. „Education 5.0 contributes skilled, adaptable talent and innovation capacity (...)” (Chigbu, Makapela, 2025). Although human-centred values are emphasized in Education 5.0 discourse, learning environments are rarely analysed as spatial systems that structure interaction co-presence, and embodied learning (Komló, 2025; Bautista, López-Costa, 2025).

Architectural space functions as a system of relationships defined by distance, orientation, thresholds, and sensory cues that collectively structure social interaction (Lawson, 2001). These spatial relationships form a nonverbal language through which behaviour, perception,

and communication are facilitated. Proxemics, introduced by Hall (1966), provides a structured means of interpreting this language by identifying interpersonal distance zones and their associated social functions.

A proxemics approach is proposed and examined through a conceptual case study to demonstrate its relevance for Education 5.0 and organizational management. Against this background, the article advances proxemics as a critical analytical approach for understanding and designing educational environments that sustain collective learning and social empathy, while situating artificial intelligence as a mediating rather than substitutive element of human interactions.

Prior to the pervasive mediation of digital technologies, public spaces frequently operated as informal learning environments, in which social knowledge was acquired through proximity, imitation, and shared attention. William H. Whyte's film *The Social Life of Small Urban Spaces* (1980) offers a systematic empirical record of such proxemics dynamics, providing a valuable point of reference for reassessing the spatial foundations of sociability and social cohesion in contemporary contexts. People observe and learn through social interactions. That is why the important role of William H. Whyte's *The Social Life of Small Urban Spaces* is justified as a **structured empirical observational dataset** from the pre-digital era, showing sociability, social learning process, human interactions in small and larger groups and human responsiveness to environmental factors in public zones, rather than as an illustrative historical reference.

2. Proxemics and Spatial Communication in Learning Environments

2.1. Space as a communicative medium

Architectural form, layout, furniture, and circulation encode social norms and behavioural expectations (Rapoport, 1982). In learning environments, spatial configuration influences attention, interaction patterns, and cognitive load. Theories of embodied and situated cognition reinforce the premise that learning is inseparable from movement and social context, making spatial communication a pedagogically relevant concern.

2.2. Proxemics as behavioural structuring

Hall's(1966) classification of intimate, personal, social, and public distances can be translated into architectural parameters such as seating density, visibility, enclosure, and acoustic separation. While proxemics norms vary culturally, the underlying relationship between distance and social function remains consistent and applicable across educational contexts. Proxemics is a tool which could improve social interactions.

2.3. Observation and co-presence

Whyte's (1980) empirical observations demonstrate how micro-spatial features—edges, seating opportunities, sunlight, and focal elements—structure social density and informal interaction together with social learning. His work anticipates contemporary interest in behavioural analytics while underscoring the enduring value of visible co-presence for learning.

2.4. Human-centred design and adaptive systems

Human-centred design prioritizes empathy, participation, and user agency. Adaptive technologies and AI-supported systems offer data-informed responsiveness but introduce governance and ethical challenges if they override human judgment. A proxemics approach positions technology as a decision-support mechanism embedded within human oversight structures. Moreover, „universities are socially and digitally engaged institutions where the teaching methodologies will need to transform to the digital space. Educational technology enables adaptive learning programs, collaborative teaching, and personalized learning, which will be the new forms of education” (Shahidi Hamedani et al., 2024). Dedicated tools like digital twins, AI tutors, personalized learning software, and immersive technologies (VR/AR) enhance, not replace, human teaching and learning, keeping teachers and students „research&learning loop”. Proxemics based approach to Education 5.0 can add the new layer to the design process in which the addaptive systems are already the part of architecture of educational environment (i.ex. through the intelligent building systems). Proxemics adds an extra human-centered value to the educational environments design methods amd helps reshaping spaces according to Education 5.0 principles.

Learning does not occur independently of physical environments. Architectural space operates as a communicative medium structured by distance, orientation, thresholds, and sensory cues that shape social interaction and behaviour. Although human-centred values are emphasized in Education 5.0 discourse, learning environments are rarely analysed as spatial systems that structure interaction and embodied learning (Komló, 2025; Koper et al., 2025).

3. Methodology: Circular Proxemics Approach to Education 5.0 (PAE 5.0) — human-centered foundations

3.1. Research approach

The study employs a conceptual research methodology integrating theoretical synthesis with design reasoning. Literature in proxemics, environmental psychology, and architectural theory is combined with visual analysis of archival film material (Whyte, 1980) as evidence of pre-digital proxemics practices. Literature review helps formulating “several questions for

future research on the concept of the smart classroom and on how learning spaces can be improved and should be designed. For instance: (...) What are the design principles for creating inclusive and sustainable learning environments? How do learning spaces influence in segregation or coeducation? These and many other questions need to be addressed in the study of physical learning space design” (Bautista, López-Costa, 2025). Synthesis presented in this research informs a structured proxemics approach (PAE 5.0) organized around three analytical dimensions: sensory conditions, interaction patterns, and reflective use. The use of proxemics is clarified as an **analytical and design-oriented framework**, grounded in recognized theory and qualitative spatial research methods. Based on the literature research the Proxemics Approach to Education 5.0 (PAE 5.0) is derived. The proposed approach aims to be practical — providing architects with a set of spatial parameters and design moves — while remaining theoretically grounded. Visual-behavioral analysis is a recognized qualitative method in architectural and spatial research, particularly for studying proxemics, social density, and interaction patterns in situated environments (Groat, Wang, 2013; Müller, Richert, 2025).

3.2. Terms and definitions- theoretical approach

Education 5.0 is understood as a human-centred educational paradigm that emphasizes social cohesion, creativity, ethical responsibility, and the supportive integration of advanced technologies. It refers to the specific contextual conditions under consideration.

Proxemics Approach to Education 5.0 (PAE 5.0) refers to a spatial-analytical approach that applies proxemics theory to the design and evaluation of educational environments, focusing on interpersonal distance, spatial configuration, and patterns of co-presence. It describes an analytical approach grounded in spatial analysis.

The AI-Driven Proxemics Loop (AIPL) denotes an adaptive spatial management mechanism in which sensing, interpretation, and adjustment processes support proxemics conditions under human oversight. It describes adaptive technological mechanism.

3.3. Rationale

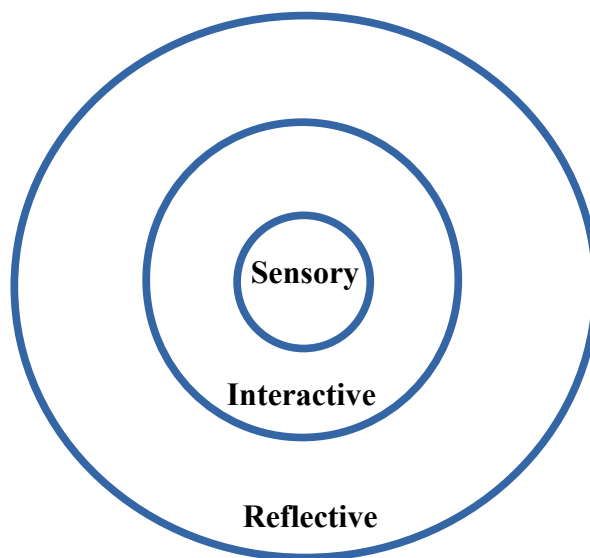
In line with recent Education 5.0 scholarship relying on qualitative synthesis and systematic literature review rather than primary empirical experimentation (Shahidi Hamedani et al., 2024; Chigbu et al., 2025), this study adopts a conceptual, design-informed qualitative research methodology. While PAE 5.0 secures a human-centred baseline, the AI-Driven Proxemics Loop (AIPL) proposes how sensing and adaptation can enhance environmental responsiveness without supplanting empathic design intent. Adaptive Spatial management is important because of human oversight. Moreover the AI-Driven Proxemics Loop (AIPL) supports dynamic spatial communication. „This also implicitly tells us that the researchers who have addressed the subject up to this point needed the flexibility in data collection and analysis that qualitative research methods provide, allowing them to adapt their approaches based on emerging findings. (...) This may also provide insight into the methodological variations among the many academic

disciplines, which, in turn, helps us gauge how comprehensively these disciplines have investigated the topic of this study. It is important to understand that methodological tools vary across disciplines, which has an impact on the types of questions that can be posed” (Shahidi Hamedani et al., 2024).

3.4. Circular Proxemics Approach to Education 5.0 (PAE 5.0) — human-centred foundations

Based on conducted research (Shahidi Hamedani et al., 2024; Komló, 2025), the circular PAE 5.0 frames proxemics relations as concentric layers radiating from the individual to culture established (Figure 1):

- **Sensory Layer:** immediate perceptual field, materials, microclimate, acoustic comfort — conditions for presence and attentional readiness.
- **Interactive Layer:** proxemics distances, seating clusters, orientation, visibility — supports dialogue, peer learning, workshops.
- **Reflective Layer:** identity, memory, belonging, ownership of space — supports reflection, mentoring, mental rest.



Sensory (centre), Interactive (middle ring), Reflective (outer ring).

Figure 1. Circular Proxemics Approach to Education 5.0 (PAE 5.0).

Source: D. Wiśniewska.

3.5. Visual analysis and archival evidence

Design operationalization involves mapping learning activities to proxemics zones, defining spatial affordances, and introducing transitional elements that support fluid movement between modes of learning. Whyte’s film sequences were analysed to extract recurring proxemics patterns: clustering behaviour, micro-seating appropriation, edge occupation,

and the role of natural elements. These patterns inform PAE 5.0 (Figure 1) suggested spatial moves, such as designing permeable edges and creating “sittable” informal surfaces.

Iterative observation and prototyping are proposed as evaluation mechanisms.

3.6. Structure of the AIPL - analytical framework

Adaptive spatial systems can support learning environments through non-intrusive sensing, pattern interpretation, and data-informed adjustment of environmental conditions such as lighting or acoustic modulation. The AIPL (Figure 2) comprises four iterative stages:

1. **Sensing:** occupancy, clustering metrics, noise, temperature, and light levels (via non-intrusive sensors).
2. **Interpreting:** machine learning models classify activities (discussion, presentation, quiet study) and proxemics patterns.
3. **Adapting:** the system proposes or executes adjustments (acoustic panels, dynamic lighting, signage suggestions, reconfigurable furniture prompts).
4. **Learning:** feedback loops refine interpretation models, guided by HCD constraints and manual overrides.

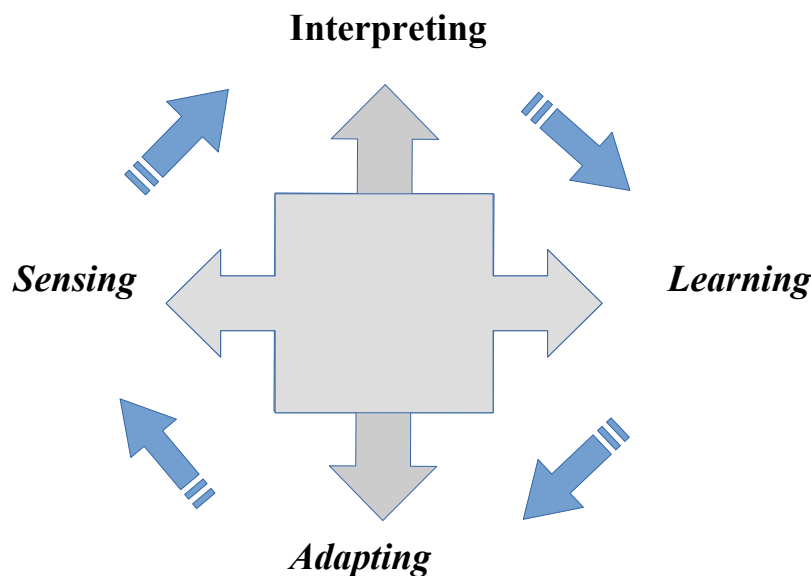


Figure 2. AI-Driven Proxemics Loop (AIPL).

Source: D. Wiśniewska.

3.7. Human-in-the-loop and ethics

Crucially, AIPL (Figure 2) must preserve human decision nodes: choices about privacy, data retention, aesthetic and ethical trade-offs are resolved through participatory protocols. AI provides suggestions and analytics but does not replace human judgment. This supports an aspirational design aim: **human-centered as inspiration for AI-driven design.**

Furthermore, these systems must operate within human-in-the-loop governance structures that define decision rights, privacy safeguards, and ethical boundaries. Technology informs spatial management but does not autonomously determine behavior.

4. Conceptual Design Theory: The Co-learning Space

4.1. Concept overview

The *Co-Learning Space* is presented as a conceptual design hypothesis illustrating how proxemics principles can inform architectural spatial organization in an Education 5.0 context. Because terms Education 5.0 and Work 5.0 are considered together in many research papers, the concept of co-learning space was analyzed according to existing co-working spaces. Conceptual and exploratory case studies are widely employed in architectural research to test theoretical frameworks and design logic prior to empirical implementation (Groat, Wang, 2013; Creswell, Poth, 2018). According to conceptual design hypothesis presented in this paper the educational environment is structured into interconnected (hybrid) *macro* and *microzones* corresponding to public, social, personal, and intimate distances (Hall, 1966). Design elements such as sittable edges, flexible furniture, and permeable visibility foster learning by observational, spontaneous collaboration, and reflective use. It is intentionally presented as a conceptual model — not an executed project — to demonstrate how PAE 5.0 and AIPL are translated into design moves. By enabling learners to modulate their level of social exposure, **the Co-Learning Space supports self-regulation and sustained engagement across varying learning modes** and stays in line with Education 5.0 principles.

4.2. Spatial program and proxemics mapping

Referring to pedagogical outcomes, when designed in accordance with proxemics and human-centered principles, the Co-Learning Space supports multiple modes of learning that extend beyond formal instruction.

Based on proxemics distances (Hall, 1966) presented below and the Education 5.0 principles, The Co-Learning Space is organized into interconnected *macrozones* (Agora and Collaboration Hub) and *microzones* (Mentoring Pod and Reflective Nooks):

- **Agora (Public Zone):** open square for lectures, exhibitions, and festivals — supports public distances (>3.6 m).
- **Collaboration Hubs (Social Zone):** movable worktables, shaded pergolas, small amphitheatres for 4-12 people (1.2-3.6 m).

- **Mentoring Pods (Personal Zone):** semi-enclosed alcoves for one-to-one feedback, tutoring, and focused small-group work (0.45-1.2 m).
- **Reflective Nooks (Intimate Zone):** secluded benches near vegetation and water features for contemplation and emotional reset (<0.45 m).

Those principles are helpful in space design process. Google offices design (Figure 3) i.ex. is the good exaple of implementation of Work 5.0 framework into space design process. Imlementing the conceptual design theory of Co-learning Space can result with better quality of educational environments.



Figure 3. Google office design in Johannesburg.

Source: <https://trendgroup.co.za/>

4.3. Design moves inspired by Whyte

Adaptive systems are introduced as supportive mechanisms that provide feedback on occupancy and usage patterns while remaining subject to human interpretation based on Whyte's (1980) findings which suggest several concrete moves:

- **Sittable edges and thresholds:** encourage informal seating and accidental grouping.
- **Focal attractors:** water, art, sunlight patches to generate social magnetism.
- **Flexible furniture:** clusters that can be reconfigured to shift proxemics relations.
- **Permeable visibility:** transparent partitions and sightlines that enable peripheral observation.

4.4. AIPL integration in the Co-Learning Space and its pedagogical outcomes

Referring to pedagogical outcomes, when designed in accordance with proxemics and human-centered principles, the Co-Learning Space supports: could:

- observational learning: students acquire knowledge through peripheral observation of peers engaged in practice,
- spontaneous collaboration: micro-interactions facilitate unplanned yet productive social exchange (compare Koper et al., 2025),
- emotional regulation: reflective zones contribute to stress reduction and improved cognitive readiness.

Furthermore within the Co-Learning Space, AIPL could:

- detect rising cluster density and suggest opening adjacent collaboration hubs via retractable partitions, or offer scheduling prompts,
- modulate localized lighting and acoustic attenuation during focused sessions,
- compile anonymized occupancy heat maps for designers to understand long-term spatial usage patterns.

4.5. Operationalizing PAE 5.0 for Co-learning Space

To translate the circular model into design, based on the conceptual design theory presented in this paper, practitioners can:

- Map typical activities and classify them by proxemics zone (intimate to public, compare Figure 4).
- Specify spatial affordances for each zone (furniture type, sight-lines, acoustic thresholds).
- Provide transitional elements (thresholds, gradients of enclosure) to allow fluid movement between zones.
- Test scenarios using small-scale observations and iterative prototyping.

Within the Co-Learning Space, the AI-Driven Proxemics Loop (AIPL) operates as an adaptive yet non-deterministic layer that supports spatial management while preserving human agency in design and use. Through non-intrusive sensing technologies, the system can detect variations in occupancy, clustering density, movement patterns, acoustic levels, and environmental comfort. When rising cluster density is identified in collaboration hubs or transitional zones, AIPL may suggest the temporary opening of adjacent spaces through retractable partitions, thereby redistributing activity and preventing spatial congestion. Alternatively, the system can generate scheduling prompts or spatial recommendations communicated to users or facility managers, enabling informed decision-making without enforcing behavioural outcomes.

During periods of focused or individual work, AIPL can modulate localised lighting conditions and acoustic attenuation to support concentration and reduce cognitive overload. Such adjustments are calibrated to proxemics conditions rather than purely functional metrics; for instance, lighting intensity and sound absorption may be adapted differently in personal versus social distance zones. Importantly, these adjustments remain reversible and transparent, reinforcing the principle that adaptive systems should augment, rather than replace, human perception and judgment.

Over longer temporal cycles, AIPL can compile anonymized occupancy heatmaps and behavioral trend visualizations. These datasets provide architects, educational managers, and institutional decision-makers with evidence-based insight into how spaces are appropriated, transformed, or avoided over time. Rather than serving as prescriptive optimization tools, these analytics function as reflective instruments that inform post-occupancy evaluation, iterative design refinement, and governance decisions related to spatial policy and resource allocation. In this sense, AIPL contributes to organizational learning by translating spatial use into intelligible patterns without reducing complex human behaviors to purely quantitative indicators.

One key postulated outcome, based on theoretical research is **observational learning**, whereby students acquire tacit knowledge through peripheral awareness of peers engaged in diverse activities. Visual permeability, layered sight-lines, and proxemics gradation enable learners to observe processes, gestures, and social interactions without direct participation. This aligns with theories of social and situated learning, in which knowledge emerges through exposure, imitation, and shared presence rather than exclusively through verbal instruction.

A second outcome is **spontaneous collaboration**, facilitated by spatial configurations that encourage micro-interactions at thresholds, edges, and transitional zones. Informal seating, shared surfaces, and semi-enclosed hubs enable brief encounters to develop into meaningful exchanges. Such interactions are often unplanned yet productive, fostering interdisciplinary dialogue, peer feedback, and collective problem-solving. The proxemics organization of the Co-Learning Space ensures that these encounters occur within socially comfortable distance ranges, reducing barriers to participation and supporting inclusive engagement (Figure 4).

A third pedagogical outcome concerns **emotional regulation and cognitive readiness**. Reflective zones—characterized by reduced sensory stimulation, proximity to natural elements, and greater spatial enclosure—provide opportunities for mental restoration and stress reduction. In high-density educational environments, the availability of such proxemically distinct spaces is critical for maintaining attention, motivation, and psychological comfort.



Figure 4. Macrozones at Bydgoszcz University of Science. Agora and Collaboration Hubs.

Source: D. Wiśniewska.

Collectively, these outcomes illustrate how spatial communication, informed by proxemics and supported by adaptive systems, contributes to learning as a holistic process encompassing cognitive, social, and emotional dimensions.

5. Discussion

This paper addresses this gap by proposing a proxemics-based analytical framework for Education 5.0 environments, positioning artificial intelligence as a supportive, non-deterministic layer embedded within human-in-the-loop governance structures. **Proxemics principles in educational environments can be described by measurable spatial parameters and recurring patterns that support interaction, observation, collaboration, and reflection (IOCR).** The proxemics approach provides a structured vocabulary for articulating how spatial arrangements influence learning behaviour and organizational culture. By integrating proxemics with adaptive systems under human oversight, learning environments

can balance technological responsiveness with social presence. Cultural variability necessitates local calibration, and the conceptual nature of the study highlights the need for empirical validation. The paper is intentionally framed as a **conceptual and analytical contribution**, aimed at developing a transferable framework rather than reporting results from an implemented project. Conceptual case studies are widely accepted in architectural, educational, and organizational research as a means of testing theoretical coherence and design logic prior to empirical application. Implementing a full empirical case study would exceed the scope of the present work and is therefore proposed as a direction for future research. Theoretical conceptual design gives structured framework for further spatial analyses and behavioral studies of reshaped space. Well structured framework helps with more detailed synthesis of design decisions.

The Co-Learning Space design concept demonstrates that educational environments can be designed as dynamic ecosystems in which architecture, pedagogy, and technology are mutually reinforcing. Within this framework, artificial intelligence functions not as an autonomous controller but as an assistive mechanism embedded within human-centered governance structures. Such positioning is consistent with Education 5.0 values, emphasizing ethical responsibility, and the cultivation of collective intelligence through spatial design.

While contemporary Education 5.0 literature extensively examines human–AI interaction, ethics, and workforce transformation (Shahidi Hamedani et al., 2024; Komló, 2025), spatial communication and proxemic structuring of learning environments remain marginal in current research. This study contributes by positioning proxemics as a strategic analytical layer linking architectural design, educational governance, and AI-mediated spatial design and management. The contribution of the paper is identifying the **lack of spatial and proxemics perspectives in literature describing human-centered perspective in design guidelines for educational environments according to current Education 5.0 approach**. While contemporary Education 5.0 literature extensively examines human–AI interaction, ethics, and workforce transformation (Shahidi Hamedani et al., 2024; Komló, 2025), spatial communication and proxemic structuring of learning environments remain marginal in current research. This study contributes by positioning proxemics as a strategic analytical layer linking architectural design, educational governance, and AI supported spatial management.

6. Conclusion

Historically, public spaces functioned as informal learning environments where social learning occurred through observation and shared presence. This study demonstrates that spatial communication, interpreted through proxemics, offers a coherent and transferable approach to the design and evaluation of educational environments in relatively new AI-mediated contexts.

By foregrounding human sensory, social, and behavioral needs, the proxemics-based approach enables architects and decision-makers to articulate how spatial configurations support collective presence, interaction, and learning outcomes.

The proposed conceptual models illustrate how human-centered spatial principles based on proxemics could help develop educational environments inform without delegating agency to AI technology. In this sense, artificial intelligence functions as an enabling layer that supports evidence-informed decisions, spatial responsiveness, and organizational learning. By treating AI-supported systems as assistive mechanisms rather than autonomous agents, the proposed approach is in line with Education 5.0 values and responsible organizational management. By embedding artificial intelligence within human-in-the-loop governance structures, the proposed proxemic approach aligns with Society 5.0 principles emphasizing ethical responsibility, human agency, and sustainable development (De Villiers, 2024; Chigbu et al., 2025). Such positioning is particularly relevant for institutions seeking to balance innovation with ethical responsibility, user security and comfort, as well as long-term sustainability.

For policy makers, educational managers, and designers, the findings underline the value of integrating architectural knowledge into broader governance frameworks for learning environments. The final hypothesis presented in this article is: *Proxemics provides a shared language through which spatial quality, social interaction, and adaptive AI-driven technologies can be evaluated and aligned with Education 5.0 objectives*. Proxemics offers a strategic tool for structuring learning environments that align architectural design, educational objectives, and adaptive technologies. The study contributes to interdisciplinary discourse across architecture, education, and management by reframing spatial design as a communicative and governable system. Furthermore, adaptive technological systems, when embedded within human oversight and governance mechanisms, can enhance responsive spatial management without undermining physical co-presence or social interaction.

Future research should test the proposed approach in implemented projects, combining spatial analytics with qualitative assessment to support informed management of educational space in increasingly complex institutional settings.

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IMPLEMENTING ESG PRACTICES AT NORTHPAL APS: A CASE STUDY OF SUSTAINABLE PALLET PRODUCTION

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Purpose: This article (constituting a case study) aims to present Northpal ApS's approach to implementing a sustainable production model, in which the values of environmental protection, care for employees and transparency of management are the foundation of a long-term development perspective.

Design/methodology/approach: This article first presents a theoretical discussion of the ESG concept, based on literature and online resources. Next, in conjunction with the theoretical considerations, the empirical section presents the case of a Polish Danish company operating in the pallet market.

Findings: The results of the analysis indicate that a strategic approach to ESG is not only a tool for building a competitive advantage for the company but can also be a catalyst for innovation and industrial transformation.

Practical implications: The text presents specific activities in the area of environmental protection, social responsibility and corporate governance carried out by the company in question, as well as discusses the challenges related to the formal confirmation of implemented practices through certification.

Originality/value: The case study discusses how the company integrates the principles of sustainable production, circular economy and ethical management, and how it builds the perception of its brand by conscious consumers. the practices implemented by Northpal can be treated as a reference model for other manufacturing companies, especially in the wood and logistics sectors.

Keywords: Research and Development, Competitiveness, Innovation, Sustainable Business, Circular Economy.

Category of the paper: Case study.

1. Introduction

In the era of global environmental challenges and changes in social expectations in this area, manufacturing companies are obliged to look for innovative solutions that combine economic efficiency with responsibility for the environment. The ESG concept – understood as the co-existing environmental, social and governance criteria – provides a framework for managing sustainable development in companies. This article first presents a theoretical discussion of the ESG concept, based on literature and online resources. Next, in conjunction with the theoretical considerations, the empirical section presents the case of a Polish Danish company operating in the pallet market. Northpal ApS – the company presented in the study is an example of a company that, although formal ESG certification is currently in the preparatory phase for implementation in business practice, is already implementing real actions and practices in accordance with ESG guidelines. This article (constituting a case study) aims to present Northpal ApS's approach to implementing a sustainable production model, in which the values of environmental protection, care for employees and transparency of management are the foundation of a long-term development perspective. Therefore, the article is an attempt to find an answer to the question: can modern manufacturing companies that have decided to voluntarily implement ESG practices in their operations increase their competitiveness on the market compared to companies that do not yet apply such practices?

2. ESG reporting obligation and principles of operation for sustainable development - current approach

The implementation of ESG principles in manufacturing companies is currently closely linked to EU regulations (Gniadkowska-Szymańska, 2025). The Corporate Sustainability Reporting Directive (CSRD, 2022/2464/EU) plays a key role in this regard. It obliges large companies and listed companies operating in the European Union to regularly disclose environmental and social risks associated with their operations and to report the actual impact on the natural and social environment (European Commission, 2025a; Sadowski, 2023).

Reports on the activities of companies must be prepared in accordance with the European Sustainability Reporting Standards (ESRS), which ensure comparability and transparency of data between companies. The first group of entities, including the largest companies already reporting under the NFRD, i.e. the Non-Financial Reporting Directive. Non-Financial Disclosures Directive — full name: Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 was the first EU piece of legislation to oblige large companies to disclose non-financial information, such as:

1. environmental data (E),
2. social and labour issues (S),
3. respect for human rights,
4. counteracting corruption,
5. corporate governance (G).

It will be covered by new regulations for the financial year 2024, and the reports will be published at the end of 2025. In the coming years, this obligation will be extended to all large companies, small and medium-sized listed companies, as well as non-EU companies with significant revenues in Europe. The reporting standards are developed by EFRAG (European Financial Reporting Advisory Group) and are aimed at ensuring consistency and comparability of disclosures across the European Union (European Commission, 2025a).

Table 1 presents a comparison of the key characteristics of the CSRD directive and the reporting principles under the ESRS standards.

Table 1.
Comparison of CSRD and ESRS

Element	CSRD (Directive 2022/2464/EU)	ESRS (European Sustainability Reporting Standards)
Legal nature	EU Directive (obligation to implement into national law)	Technical standards adopted by the European Commission
Purpose	Expanding ESG reporting obligations and ensuring non-financial transparency	Unify ESG reporting methods and metrics
Scope	All large companies, listed companies in the EU, and ultimately also selected companies from outside the EU	Specific disclosure requirements in areas E (environment), S (social), G (corporate governance)
Developing body	European Commission	EFRAG (European Financial Reporting Advisory Group)
Obligation to use	Yes, for companies that meet the CSRD criteria	Yes, as a tool for fulfilling the CSRD obligations
Implementation schedule	From the financial year 2024 (reports in 2025) for the largest companies, then gradual expansion	Applied in parallel with the entry into force of the CSRD (from 2024/2025)
Importance for practice	Imposes ESG reporting obligations	Specifies <i>how</i> companies should report (content, indicators, format)

Source of the study: based on the European Commission, 2025a.

The process of implementation of the CSRD Directive and related ESRS standards has been spread over time and provides mechanisms to facilitate the adaptation of companies. Public consultations on the amendments to the ESRS were conducted between 31 July 2025 and 29 September 2025., which indicates the dynamic nature of the legislative process and the readiness of the European Commission to adapt regulations to the needs of the market. As part of the work on the introduction of the CSRD, the so-called "quick-fix" was also introduced¹ in the form of delegated acts, which are to provide greater flexibility for companies

¹ "quick-fix" means, in the context of European Union law: A temporary, simplified or accelerated change of rules to address problems or facilitate the implementation of existing regulations – before the full targeted solutions come into force.

with the so-called "wave one"². As a result, companies reporting according to the CSRD rules for the financial year 2024 will not be burdened with additional requirements in 2025 and 2026 beyond what is absolutely required. In addition, a solution called "stop-the-clock" has been used³, which delays the entry into force of reporting obligations for companies from the second and third waves (wave two and wave three). The aim of this approach is to balance regulatory ambitions with the real organisational capabilities of companies.

The EU public debate has also included proposals for simplification, m.in. limiting the full requirements of the CSRD primarily to large entities (e.g. more than 1000 employees), which would reduce the administrative burden for smaller companies and allow them to gradually adapt to the new reporting rules (European Commission, 2025a).

3. ESG, circular economy and pallet industry

The concept of Environmental, Social, Governance (ESG) refers to the three dimensions of sustainable development: environmental, social and corporate governance. It therefore includes three dimensions of sustainability management (United Nations, 2004; Hajos-Iwańska et al., 2025):

1. environmental (E), which focuses on reducing greenhouse gas emissions, energy and resource efficiency, and reducing waste,
2. social (S), which focuses on the well-being and safety of workers, gender equality and relations with the local community, and
3. management (G), in which transparency of decisions, business ethics and oversight mechanisms play an important role.

In the European Union, ESG policy is closely linked to the circular economy (CE) (Kulczycka, 2019), the strategic foundations of which are set out in the Circular Economy Action Plan (European Commission, 2020) which is part of the European Green Deal. This document emphasizes the need to design products with a long-life cycle, ease of repair, reuse and recycling in mind, which reduces pressure on natural resources and minimizes waste (European Commission, 2020). It also stresses the need to reduce the waste of raw materials and to develop new business models that are based on circularity rather than a linear take-use-

² The term "wave one" refers to the first group of companies required to report under the CSRD, which includes large listed companies and entities already covered by the NFRD (Non-Financial Reporting Directive). These companies are required to prepare the first sustainability reports for the financial year 2024, to be published in 2025 (European Commission, 2025a).

³ The term "stop-the-clock" refers to the European Commission's decision to temporarily suspend the entry into force of ESG reporting obligations for some companies covered by the CSRD. This mechanism is intended to enable companies from the so-called second and third waves ("wave two" and "wave three") a longer preparation period for the implementation of ESRS standards and non-financial reporting systems (European Commission, 2025b).

throw scheme. In practice, this means that manufacturing companies should treat waste not as a problem, but as a resource that can be reintegrated into the value chain (European Environment Agency, 2023).

According to data from the European Environment Agency, the material circularity rate in the EU in 2023 was only 11.8%, which means that only a small proportion of the materials used in the economy are reused (European Environment Agency, 2023).

For the pallet industry, which is characterized by the high reparability and reusability of products, this represents an important opportunity to position itself as an industry that supports circular goals and is in line with European sustainability strategies. This situation generates both challenges and opportunities for the timber and logistics industries. The production of wooden pallets is one of the sectors that naturally fits into the assumptions of the circular economy. Wooden pallets can be repaired and reused many times, and at the end of their life cycle, the wood can be recycled or used as energy biomass (Sowa, 2023). LCA (Life Cycle Assessment) studies confirm that with the right repair and recovery system, wooden pallets have a smaller carbon footprint than alternative plastic pallets, especially over a long period of use (Stern, Becker, 2021). Moreover, industry analyses indicate that up to 95% of wooden pallets in Europe are recovered and repaired, which makes this branch of logistics one of the most adapted sectors to the requirements of circular economy⁴. The pallet industry is thus a model example of how EU policy objectives can be translated into practical operational actions in industry (United States Department, 2020).

4. Northpal ApS Case Study

In this study, in order to assess the implementation of ESG activities in the organization, an analysis of the operation of Northpal ApS was conducted. To this end, the company's internal documents, including sustainability policies, quality reports and internal procedures related to the acquisition of raw materials and energy management, were first analyzed. Particular attention was paid to the documentation relating to compliance with environmental and social standards, as well as to the company's preparations for the reporting requirements resulting from the CSRD Directive and ESRS standards (European Commission, 2025a). Secondly, semi-structured interviews were conducted with management representatives, including those responsible for environmental policy, human resources and compliance issues. The interviews allowed us to capture the strategic perspective, including the goals that Northpal associates with the implementation of ESG, and the organizational and financial barriers that emerged during the implementation phase. Thirdly, the company's external communication was analyzed – in particular the content contained on the official website, promotional materials and information addressed to contractors and customers. This analysis made it possible to assess

how the company communicates its ESG activities, and what elements of the narrative are emphasized in building the image of an environmentally and socially responsible brand. Ultimately, all the data collected were embedded in the context of the EU regulatory framework (CSRD, ESRS, EU Taxonomy), which allowed them to be systematized according to the non-financial categories required by the reporting standards. As a result, the analysis was not limited to the company's internal perspective but also considered compliance with growing regulatory and market expectations (European Commission, 2025c).

Northpal ApS is a Polish Danish company operating in the wooden pallet production sector, whose activities are based on the principles of sustainable development and circular economy. The company is licensed to manufacture and repair DS (Dansk Standard) pallets, which are widely used in logistics in Scandinavia and Northern Europe. Northpal Activities range from the manufacture of new pallets compliant with DS 364.1:1983⁴ to the refurbishment and repair of used units, which is in line with the model of extending the life cycle of products and minimizing the environmental footprint. The company emphasizes that "bæredygtig production" (sustainable production) and "ESG-rapportering" are an integral part of its business. Northpal ApS also exposes a close connection with the local environment — both in Denmark and in Poland, where it develops cooperation with business partners, local governments and local communities.

The company declares that its business is based on three pillars, aligned with ESG, namely:

1. environment: production using renewable energy sources, certified wood, closed loop materials,
2. society: safe working conditions, integration of foreign workers, support for local communities,
3. corporate governance: governance transparency, ESG compliance, anti-corruption policies and ethical purchasing.

With these activities, Northpal is an interesting example of a medium-sized company that, although the formal ESG certification process is ongoing, is already implementing CSRD and ESRS compliant activities and communicating them transparently to stakeholders.

Northpal has consistently implemented practices to reduce the negative impact on the environment. The key element is the full use of renewable energy sources. The company declares that 100% of the energy consumed in production processes comes from its own photovoltaic installations, which supports the reduction of emissions compared to traditional fossil fuels.

⁴ DS 364.1:1983 is a Danish technical standard developed by the *Danish Standards Association* that specifies quality requirements, dimensions and strength parameters for wooden transport pallets with dimensions of 800×600 mm. The standard defines, m.in, the permissible dimensional tolerances, the types of wood used, the rules of assembly and the conditions for admission to marketing in the pallet exchange system in the Nordic countries (Danish Standards Association, 1983).

The company has also implemented the principles of the circular economy (CE) through the development of a repair and refurbishment system for DS pallets, which significantly extends their life cycle and reduces the need for new raw materials. In terms of timber harvesting, Northpal uses only certified FSC and PEFC sources, which ensure responsible management of forest resources and compliance with international standards for biodiversity protection.

Industry literature emphasizes that wooden pallets are highly repairable and reusable, and in life cycle analyses (LCAs) they show an environmental advantage over plastic pallets, especially in terms of energy and material recycling (Stern, Becker, 2021; United States Department of Agriculture, 2020). Northpal products meet the requirements of DS 364.1:1983, which defines quality standards for 800×600 mm pallets (Danish Standards Association, 1983). The requirements of the standard are met through strict quality control of raw materials. The wood used to produce pallets comes exclusively from FSC and PEFC certified sources, which guarantees its appropriate technical parameters and humidity, and thus the durability and stability of the product. The production process involves precise cutting and assembly of elements according to specified dimensional tolerances, while each batch of products is subjected to technical inspection in terms of load-bearing capacity, rigidity and quality of joints.

In the social dimension, Northpal pursues a policy based on inclusivity and equality. The company employs employees from Georgia, providing them with legal working conditions, social integration and health and safety training conducted in their native language. These activities not only support the safety of employees but also foster the creation of a work environment based on mutual respect and trust. Northpal also has a transparent pay policy, which increases trust among employees and reduces the risk of inequality. In addition, she is involved in initiatives supporting local communities in Poland, e.g. through cooperation with local governments and support for local events. Such activities are in line with broader trends in corporate social responsibility (CSR), which emphasize the role of enterprises in building bonds with the community in which they operate.

Northpal's ownership model is based on the cooperation of Polish and Danish capital, which is conducive to the exchange of experience and best practices. In the area of corporate governance, the company declares compliance with the CSRD framework, implementing solutions that prepare for full ESG reporting in accordance with ESRS. Northpal also conducts regular quality and compliance audits, which increase the transparency of all processes (both administrative and production) and minimize operational risk. Anti-corruption policies and ethical purchasing policies have also been implemented, which strengthens the company's credibility in relations with business partners. A special element is the preparation of a reporting infrastructure enabling the collection of environmental and social data in such a way that it is consistent with regulatory requirements and investor expectations.

An analysis of Northpal ApS's implemented ESG practices shows that these actions not only respond to regulatory requirements but also fit into changing consumer attitudes. Consumer research at the European level indicates that transparency and authenticity in ESG are becoming one of the key factors building brand loyalty. According to a 2024 PwC report, the average willingness of European consumers to subsidize sustainable products is +9.7% (PwC, 2024). On the other hand, Eurobarometer and European Environment Agency (2024) show that around 60% of Europeans are willing to pay a higher price for environmentally friendly products, although this trend has weakened as a result of inflationary pressures. McKinsey (2025) analyses, on the other hand, highlight that consumers are becoming increasingly price-sensitive, but still prefer brands with a clearly communicated ESG profile, especially if it is associated with transparency and consistency. Similar trends are visible on the Polish market. Exorigo-Upos research (2024) shows that 64% of e-consumers indicate the environmental and social responsibility of brands as an important criterion when choosing a product. At the same time, about 40% of respondents declare their readiness to subsidize ecological packaging, which confirms that even in the conditions of growing price pressure, some consumers see value in sustainable products.

For Northpal, this means that transparent communication of ESG activities – such as the use of renewable energy, certification of raw materials or the circular economy model – can be an important part of building a competitive advantage. Consumer price sensitivity limits the scale of subsidies they are able to accept, but consistency and authenticity in ESG activities strengthen trust and brand loyalty.

The implementation of ESG practices at Northpal ApS should be analyzed in a broader regulatory context that sets directions for the entire wood and logistics industry. The EUDR (EU Deforestation Regulation), which formally entered into force on 29 June 2023, is particularly important. This regulation is aimed at limiting imports and placing on the EU market of products from areas associated with deforestation or forest degradation. Initially, the EUDR was supposed to apply from 30 December 2025, but due to administrative and technological burdens, the deadline for its application was postponed. In September 2025, the European Commission proposed another postponement until 30 December 2026, which requires approval by the European Parliament and the Council of the EU (EU Trade, 2025).

For a manufacturer of wooden pallets such as Northpal, this regulation is crucial, as it covers, m.in, HS 4415 (wooden pallets). A company that uses only certified wood (FSC, PEFC) is in a privileged position, as meeting the traceability and due diligence standards required by the EUDR is in line with already established practices. At the same time, however, the new requirements create challenges related to the documentation of the supply chain, the interoperability of IT systems and the potential costs of certification.

At the same time, an important element of the regulatory environment is the agreement of May 2024 on the interoperability of ESRS (European Sustainability Reporting Standards) and ISSB (International Sustainability Standards Board) standards. This agreement reduces the risk

of duplication of reporting obligations and makes it easier for companies operating in global markets to report within a uniform framework (Reuters, 2024). For Northpal, which operates at the intersection of the Polish, Danish and wider European markets, the integration of these standards means greater consistency and efficiency of reporting, as well as the possibility of better positioning towards investors and foreign contractors.

To sum up, the implementation of ESG at Northpal is not just a matter of complying with regulations but is a strategic element of building a competitive advantage in the face of tightening legal requirements. The company takes advantage of the fact that practices based on renewable energy sources and certified raw materials not only respond to the EUDR targets but also allow it to prepare for harmonized reporting requirements resulting from the CSRD, ESRS and ISSB.

5. Summary and Conclusions

The analysis of the Northpal ApS case study indicates that the implementation of ESG practices in the manufacturing industry is not only a reaction to EU regulations but can become a strategic tool for building company value both now and in the long term. The company shows that even before the formal reporting obligation resulting from the CSRD directive, it is possible to develop consistent activities that simultaneously respond to the expectations of stakeholders and support long-term competitiveness.

Based on the analysis, the following recommendations were formulated:

A. On environmental issues:

1. deepening investments in renewable energy sources, e.g. photovoltaic installations, which will reduce CO₂ emissions and become independent of energy costs,
2. use of raw materials from only FSC/PEFC certified sources, which will minimize the risks associated with the EUDR regulation and support the responsible management of forest resources,
3. development of DS pallet repair and renovation systems as a practical implementation of the circular economy (CE),
4. implementation of monitoring of environmental indicators (emissions, material recovery), in line with the recommendations of the LCA literature (Stern, Becker, 2021; United States Department of Agriculture, 2020).

B. in the field of social issues:

1. developing programs for the integration of foreign workers, m.in. through OHS training in their native languages,
2. the use of a transparent remuneration policy that strengthens the internal trust of employees and reduces the risk of inequalities,

3. involvement in local initiatives that build a bond with the environment and strengthen the image of a socially responsible brand.
- C. On corporate governance issues:
4. conducting regular quality and compliance audits, increasing the transparency of processes and minimizing operational risks,
 5. implementing and maintaining anti-corruption policies and ethical purchasing principles, which are the foundation of transparent organizational governance,
 6. preparing for full compliance with ESRS requirements, which will avoid costly adjustments in the future and increase the attractiveness of the company and its activities in the eyes of investors.

The example of Northpal ApS therefore shows that a systemic approach to ESG can bring multidimensional benefits: from increasing operational efficiency, through strengthening the competitive position, to building lasting consumer trust. For this reason, the practices implemented by Northpal can be treated as a reference model for other manufacturing companies, especially in the wood and logistics sectors.

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FROM CONCEPT TO PRACTICE: BLOCKCHAIN TECHNOLOGY IMPLEMENTATION IN SUSTAINABLE AND CIRCULAR SUPPLY CHAINS

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Purpose: This study addresses the theory-practice gap in blockchain-enabled circular supply chains by analyzing real-world implementations in material recovery sectors rather than validating theoretical frameworks. The research examines how organizations deploy blockchain technology to advance circularity, traceability, and sustainability objectives, and what lessons emerge from on-the-ground experiences across e-waste, textile, and battery recycling context.

Design/methodology/approach: A multiple case study methodology was employed, combining analysis of documented blockchain implementations with exploratory scenarios illustrating potential applications in circular economy contexts. Data were gathered from secondary sources including academic case studies, industry reports, corporate sustainability documentation, and technical specifications. Each case was analyzed using a descriptive and contextual approach.

Findings: Blockchain enhances supply chain visibility in material recovery contexts, textile systems enable higher recovery efficiency through composition tracking, and battery recycling improves capacity identification. However, blockchain's contribution to broader circular economy goals remains indirect and contingent on complementary organizational structures, regulatory alignment, and ecosystem coordination. Successful implementations share characteristics: clearly defined operational problems, strong cost-benefit justification, regulatory drivers, critical mass ecosystem participation, and support infrastructure. Persistent barriers include high initial costs, standardization deficits, stakeholder mistrust, regulatory uncertainty, and organizational inertia.

Research limitations/implications: Reliance on secondary data sources limits depth of analysis compared with primary research; selection bias may favor publicized, mature implementations; the three-case sample may not represent all blockchain-circular economy applications globally.

Practical implications: Practitioners should approach blockchain pragmatically as a targeted tool addressing specific transparency or coordination challenges rather than a comprehensive circular economy solution. Technology developers should prioritize interoperability, user accessibility, equitable governance, and sector-specific design. Policymakers should establish clear regulatory frameworks, develop standardization initiatives, consider mandating blockchain participation in high-risk sectors, invest in capacity building, and provide regulatory clarity to accelerate adoption.

Originality/value: This study contributes to bridging the theory-practice gap by analyzing real-world blockchain implementations in material recovery rather than proposing novel frameworks. The findings highlight that blockchain adoption depends fundamentally on ecosystem orchestration, regulatory alignment, and stakeholder incentive design—insights valuable for practitioners, technology developers, and policymakers navigating blockchain-enabled circular supply chain transformation.

Keywords: blockchain technology, circular economy, sustainable supply chains.

Category of the paper: case study.

1. Introduction

The transition toward sustainable and circular supply chains has become a critical imperative in addressing global environmental challenges, resource depletion, and climate change (Rane, Chaudhari, Rane, 2025). The circular economy model, grounded in the principles of reducing waste, reusing materials, and maximizing resource efficiency, represents a fundamental departure from traditional linear production systems (Korhonen, Honkasalo, Seppälä, 2018). However, realizing this transformation requires unprecedented levels of transparency, stakeholder collaboration, and data integration across complex multi-tiered supply networks (Hassan et al., 2023). Without reliable mechanisms to track material flows, verify sustainability claims, and coordinate activities among diverse actors, organizations struggle to implement meaningful circular practices (Klein, Ramos, Deutz, 2020). Blockchain technology has emerged as a potentially transformative solution to these challenges. With its distinctive features—including data immutability, decentralized architecture, smart contracts, and enhanced traceability capabilities—blockchain offers technical affordances that align naturally with circular economy objectives (Kumar, Chopra, 2022). Numerous academic studies have highlighted blockchain's theoretical potential to improve supply chain visibility, enable automated compliance mechanisms, and create trustworthy records of material flows and environmental performance (Cole, Stevenson, Aitken, 2019). The technology promises to facilitate the verification of recycled content, automate incentive systems for circular behaviors, and establish digital infrastructure for tracking products and materials throughout their lifecycles (Bułkowska, Zielińska, Bułkowski, 2024).

Despite this compelling theoretical proposition, a significant gap persists between conceptual frameworks and real-world implementation. Recent analyses have revealed that most blockchain-enabled circular economy initiatives remain confined to pilot phases, with few organizations progressing to full-scale deployment (Lukić et al., 2025). Barriers including technological limitations, organizational complexity, standardization challenges, and high implementation costs continue to hinder widespread adoption (Bag et al., 2021). Moreover, while scholarly literature has increasingly focused on developing assessment frameworks and measuring blockchain's potential contribution to circular economy goals, relatively limited

attention has been devoted to analyzing how organizations are actually implementing these solutions in practice and what lessons emerge from on-the-ground experiences. This research addresses this gap by examining case studies of blockchain implementation across sustainable and circular supply chains. Rather than proposing novel assessment methodologies or validating theoretical models, this article synthesizes practical experiences from organizations that have deployed blockchain solutions to advance circularity, traceability, and sustainability objectives.

2. Materials and methods

This study adopts a multiple case study and scenario analysis methodology. The approach combines analysis of documented blockchain implementations with exploratory scenarios illustrating potential applications in circular economy contexts. This mixed approach is suitable for research addressing emerging technologies, where mature, large-scale implementations remain limited and where exploration of broader application possibilities complements analysis of existing cases. The study examined three primary subjects across material recovery and recycling contexts, selected based on the following criteria: (1) documented implementation of blockchain technology, or well-developed scenarios/pilot projects demonstrating blockchain application, in a sustainable or circular supply chain context; (2) availability of sufficient secondary data; (3) diversity across sectors and application domains; and (4) representation of different implementation maturity levels. This methodological approach acknowledges that blockchain-circular economy integration remains an emergent field: many applications exist as pilots, proof-of-concepts, or technology scenarios rather than as mature, widely-scaled implementations. Distinguishing between fully operational case studies and illustrative scenarios reflects the empirical reality of blockchain adoption in circular supply chains, where innovation often precedes widespread implementation.

Data Collection and Sources

Data for each case study and scenario were gathered from secondary sources, including: published academic case studies and white papers, industry reports and technology vendor documentation, sustainability reports and corporate communications, journal articles, publicly available case studies descriptions, technical documentation and system design papers, regulatory and policy documents. Each case study or scenario was analyzed using a descriptive and contextual approach, adapted to the implementation maturity level.

Limitations

Limitations of this approach include: (1) the quality and depth of analysis are constrained by the completeness and accessibility of publicly available information; (2) the sample of six primary subjects, while purposively selected for diversity, may not represent the full spectrum of blockchain-circular economy applications globally; (3) secondary data analysis relies on information as reported by technology vendors, implementing organizations, or academic analysts, introducing potential reporting bias toward successful implementations or intended functionality; (4) selection bias may favor publicized initiatives willing to share information about their projects.

3. Blockchain Applications in Circular Supply Chains: Case Studies from Material Recovery and Recycling Sectors

The recovery and recycling of materials from end-of-life products represent critical components of circular economy implementation, yet these reverse logistics processes have historically suffered from transparency deficits, stakeholder fragmentation, and difficulty in verifying material flows (Julianelli et al., 2020). Blockchain technology addresses these sector-specific challenges by providing immutable records of material movement, enabling automated verification of recycling claims, and creating transparent marketplaces for recovered materials (Khadke et al., 2021). The following three case studies illustrate how organizations are implementing blockchain to enhance material traceability, improve recovery rates, and strengthen stakeholder accountability across distinct material streams.

3.1. Case Study 1: Blockchain-Enabled E-Waste Tracking and Material Recovery

The global e-waste management crisis presents a fundamental transparency problem: electronic devices entering formal recycling channels lose traceability once they leave the collection point, and no reliable mechanisms exist to verify that materials are reaching legitimate processing facilities rather than informal networks or illegal export routes (Global Ardour, 2025). Certain cities or regions face following challenges: significant volumes of electronic waste remained uncaptured in informal streams, material recovery processes lacked credible documentation, and corporate clients had limited ability to substantiate their e-waste management claims for sustainability reporting (Azman et al., 2024).

Blockchain Solution Implemented

The Global Ardour Recycling Limited organization implemented a blockchain-based reverse logistics system in which each electronic device receives a unique digital identifier upon collection entry. When equipment is accepted at a collection depot, staff members record device specifications on a blockchain ledger alongside a timestamp and unique identifier. As the item moves through subsequent processing stages—transfer to processing facilities, depollution, component disassembly, and final material recovery—each handler scans the device identifier and records their transaction on the chain. Smart contracts embedded in the system verify that each handler maintains appropriate environmental permits and waste carrier licenses before accepting the transfer. Processing facilities document component outputs (precious metals recovery, plastic reprocessing, hazardous material treatment) with blockchain records linked to the original item, creating an auditable material flow trail from collection through final processing. The implementation leveraged three core blockchain affordances: (1) immutable material tracking; (2) automated compliance verification through smart contracts; and (3) transparent environmental impact calculation, which tracked the carbon footprint of different recycling pathways (Global Ardour, 2025).

Outcomes

Corporate clients gained detailed blockchain-verified documentation of their e-waste disposal, supporting sustainability reporting and eliminating auditing friction. The transparent recording of material flows provided manufacturers with actionable data on material composition and recovery potential, enabling more informed design decisions for end-of-life recovery. Recycling facilities reported reduced processing costs through accurate material identification and improved sorting efficiency, while regulatory compliance became automated rather than manually audited. Despite demonstrated benefits, the case highlighted implementation realities: the system's success depended critically on consistent data entry discipline at collection points and on all stakeholders understanding how to interact with the blockchain interface.

3.2. Case Study 2: Blockchain Traceability in Circular Textile Supply Chains

The textile industry exemplifies the opacity inherent in complex, globally fragmented supply chains (Brun, Karaosman, Barresi, 2020). Fashion brands face persistent challenges in verifying sustainability claims: confirming organic cotton origins, documenting non-toxic dye applications, validating fair labor practices, and substantiating environmental impact claims requires transparency that traditional supply chain systems cannot provide (Cheah, Shimul, Teah, 2023). These information gaps enable greenwashing and prevent genuine circular practices. Additionally, the absence of reliable material composition data at end-of-life complicates recycling decisions: sorters cannot efficiently direct textiles to appropriate

recovery streams without knowing exact fiber content and chemical treatments (Seifali et al., 2025).

Blockchain Solution Suggested

A consortium of fashion brands, textile manufacturers, and recycling organizations could implement blockchain-based digital product passports, where each garment receives a unique, immutable record documenting its complete lifecycle. The system captures material composition, provenance data, care and repair instructions, and disassembly guidance for recyclers. Smart contracts automate extended producer responsibility financial flows: when a garment is sold, the contract automatically levies a fee on the producer; when a certified recycler processes the garment at end-of-life, the contract releases accumulated funds to the processor. The blockchain platform also enables tokenization of recovered materials: after processing returned clothing, recyclers tokenize resulting bales of sorted recycled fibers, which manufacturers can purchase with smart contracts guaranteeing quality and provenance. The implementation emphasized several blockchain capabilities: (1) immutable material passports, creating permanent, verifiable records of material composition and processing history enabling accurate sorting decisions and recycling efficiency; (2) transparent supply chain mapping, where each production and recovery stage is recorded and visible to permissioned network participants, reducing information asymmetries and enabling verification of sustainability claims; (3) automated compliance mechanisms, through smart contracts managing EPR obligations, fee collection, and fund distribution without manual administration; and (4) liquid markets for secondary materials, where tokenized recycled fibers can be traded on transparent, open-source marketplaces with quality and provenance guarantees embedded in smart contracts.

Outcomes

This scenario could offer several benefits: brands gain verifiable documentation of material origins and processing practices, supporting authentic sustainability claims while reducing greenwashing risk. Recyclers access detailed fiber composition data at collection points, enabling higher sorting accuracy and directing materials to appropriate recovery streams rather than downcycling. Consumers receive interactive, blockchain-verified information about their garments' origins and could participate in take-back schemes with transparent, automated incentive mechanisms. The transparent marketplace for recycled materials stabilizes pricing and legitimized secondary raw material streams, creating economic incentives for high-quality textile-to-textile recycling. Extended producer responsibility mechanisms operate more efficiently through smart contract automation, reducing administrative overhead and ensuring accurate fund flows. That scenario demonstrates that blockchain value in circular textiles depends on establishing open, interoperable standards across fragmented networks—individual

brand-specific blockchains risk digital fragmentation replicating the supply chain opacity the technology was designed to solve.

3.3. Case Study 3: Blockchain Implementation in Power Battery Recycling and Circular Material Recovery

Power battery recycling presents a distinctive circular economy challenge combining technical complexity and economic significance: lithium-ion batteries contain valuable materials recoverable through specialized processing, yet identifying battery capacity and remaining utility is technically demanding (Fan et al., 2020). Manufacturers of electric vehicles and energy storage systems face regulatory obligations to organize battery classification, recovery, and recycling, yet traditional systems lack reliable mechanisms for assessing battery condition and enabling market-based echelon utilization. This opacity creates inefficiencies: batteries suitable for second-life applications may be unnecessarily dismantled and recycled, while batteries incapable of further use may be misallocated, leading to waste of processing capacity and lost material recovery potential (Hossain et al., 2019).

Blockchain Solution Implemented

Power battery manufacturers embedded blockchain technology into closed-loop supply chains involving manufacturers, retailers, echelon utilizers and third-party recyclers. The system assigns each battery a digital identity recorded at manufacturing, containing chemistry information, design specifications, and performance data. As batteries move through their lifecycle—electric vehicle use, removal from vehicles, assessment for echelon utilization, second-life application, and eventual recycling—each participant records transactions with timestamps and data updates on the blockchain ledger. Smart contracts enable reliable capacity identification: when recycling facilities receive batteries, they access blockchain records detailing remaining capacity, usage history, and previous treatment, enabling more accurate assessment and directing batteries to appropriate recovery pathways. The system implements two operational models: Model I involves joint recycling by retailers and third-party recyclers with echelon utilizer participation in determining battery suitability for secondary use; Model II features direct manufacturer coordination without retailer participation (Xing et al., 2024).

The implementation leveraged several blockchain affordances: (1) immutable battery identity, creating a permanent digital record enabling reliable capacity identification and reducing processing costs for echelon utilization; (2) transparent traceability, documenting battery movement through the lifecycle and supporting regulatory compliance documentation; (3) automated stakeholder coordination, where smart contracts execute material recovery processes and manage financial flows between manufacturers, retailers, and recyclers based on blockchain-recorded information; and (4) capacity-based material routing, using blockchain records to match batteries to appropriate recovery streams (echelon utilization for secondary-use candidates versus direct recycling for end-of-life batteries).

Outcomes

Case analysis indicated several measurable improvements: blockchain-embedded capacity identification reduced processing costs for echelon utilization, increasing market demand for secondary-use batteries and enabling extended material lifecycle. Manufacturers gained confidence in material recovery data, supporting reverse supply chain decision-making and producer responsibility compliance. The transparent transaction records provided regulatory agencies with real-time compliance data without requiring manual reporting. Smart contract automation reduced transaction costs between supply chain participants and accelerated recycling decisions. Manufacturers' investment in blockchain embedding demonstrated positive returns when recycling competition was not intense and cost optimization coefficients were high, though competitive dynamics and parameter sensitivity affected the financial viability of participation models. The power battery case illustrated that blockchain's technical contribution—enabling accurate capacity identification and transparent traceability—creates economic value primarily in contexts where these data were previously unavailable or unreliable (Xing et al., 2024). However, the business model implications proved complex: the viability of different recycling models depend on competitive intensity and cost structures, suggesting that blockchain technology alone insufficient to guarantee circular adoption without complementary business model and regulatory alignment.

3.4. Cross-Case Analysis and Common Patterns in Material Recovery and Recycling

These three case studies from material recovery and recycling sectors reveal several consistent patterns in how blockchain technology is implemented and what outcomes organizations achieve:

- **Data-Driven Decision Making:** Across e-waste, textiles, and battery recycling, blockchain's primary value derives not from the immutability of data itself, but from capturing information previously unavailable or fragmented—material composition in textiles, device identifiers in e-waste, and battery capacity data in power recycling. The technology enables sorting, routing, and recovery decisions that would otherwise remain opaque or require costly manual assessment.
- **Stakeholder Coordination Across Fragmented Networks:** All three cases involved multiple independent organizations (recyclers, processors, manufacturers, retailers, second-life operators) with competing interests and information asymmetries. Blockchain's decentralized architecture and smart contract capability enabled automated coordination and trustless transactions—critical advantages in scenarios where a single authority cannot control the system and where transaction efficiency determines economic viability.

- **Regulatory Alignment as Implementation Driver:** Case adoption accelerated when regulatory frameworks (EU e-waste directives, new battery regulations, digital product passport mandates) aligned with blockchain capabilities. Regulatory requirements created compliance obligations that motivated investment and provided justification for technology costs, suggesting that blockchain adoption in circular supply chains may be fundamentally dependent on policy frameworks that make traditional compliance mechanisms insufficient.
- **Network Effects and Ecosystem Density:** All three cases demonstrated that blockchain value increased with ecosystem participation—the e-waste system's benefits depended on adoption by multiple recyclers, the textile blockchain required engagement from brands, manufacturers, and retailers across supply networks, and battery recycling benefited from ecosystem-wide participation. This suggests that blockchain implementations may face critical mass thresholds below which value proposition remains marginal, and that ecosystem orchestration is as important as technology deployment.

Table 1.

Key problems addressed and blockchain mechanisms deployed across case studies/scenarios

Case Study	Key Problems	Blockchain Mechanisms
E-Waste	-traceability loss, -illegal export, -unverifiable disposal claims.	-digital device IDs, -immutable transaction records, -smart contracts for compliance verification, -environmental impact tracking.
Textile Circular Supply	-supply chain opacity, -greenwashing, -unknown material composition.	-digital product passports; smart contract EPR automation, -tokenized recovered materials, -permissioned transparency.
Battery Recycling	-capacity identification, -inaccurate echelon utilization, -compliance documentation.	-digital battery identity, lifecycle records, -smart contract capacity routing, -automated recycling decisions.

Source: own elaboration.

Table 1 synthesizes the core operational challenges and blockchain-enabled solutions across the three material recovery case studies, illustrating how sector-specific problems drive distinct technology implementation approaches while revealing common patterns in data-driven decision-making and stakeholder coordination mechanisms.

4. Discussion

Blockchain's Actual Contribution to Circular Economy Goals

The three case studies presented—spanning material recovery sectors including electronic waste tracking, textile circular supply chains, and power battery recycling—reveal a picture of blockchain's actual, versus theoretical, contribution to circular economy objectives. Blockchain enhances key circular economy metrics in specific contexts. Textile blockchain systems enable higher recovery efficiency by providing immutable material composition data to recyclers, directly supporting sorting accuracy and the material circularity rate metric (Tang, 2023). Battery recycling implementations improve capacity identification through blockchain-recorded battery history, enabling more accurate echelon utilization decisions and extending material lifecycles (Faria et al., 2025). These outcomes suggest blockchain genuinely addresses specific, measurable supply chain transparency gaps that previously required manual, time-consuming processes. However, the cases also reveal critical limitations in blockchain's broader circular economy impact. The e-waste case highlighted that the system's success depended critically on consistent data entry discipline at collection points and stakeholder understanding of blockchain interfaces—factors suggesting implementation challenges extend beyond technology deployment. The textile scenario, while proposing compelling blockchain mechanisms, acknowledged that ecosystem-wide adoption depends on establishing open, interoperable standards across fragmented networks; individual brand-specific blockchains risk digital fragmentation replicating the supply chain opacity the technology was designed to solve. Battery recycling implementations achieved measurable operational improvements but did not fundamentally transform the circular battery ecosystem; rather, they optimized existing recovery pathways through improved capacity identification without enabling radically new business models. This pattern suggests that blockchain addresses tactical supply chain challenges—visibility, traceability, coordination—rather than enabling strategic circular economy transformation.

Key Enablers, Success Factors and Challenges Across Material Recovery Cases

Among key enablers and success factors of blockchain based solution, several of them could be indicated:

- **Clear Problem Definition and Value Proposition:** All three cases addressed specific, recognized operational problems. E-waste faced material tracking opacity and stakeholder fragmentation; textiles confronted greenwashing and material composition unknowns at end-of-life; battery recycling struggled with capacity identification and echelon utilization accuracy. Rather than pursuing abstract circularity goals, each case deployed blockchain to solve concrete transparency or coordination challenges.

- **Regulatory and Policy Alignment:** Multiple cases benefited from regulatory drivers. E-waste blockchain adoption accelerated within regulatory contexts emphasizing formal recycling channel participation and illegal export prevention. Textile initiatives aligned with emerging EU extended producer responsibility directives and digital product passport mandates. Battery recycling systems aligned with regulatory obligations for battery classification, recovery tracking, and producer responsibility compliance.
- **Network Effects and Critical Mass:** All three cases demonstrated that blockchain value increased with ecosystem participation. E-waste systems required adoption by multiple recyclers, processors, and material handlers to generate meaningful tracking and efficiency value. Textile initiatives required engagement from brands, textile manufacturers, recyclers, and material handlers across supply networks. Battery recycling benefited from participation by manufacturers, retailers, echelon utilizers, and recyclers.
- **Data Standardization and Interoperability as Critical Success Factors:** A key enabler—and barrier—across all three cases involved establishing common data standards and system interoperability. The textile case explicitly emphasized that blockchain value depends on establishing "open, interoperable standards across fragmented networks", with warning that "individual brand-specific blockchains risk digital fragmentation". E-waste and battery recycling cases similarly relied on stakeholders sharing common data formats and being able to access blockchain records across diverse organizations.
- **Stakeholder Capability and Support Infrastructure:** The e-waste case noted explicitly that smaller recycling partners faced technology adoption barriers requiring training and support. Battery recycling success depended on manufacturers having technical capacity to embed blockchain records into product information systems.

Despite diverse sectoral contexts within material recovery, several consistent barriers appeared across all three cases:

- High Initial Investment Costs and ROI Uncertainty.
- Interoperability and Standardization Deficits.
- Stakeholder Coordination and Misaligned Incentives.
- Regulatory and Governance Uncertainty.
- Technological Resistance and Organizational Inertia.

Gaps Between Conceptual Potential and Practical Reality in Material Recovery

The contrast between blockchain's theoretical potential and these three material recovery implementations reveals persistent gaps:

- Academic frameworks often emphasize blockchain's technical affordances—immutability, decentralization, smart contract automation—without adequately addressing the organizational, governance, behavioral, and ecosystem coordination requirements necessary for actual implementation.
- Theoretical frameworks often propose blockchain as universally applicable across diverse supply chain contexts. The three cases reveal that blockchain value proves highly context-specific: successful in addressing particular problems but requiring distinct implementation approaches across sectors.
- Case studies demonstrate that network effects depend not merely on participation numbers but on value distribution, incentive alignment, cost structures, and willingness of diverse stakeholders to coordinate and share data.
- Defining blockchain's actual contribution to circular economy outcomes proves complex. Improvements in supply chain visibility across all three cases are clearly attributable to blockchain. However, claims about waste reduction, material circularity expansion, and emissions impact often conflate blockchain's role with complementary operational changes that blockchain enables but does not directly cause. The technology operates as an information infrastructure supporting circular decisions rather than as a direct driver of circular outcomes.

Implications for Practitioners, Technology Developers and Policymakers

Rather than viewing blockchain as a comprehensive circular economy solution, practitioners should approach it as a targeted tool addressing specific material recovery transparency or coordination challenges. In material recovery contexts, successful adoption requires: (1) clearly defining the operational problem blockchain will solve; (2) conducting thorough cost-benefit analysis ensuring ROI justifies investment; (3) assessing organizational capability for system integration and process change; (4) identifying all ecosystem participants and establishing aligned incentives for participation; (5) investing in support infrastructure including training, technical assistance, and standardized interfaces for diverse stakeholders; and (6) securing complementary regulatory drivers that mandate participation or establish compliance requirements. Organizations should avoid implementing blockchain for abstract sustainability goals; instead, blockchain adoption should address concrete operational challenges with clear performance metrics and cost justifications.

Successful blockchain implementations require substantial ecosystem design and support infrastructure beyond technology deployment. Developers serving material recovery sectors should: (1) prioritize interoperability and standardization, enabling multiple blockchain

platforms and legacy systems to integrate seamlessly; (2) develop user interfaces and support infrastructure enabling non-technical stakeholders to participate effectively; (3) design governance frameworks ensuring equitable benefit distribution across diverse participants with varying economic power; (4) work with domain experts and stakeholders to define data standards and processes that address specific sectoral challenges rather than proposing generic solutions; and (5) provide implementation guidance and capacity building resources recognizing that many material recovery organizations lack in-house blockchain expertise. Technical sophistication matters less than alignment with stakeholder incentives, ecosystem orchestration, and practical usability.

The three material recovery cases demonstrate that blockchain adoption accelerates when aligned with regulatory requirements and public policy objectives. Policymakers should: (1) establish clear regulatory frameworks that specify data standards, interoperability requirements, and governance models for blockchain supply chain implementations in material recovery sectors; (2) develop certification and compliance mechanisms ensuring blockchain platforms meet sustainability, data protection, and recycling effectiveness requirements; (3) consider mandating blockchain participation in high-risk or strategically important sectors where technology can materially improve traceability, regulatory compliance, or environmental outcomes; (4) invest in stakeholder capacity building, particularly supporting SME adoption in fragmented material recovery ecosystems; (5) facilitate industry standardization efforts at sector level rather than allowing fragmented, incompatible platform development; and (6) provide regulatory clarity regarding blockchain status under data protection regulations, consumer protection frameworks, and environmental compliance standards to reduce implementation uncertainty and accelerate adoption. Active regulatory engagement appears critical for ecosystem-wide blockchain adoption in material recovery sectors.

5. Conclusion

This study examined three case studies of blockchain implementation in circular supply chains focused on material recovery and recycling sectors: electronic waste tracking, supply chain circularity and power battery recycling. Rather than validating optimistic theoretical frameworks about blockchain's circular economy potential, these implementations or scenarios reveal a more nuanced reality: blockchain demonstrably enhances specific supply chain transparency and coordination functions, yet its actual contribution to broader circular economy goals remains contingent on complementary organizational structures, regulatory alignment, and ecosystem orchestration. Blockchain successfully addresses supply chain visibility challenges in material recovery contexts. Successful material recovery implementations share common characteristics: clearly defined operational problems that blockchain solves (tracking,

composition verification, capacity identification); strong cost-benefit justification supporting investment; regulatory or market drivers creating adoption incentives; ecosystem participation at critical mass; and support infrastructure enabling diverse stakeholders to participate effectively. Conversely, implementations face consistent barriers including high initial costs, standardization deficits, stakeholder mistrust and misaligned incentives, regulatory uncertainty, and organizational resistance to process change.

Material recovery sectors exhibit contextual factors affecting blockchain implementation: stakeholder heterogeneity—ranging from highly fragmented e-waste ecosystems to more concentrated battery recycling networks—creates varying coordination complexity. Regulatory maturity differs across sectors, with e-waste operating within established frameworks while textiles align with emerging regulations. Information asymmetries that blockchain addresses vary by sector—chain-of-custody visibility for e-waste, material composition transparency for textiles, capacity identification for batteries—reflecting sector-specific operational challenges.

The gap between blockchain's conceptual potential and empirical material recovery outcomes reflects underestimation of organizational, governance, behavioral, and ecosystem coordination dimensions. Blockchain operates as a tool enabling specific transparency and coordination functions rather than as a sufficient driver of circular economy transition. Its value depends fundamentally on complementary business model innovation, regulatory alignment, stakeholder incentive design, and ecosystem orchestration. This study contributes to bridging the theory-practice gap by analyzing real-world blockchain implementations in material recovery sectors rather than merely validating theoretical frameworks. The findings highlight that blockchain adoption in circular supply chains should be approached pragmatically—assessing specific operational challenges, organizational capabilities, ecosystem readiness, regulatory alignment, and stakeholder incentive structures—rather than pursuing blockchain as a comprehensive solution to circular economy challenges.

This qualitative case study approach, while providing rich empirical insights into material recovery sector implementation, has inherent limitations: the sample of three cases, though purposively selected within material recovery domains, represents only a portion of potential blockchain-circular economy applications globally; selection bias toward publicized, relatively mature implementations may skew toward more successful cases; and reliance on secondary data sources limits depth of analysis and access to proprietary implementation details compared with primary research. Future research should include: direct organizational studies investigating implementation processes and success factors in material recovery sectors; longitudinal studies tracking blockchain initiatives over time to assess sustainability and actual performance outcomes; comparative studies examining how blockchain implementation approaches differ across material streams; research specifically addressing how blockchain integrates with other digital technologies in material recovery contexts; and investigation of how blockchain implementation can be scaled from pilot initiatives to ecosystem-wide adoption in material recovery sectors.

The transition toward circular supply chains in material recovery sectors represents a profound challenge requiring integration of technological innovation, organizational change, stakeholder coordination, regulatory alignment, and behavioral transformation. Blockchain offers valuable technological affordances supporting transparency, traceability, and automated coordination—capabilities particularly valuable in fragmented material recovery ecosystems. However, blockchain remains one component within broader circular economy transition rather than a comprehensive solution.

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EMPLOYEES' PERCEPTIONS OF INFORMATION SYSTEMS, AUTOMATION, AND IOT IN PRODUCTION MANAGEMENT: EVIDENCE FROM AN INDUSTRIAL ENTERPRISE

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Purpose: The purpose of this paper is to evaluate the effectiveness of implementing modern information systems, automation, and Internet of Things (IoT) solutions in production management within an industrial enterprise. The study aims to assess their impact on production processes and to identify organisational and human-related factors influencing digital transformation.

Design/methodology/approach: The research adopts a quantitative approach based on a diagnostic survey method. An original questionnaire consisting of 23 closed-ended questions was conducted among 117 employees representing different organisational positions in a manufacturing enterprise. The study focuses on production management systems, automation, robotisation, and IoT within the Industry 4.0 framework. Data were analysed using descriptive statistics.

Findings: The results indicate a high level of integration and effectiveness of the implemented information systems in supporting production planning, monitoring, and control. Digital solutions are generally perceived positively by employees and contribute to improved operational efficiency and production continuity. Automation and robotisation are viewed as supportive tools rather than full substitutes for human labour. IoT solutions are recognised as particularly valuable for process monitoring and predictive maintenance, while cybersecurity emerges as an important challenge.

Research limitations/implications: The study is limited to a single industrial enterprise, which restricts the generalisability of the findings. Future research should include comparative studies across multiple organisations or sectors and consider qualitative methods to further explore employee perceptions and organisational readiness for advanced digital solutions.

Practical implications: The findings provide practical guidance for enterprises planning or continuing digital transformation initiatives. They highlight the importance of system integration, continuous investment in IT infrastructure, employee training, and maintaining a balance between technological advancement and human involvement.

Social implications: The study emphasises the significance of human factors in digital transformation, including employee acceptance, competencies, and cybersecurity awareness, which may contribute to improved working conditions and more sustainable implementation of Industry 4.0 solutions.

Originality/value: This paper offers empirical evidence on the effectiveness of integrated information systems, automation, and IoT in production management from the employees' perspective, contributing to research that combines technological and organisational dimensions of digital transformation.

Keywords: production management; Industry 4.0; information systems; automation; Internet of Things.

Category of the paper: Research paper.

1. Introduction

Contemporary manufacturing enterprises operating in an increasingly competitive and demanding market environment are progressively adopting advanced technological solutions to enhance operational efficiency and maintain competitive advantage. Key objectives of these initiatives include reducing operational costs, improving distribution processes, enhancing product quality, and increasing customer service standards (Javaid et al., 2022; Skórnóg, 2023). As a result, digitalisation and automation, which constitute the core of the Industry 4.0 concept, currently permeate nearly all areas of enterprise operations—from production and inventory management to the final stages of distribution (Javaid et al., 2024; Matt et al., 2023; Śledziowska, Włoch, 2020).

This process constitutes the foundation of digital transformation, which underpins the transition toward the Industry 4.0 paradigm. Modern technologies enable the automation of industrial operations, integration of heterogeneous data sources, and optimisation of resource utilisation across the entire value chain. Consequently, highly integrated, flexible, and adaptive production systems emerge, based on solutions such as the Internet of Things, cyber-physical systems, Big Data analytics, cloud computing, and advanced robotics.

At the same time, numerous studies indicate that the effectiveness of Industry 4.0 implementation depends not only on technological advancement but also on organisational and social factors (Xu et al., 2021; Mourtzis et al., 2022). In particular, employee competencies and acceptance of new technologies significantly influence the success of organisational transformation processes. Understanding how employees perceive digital technologies and how these technologies affect their daily work routines is therefore essential for achieving sustainable digital transformation (Zhou et al., 2015, Nowakowska, 2023; Biernikowicz, 2024, Homera, 2024).

In recent years, increasing attention has also been paid to the potential for further intensifying production digitalisation through advanced analytical mechanisms, including elements of artificial intelligence. Operating as an extension of existing ERP, MES, or SCADA systems, AI-based solutions enable a transition from traditional automation toward predictive planning, process optimisation, and real-time decision support (Peres et al., 2020; Gunia, 2019).

At the same time, their implementation introduces new challenges related to data quality, specialist competencies, and information security (Gabsi, 2024; Jagatheesaperumal et al., 2021).

Despite these challenges, the integration of advanced digital technologies, including artificial intelligence, remains one of the most important directions shaping the future of modern manufacturing. In the long term, it lays the foundation for the evolution toward the Industry 5.0 paradigm, in which human–technology collaboration becomes a central element of resilient and sustainable industrial systems (Breque et al., 2021).

Against this background, there is a clear need for empirical research aimed at assessing the effectiveness of implementing modern information systems, automation, and IoT solutions in production management, while taking into account the perceptions of employees directly involved in production processes (Benotsmane et al., 2019; Żarski, Borys, 2025). The objective of this paper is to evaluate the impact of these technologies on the functioning of a production system in an industrial enterprise and to identify factors facilitating further development of digital transformation.

Based on the research objective, the study addresses the following research questions:

RQ1: How do employees perceive the effectiveness of information systems in production management?

RQ2: How are automation and IoT assessed as support tools in production processes?

2. Materials and Methods

The research was conducted in an enterprise operating in the manufacturing sector and specialising in the production of railway infrastructure components. The enterprise is characterised by a high level of production process complexity and intensive use of modern information and automation technologies, which makes it an appropriate research object for analysing the effectiveness of digital transformation.

A quantitative research method in the form of a questionnaire survey was applied. The research tool was an original questionnaire consisting of 23 closed-ended questions covering issues related to production management, information systems, automation, robotisation, the Internet of Things (IoT), and the assessment of the effectiveness of implemented solutions. Respondents were informed about the purpose of the study and assured of the anonymity of their responses.

The survey was conducted from April 1 to April 30, 2025. The study involved 117 employees of the enterprise representing various positions, including managerial staff, specialists, machine operators, IT department employees, and designers. Such a sample

composition enabled the collection of a multi-perspective view of the functioning of information systems in the production process.

The analysis of results was carried out using descriptive statistics, in particular percentage structure analysis of responses. The collected data were compiled to identify dominant opinions among respondents and key areas of influence of IT systems on production management. Due to the exploratory nature of the study and the focus on employee perceptions, descriptive statistics were considered sufficient for identifying dominant trends and opinions.

Table 1.

Structure of survey questions and their linkage to production management and Industry 4.0 domains

Figure No.	Scope of the survey question (conceptual meaning)	Production management domain	Digitalisation / Industry 4.0 domain
Fig. 1	Employees' perception of the level of complexity of production management	Production planning and coordination	Complexity of digitally supported production systems
Fig. 2	Key elements determining the proper functioning of the production management process	Management functions (planning, organising, directing, control)	System-based and data-driven management
Fig. 3	Availability of information systems supporting production management	Information and production planning management	ERP / MES systems
Fig. 4	Level of alignment and integration of information systems supporting production management	Systems integration and coordination	Interoperability of ERP–MES–SCADA–CMMS systems
Fig. 5	Investment in the development of production management information systems	Strategic production management	Digital transformation and system modernisation
Fig. 6	Development of the machinery park through automation and robotisation	Production execution and operations management	Automation and industrial robotics
Fig. 7	Employees' attitudes toward full automation of production processes	Organisation of work and human involvement	Human–machine interaction
Fig. 8	Perceived importance of the Internet of Things in production management	Maintenance and process monitoring	Internet of Things (IoT)
Fig. 9	Problems related to operating implemented information systems	Human resources and competency management	Digital skills, system usability, cybersecurity awareness
Fig. 10	Perceived benefits of implementing modern information systems in the production process	Process improvement and operational control	Digital efficiency and performance optimisation

Source: own study.

3. Research Results

3.1. Perception of the complexity of production management

The analysis of respondents' answers indicates that production management in the analysed enterprise is perceived as a complex process requiring coordination of many interrelated activities. A significant proportion of employees assessed that contemporary production management may generate difficulties both for managerial staff and operational employees. This results primarily from the need to simultaneously consider technical, organisational, logistical, and quality-related aspects.

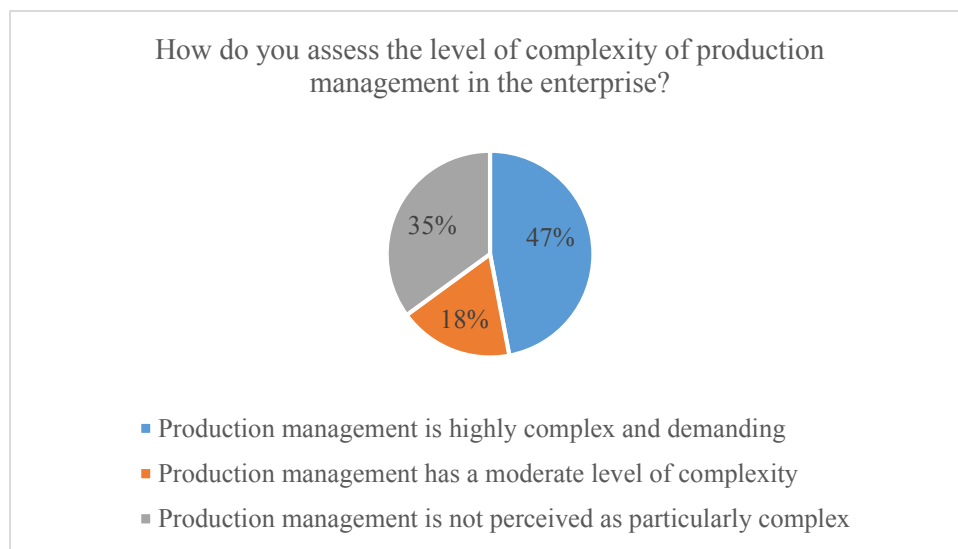


Figure 1. Assessment of the level of complexity of production management in the enterprise according to employees' opinions (n = 117).

Source: own study.

At the same time, a substantial group of respondents indicated that despite the high level of complexity, the production management process in the enterprise operates in a stable manner and does not cause significant operational problems. This may indicate the effectiveness of implemented information tools and the organisational maturity of the enterprise.

Respondents were also asked about the key elements determining the proper course of the production management process. The vast majority pointed to the importance of planning and organising production, which highlights the role of a systemic approach to resource management, scheduling, and synchronisation of production activities. Less importance was attributed to directing and control functions, which may suggest that well-designed information systems partially assume these roles by automating supervisory processes.

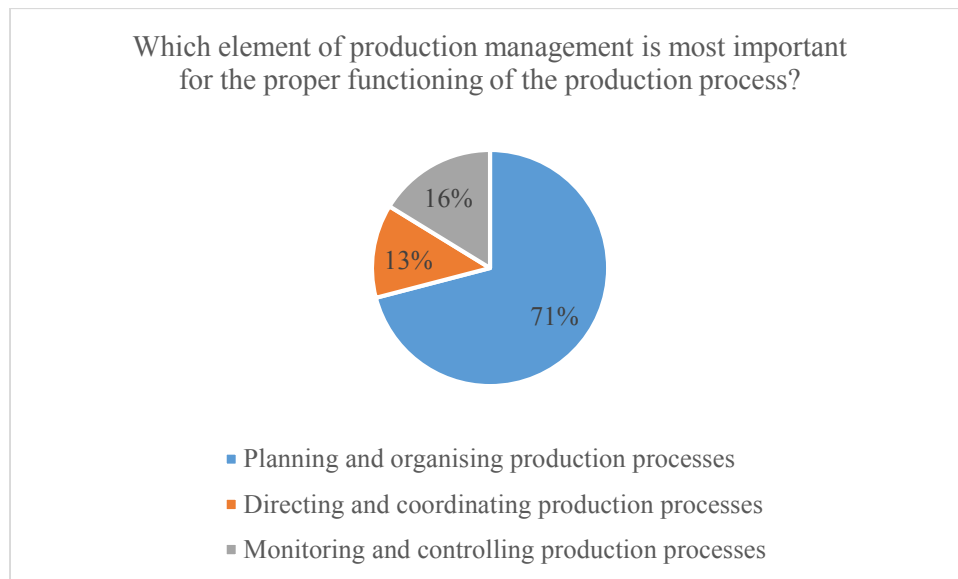


Figure 2. Key elements of production management determining the proper functioning of the production process in the enterprise – employees' opinions (n = 117).

Source: own study.

3.2. Availability and integration of information systems

The research results clearly indicate that the analysed enterprise possesses an extensive set of information systems supporting production management. The vast majority of respondents confirmed the existence of appropriate IT tools enabling effective planning, monitoring, and control of production processes. Only a small proportion of respondents indicated limited availability of such solutions.

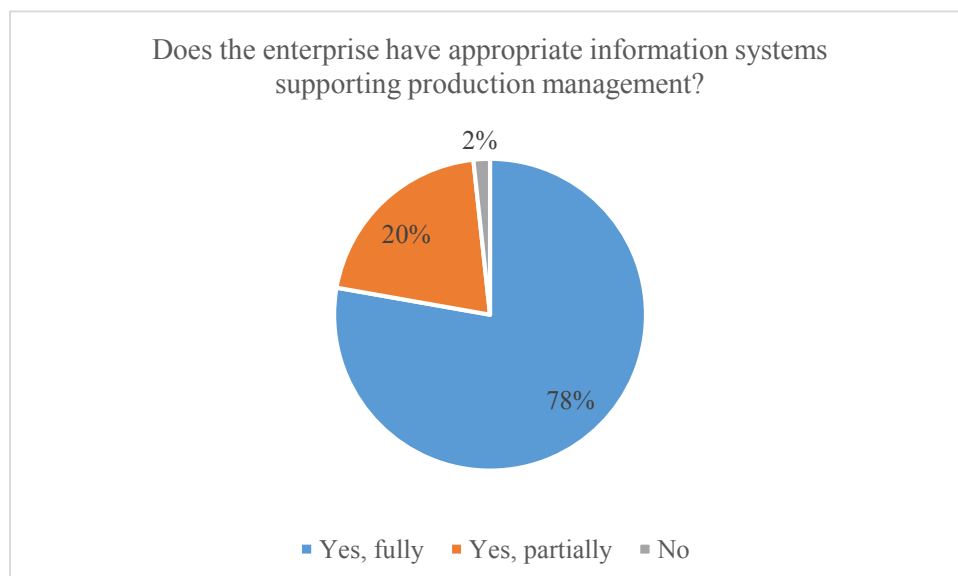


Figure 3. Availability of information systems supporting production management in the enterprise – employees' opinions (n = 117).

Source: own study.

A particularly important aspect emphasised by respondents was the degree of alignment and mutual integration of the applied information systems. Most employees assessed that the existing solutions form a coherent information ecosystem enabling smooth data flow between individual areas of enterprise activity. The integration of ERP, MES, SCADA, and CMMS systems allows for reduction of data redundancy, minimisation of error risks, and shortening reaction times to production irregularities.

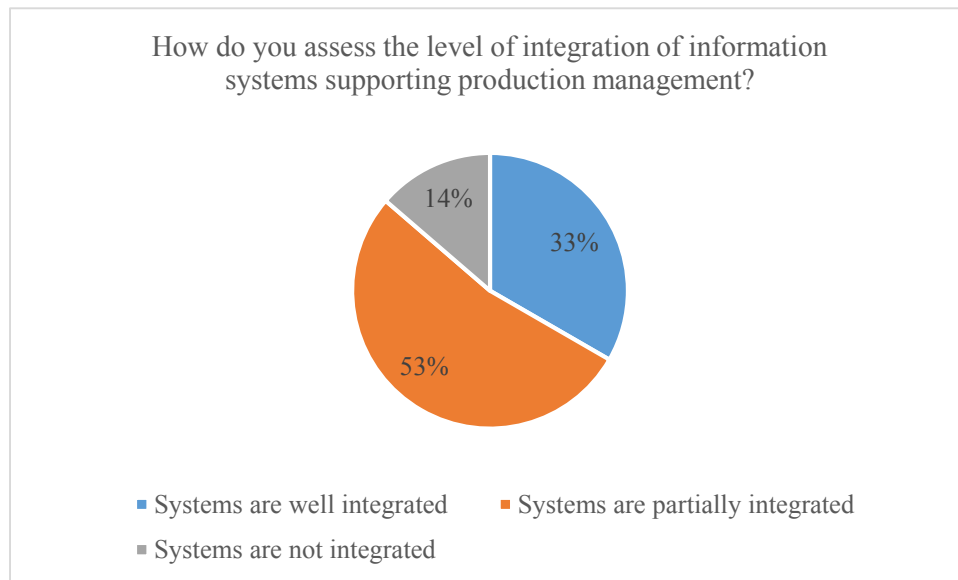


Figure 4. Assessment of the level of integration of information systems supporting production management in the enterprise (n = 117).

Source: own study.

Respondents also highlighted the importance of systematic investments in the development of information systems. Regular updates and implementation of new solutions are perceived as a condition for maintaining the enterprise's competitiveness and adapting to changing market conditions. At the same time, it was indicated that the lack of IT investments may lead to system obsolescence and reduced effectiveness of production management.

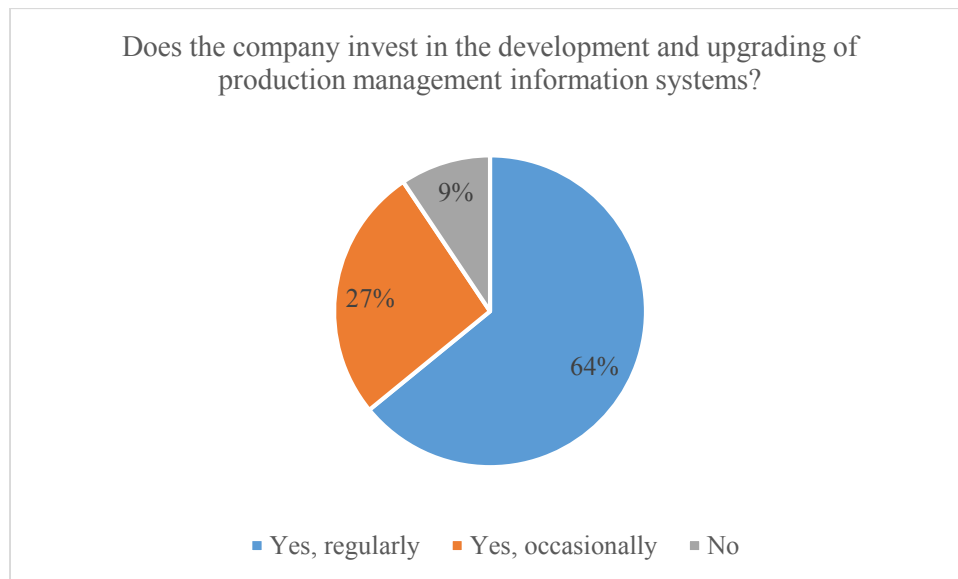


Figure 5. Investment in the development of production management information systems in the enterprise – employees’ opinions (n = 117).

Source: own study.

An important complement to the obtained results is employees’ declared perception of the enterprise’s readiness for further development of digital infrastructure and updating of applied information systems. The high level of integration of existing solutions creates favourable conditions for the next stage of digital transformation, namely the intensification of the use of tools based on artificial intelligence.

3.3. Automation and robotisation of production processes

The analysis of results concerning automation and robotisation indicates that the enterprise consistently develops its machinery park by implementing modern technological solutions. A significant proportion of respondents confirmed that the company plans or carries out investments in industrial robots and intelligent machines, which demonstrates its efforts to increase productivity and stability of production processes.

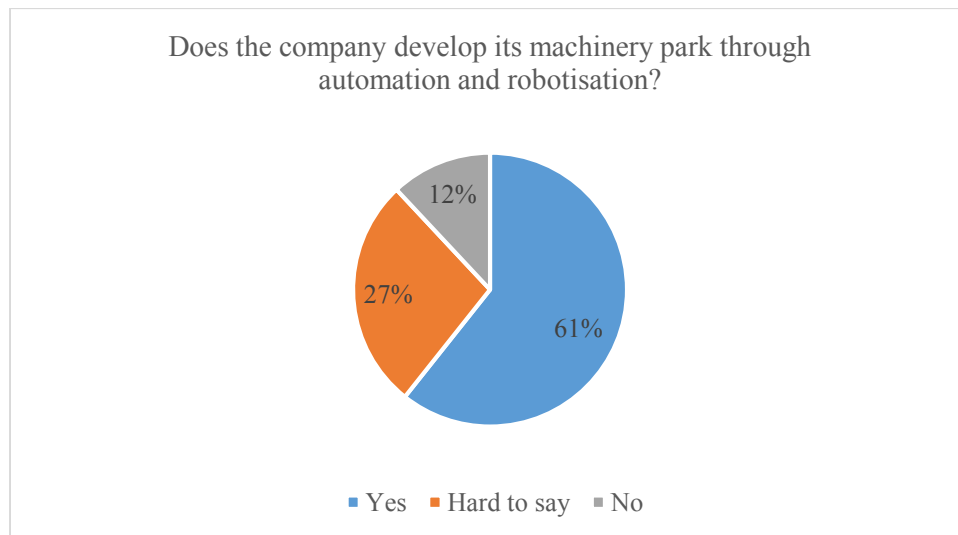


Figure 6. Development of the machinery park through automation and robotisation in the enterprise – employees' opinions (n = 117).

Source: own study.

At the same time, employees' opinions regarding full automation of production are diversified. The largest group of respondents indicated that automation should play a complementary role to human work rather than fully replace it. This approach may result both from practical experience and from concerns related to loss of flexibility or excessive dependence of processes on technology.

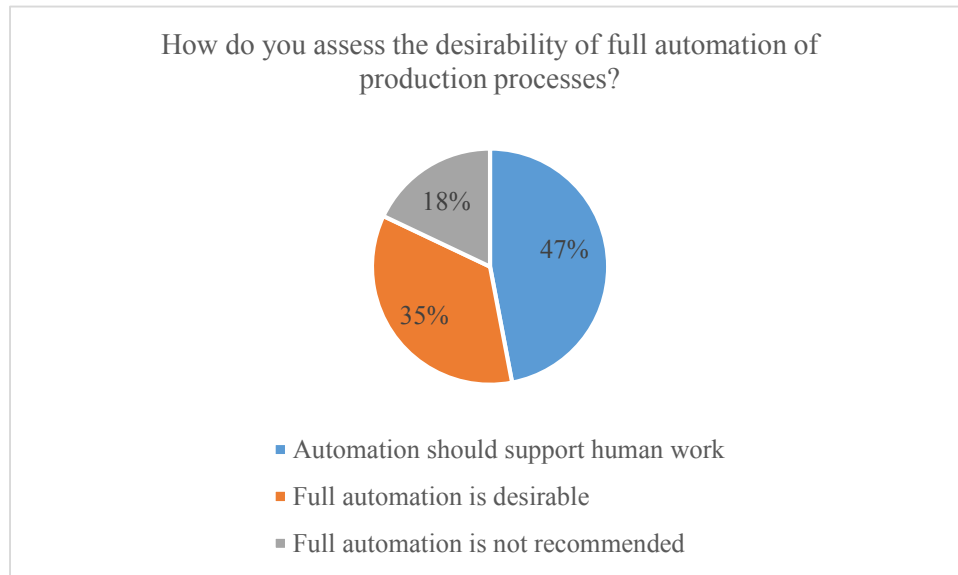


Figure 7. Employees' opinions on the desirability of full automation of production processes in the enterprise (n = 117).

Source: own study.

Nevertheless, some respondents perceive the potential of full automation in the context of accelerating production task execution and reducing human errors. These results indicate the need for gradual and well-considered implementation of robotic solutions, taking into account process specificity and employee competencies.

3.4. The role of the Internet of Things in production management

The Internet of Things was assessed by respondents as one of the most promising solutions supporting production management. The vast majority of respondents indicated that IoT implementation contributes to faster production processes, improved machine monitoring, and increased operational efficiency. Particular emphasis was placed on the importance of IoT in the context of predictive maintenance and rapid response to irregularities.

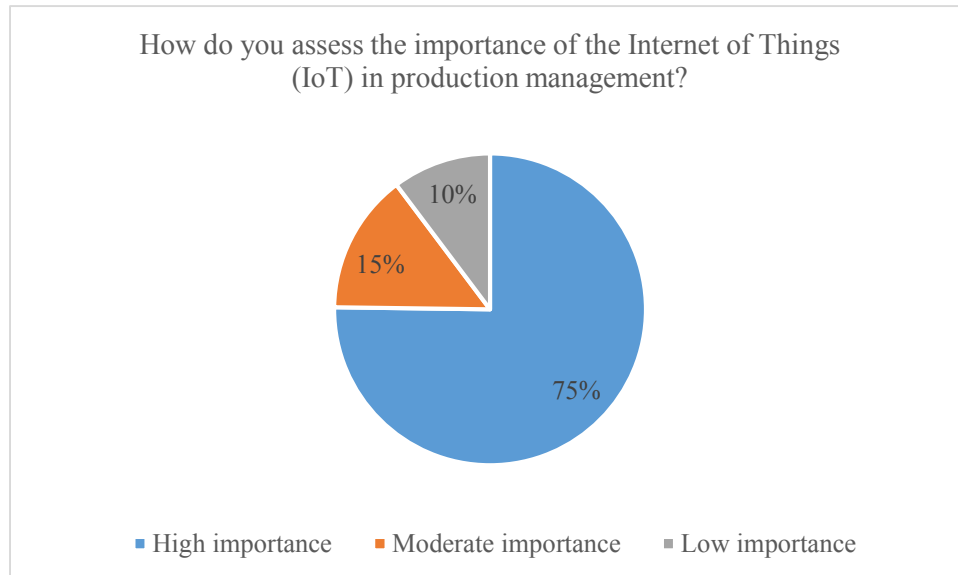


Figure 8. Assessment of the importance of the Internet of Things (IoT) in production management in the enterprise – employees' opinions (n = 117).

Source: own study.

At the same time, some respondents pointed to high costs and complexity of IoT implementation, which may constitute a barrier to further development in this area. These concerns relate to both technical and organisational aspects, including the necessity to ensure an adequate level of data security.

3.5. Employee competencies, system effectiveness, and security

The research results indicate that most employees do not experience significant problems in operating the implemented information systems, which is the result of conducted training and activities aimed at improving digital competencies. Respondents emphasised that proper staff preparation is crucial for effective utilisation of the potential of IT systems.

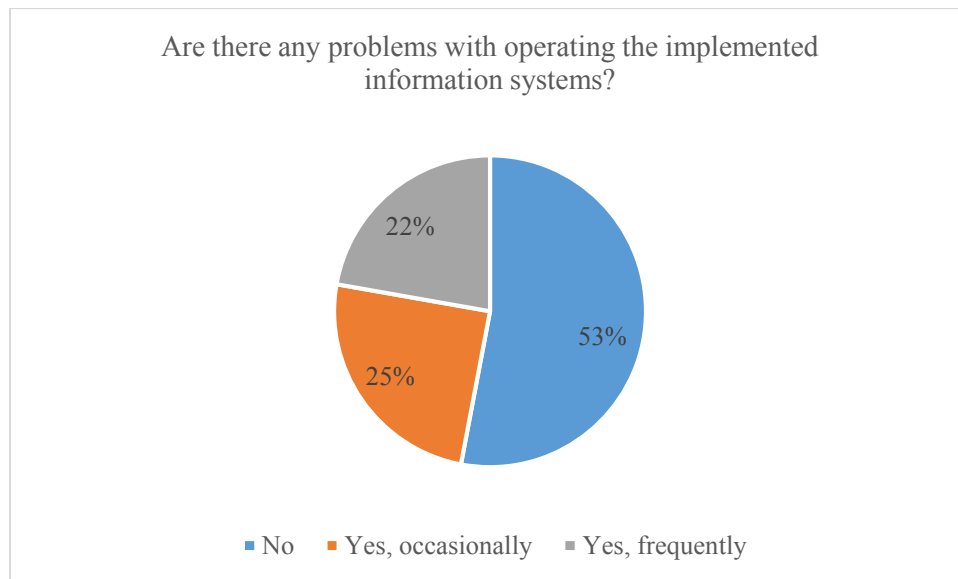


Figure 9. Problems with operating information systems implemented in the enterprise – employees' opinions (n = 117).

Source: own study.

At the same time, cases of losses and disruptions in the production process related to the functioning of information systems were identified, including incidents of a cyber nature. These results indicate the growing importance of cybersecurity as an integral element of production management in the Industry 4.0 environment.

Respondents unequivocally assessed modern information systems as more effective than traditional production management methods. Among the most frequently indicated benefits were faster fault detection, increased precision of order execution, better production supervision, and improved work efficiency.

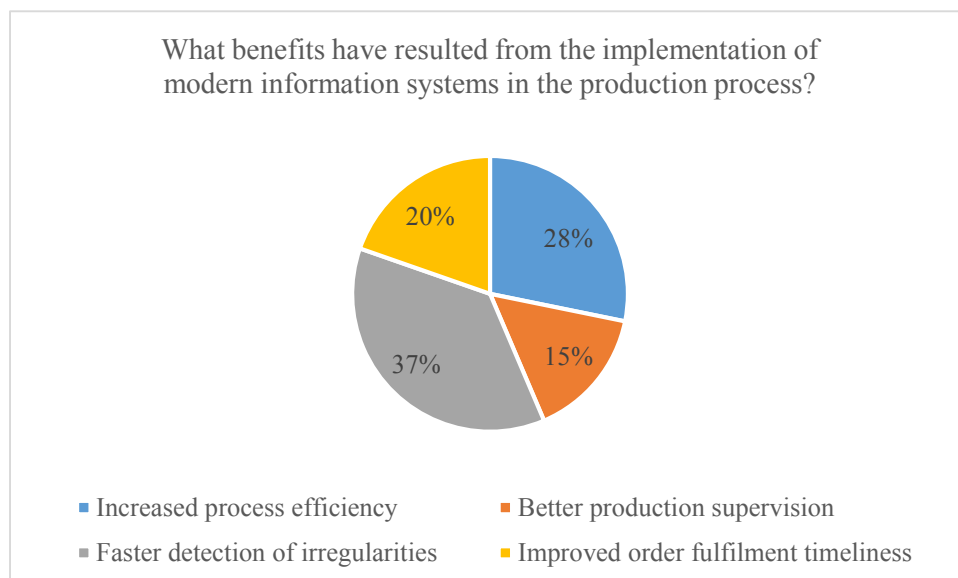


Figure 10. Benefits of implementing modern information systems in the production process in the enterprise – employees' opinions (n = 117).

Source: own study.

4. Discussion of Results

The obtained results confirm that information systems, automation, and IoT constitute an important element of modern production management, which is consistent with the assumptions of the Industry 4.0 concept. The high level of system integration and their positive evaluation by users indicate the digital maturity of the analysed enterprise.

At the same time, the research results reveal the significant role of the human factor in the digital transformation process. Employees' cautious approach to full automation confirms the need to maintain a balance between technology and human competencies. Similar conclusions are presented in the literature, which emphasises the importance of user acceptance for the success of technological implementations.

The identified threats in the area of cybersecurity indicate the necessity to treat the security of industrial systems as an integral element of production management. The development of IoT and system integration increase enterprises' susceptibility to cyber incidents, which requires continuous improvement of protection procedures and raising employee awareness.

An important conclusion drawn from the analysis is also the openness of the analysed enterprise to further investments in the development of production digitalisation. Respondents' declared orientation toward updating information systems and implementing new technological solutions indicates that the digital transformation process is not treated as a one-time initiative but as a continuous and long-term activity. Such an approach supports gradual growth of the organisation's digital maturity and enables flexible response to changing market and technological conditions.

In this context, further intensification of production digitalisation may primarily focus on extending the functionality of existing information systems with advanced analytical mechanisms, including solutions using elements of artificial intelligence. These technologies, functioning as a complement to current ERP, MES, or SCADA systems, may support predictive planning processes, schedule optimisation, and early detection of process deviations. The research results suggest that regular investments in IT infrastructure development and positive employee attitudes toward new technologies create favourable conditions for the gradual implementation of such solutions without disturbing the balance between automation and the human role in the production system. Despite its single-case design, the study provides valuable insights into digital transformation processes in complex manufacturing environments.

Conclusions

The conducted empirical research confirms that modern information systems, automation, and Internet of Things solutions play a significant role in production management in the analysed industrial enterprise. The high level of integration of applied IT systems and their positive evaluation by employees indicate the organisation's digital maturity and the effectiveness of undertaken transformation activities.

The obtained results simultaneously emphasise the key importance of the human factor in the production digitalisation process. User acceptance, appropriate digital competencies, and training activities significantly influence the effectiveness of implemented technological solutions. Respondents perceive automation and robotisation as important support for production processes, while recognising the need to maintain a balance between technology and the human role.

Another important conclusion is the enterprise's openness to further investments in the development of digital infrastructure and updating information systems. This creates conditions for gradual intensification of production digitalisation, including extending the functionality of existing systems with advanced analytical mechanisms. In this context, solutions using elements of artificial intelligence may constitute a natural complement to current production management systems.

At the same time, the research results indicate the growing importance of cybersecurity issues in the environment of integrated production systems. Effective digital transformation therefore requires a balanced approach combining technological development with risk management and conscious shaping of employee competencies.

A limitation of this study is its focus on a single enterprise, which justifies the need for further empirical research, particularly of a comparative nature.

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