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REVERSE LOGISTICS INCLUSION IN THE MATURITY MODEL OF LOGISTIC CENTRES

Piotr KRYŚ

Politechnika Warszawska; piotr.krys@pw.edu.pl, ORCID: 0000-0001-8705-1086

Purpose: The main aim of the article is to present the author's model of the maturity of logistic centres, in its improved version.
Design/methodology/approach: To carry out the research and prepare the article, an expert (Delphic) method was used, using the knowledge of experts professionally connected with logistic centres, and a literature review.
Findings: The conclusion of the research and analysis of the results is an improved model of logistic centre maturity compared to previous work. The developed model of logistic centre maturity allows for a comprehensive analysis of the logistic centre's maturity, locating points in need of improvement, and allows continuity and reliability of the centre's operation to be ensured.
Practical implications: The model developed has practical use for management of logistics centres and is a universal one, meaning it can be utilised in any logistic centre in order to improve its inner workings.
Originality/value: The main value of the paper is improvement upon author's original model of the maturity of logistics centres, with inclusion of additional arenas. The developed model is the authors' own input into logistics science.
Keywords: logistic centre, logistic, reverse logistics, maturity model.
Category of the paper: Research paper.

1. Introduction

The scientific literature, particularly the Polish one, does not generally address the problem of the correctness and effectiveness of logistic centres, usually taking them for granted instead. Simultaneously, it should be noted that the topic of the effectiveness in logistics, both in Polish and foreign works, is discussed widely and in many aspects. Most of these works, however, focus on the effectiveness of the supply chains; an example being the cited often article "A framework for analysing supply chain performance evaluation models" by Estampe D., Lamouri S., Paris J-L. and Brahim-Djelloul S. (2013). In the authors' opinion, however, it is worth to focus on the specific link of the supply chain, in another words: the effectiveness

of a logistics centre's. It is a subject rarely touched upon, but crucial, as logistic centres are among the most important facilities of point infrastructure in supply chains and have a significant and far-reaching impact on their functioning. This opinion is confirmed by S. Kauf and A. Laskowska-Rutkowska (Kauf, Laskowska-Rutkowska, 2019, p. 74) in their article, stating "they are the main elements of regional and international macrologistics systems, linking streams of goods flowing through global supply chains". This gap is particularly important because (Rutkowski, 2015, p. 93) "supply chains are now, as never before, extremely complex and sophisticated in nature, which makes them exceptionally vulnerable to various threats".

To address the research gap concerning the efficiency and effectiveness of logistic centres, the author of this article has been working for several years on creating a maturity model of logistic centres. In this article, the author intends to present the third, currently planned as the final version of the mentioned model. Previous versions were presented in earlier works (Kryś, 2020; Kryś, Izdebski, 2022). The most significant change in comparison to the previous versions is the inclusion of increasingly important processes of reverse logistics and sustainability in logistics. This modification is crucial due to the progressing climate crisis in recent years, combined with growing public environmental awareness, leading to significant changes in management and logistics approaches. It is important to emphasize that logistics is largely responsible for ongoing environmental degradation and faces a substantial challenge, as logistic processes have a substantial and negative impact on the natural environment. According to existing estimates, logistic processes account for up to 24% of greenhouse gas emissions, and it is widely accepted that reducing the carbon footprint of customers of large logistics companies can significantly contribute to overall CO2 emissions reduction (Paksoy, Kochan, 2021). Therefore, the author decided to meet business and research expectations by modifying the model to include key methods used in logistics to reduce emissions – sustainability, reverse logistics, and circular economy.

An additional, added value for the model developed is the relatively low popularity of research on maturity models in the Polish management science, which additionally contributes to the novelty of the solution. Even in the world scope literature, this topic is relatively rarely touched upon, as the majority of the publications which describe the maturity levels in logistics concentrate on the maturity models of enterprises in various branches (Battista, Schiraldi, 2013; Barbalho, de Faria Dantas, 2021; Tetik, Peltokorpi, Seppänen, Holmström, 2022), warehouses/storages (Wei Cao, Pingyu Jiang, 2013; Salhieh, Alswaer, 2021) or the supply chain (Helo, 2009; Reefke, Sundaram, Ahmed, 2010; Asdecker, Felch, 2018; Cheshmberah, Beheshtikia, 2020; Soares, Tortorella, Bouzon, Tavana, 2021) and not particularly on the logistics centre, which is a specific nodule of supply chains.

A broad literature review and expert (Delphic) studies were used as research methods for the development of the logistic centre maturity model discussed in the article.

2. Defining subject of research - logistic centre

Based on the previous literature review and related works on formulating a unified definition of a logistic centre, the article adopts the following authorial definition of a logistic centre: (Izdebski, Szwed, Skudlarski, Kryś, 2017, pp. 373-374) "A Logistics Centre is an autonomous economic entity with a separated area, in which by the rules of free competition a few (at least two) autonomous companies rendering logistic services to internal and external clients function as an open, not limited to a particular entity service, administered by an autonomous and neutral organisation taking care of the growth and efficient functioning of the complex logistics services (including, among others, transport, storing, distribution, freight forwarding and administering the information) or coordinating them, rendering accompanying services such as financial services or administering, having proper infrastructure and suprastructure (including, among others, roads, open spaces, parking lots, warehouses, workshops and buildings), preferably having an access to two or more branches of transport and a transloading terminal for combined transport". Depending on the strictness of its application, a few to several facilities in Poland match this definition.

3. Methodology and results of research conducted

The study was preceded by a literature review and expert consultation to prepare a research questionnaire, which utilised expert (Delphic) studies as research methods. During the research, the work of leading Polish and foreign researchers dealing with logistic centres was used – especially I. Fechner (Fechner, 2004, 2007; Fechner, Krzyżaniak, 2013), J. Fijałkowski (Fijałkowski, 2003), S. Bartosiewicz (Głodowska, Bartosiewicz, 2015), E. Gołembska (Gołembska, 2012), I. Meidutė (Meidutė, 2005), S. Markusik (Markusik, 2013), J. Miklińska (Miklińska, 2012), L. Mindur (Mindur, 2000), M. Mindur (Mindur, 2012), B. Skowron-Grabowska (Skowron-Grabowska, 2010, 2016) and C. Thies (Thies, 1998). In addition to the preparation of the questionnaire, the main objective of the review was to develop an original definition of logistic centres (Izdebski, Szwed, Skudlarski, Kryś, 2017), in order to facilitate the proper selection of research facilities, including the elimination of facilities commonly referred to as logistic centres, but which do not actually meet their requirements – primarily distribution centres (Izdebski, Kryś, 2018). This is particularly important because of the large number of facilities wrongly referred to as logistic centres in Poland (Górecka, Maksymiuk, 2017). Due to the variety of concepts of the logistic centre in Europe, differing in scope and operational capabilities (Mindur, Turoń, Sierpiński, 2018), it should be noted that the definition developed and applied to the selection of research facilities is a general definition, however, adapted primarily to Polish conditions.

After receiving positive opinions from the experts consulted on the planned expert (Delphic) research questionnaire, its form was finalised and the research was started. The questionnaire contained five main factors examined: the cost of services offered, the range of logistics services offered, the quality of logistics services provided, the technical solutions used, and the location of the logistic centre. Each of the above factors contained five lower-order elements – a total of 25 lower-order factors. Managers and employees in senior logistics positions in the logistic centres, as well as independent experts cooperating with them, have been selected as experts. The results of the study are presented in the tables below.

Table 1.
Factors that have a decisive influence on the functioning of a logistic centre (Level II objectives)

Target name		Mean	Standard deviation	Coefficient of variation
C1	Cost of the services offered	32.1	3.83	0.12
C2	Range of logistics services offered	15.6	2.54	0.16
C3	Quality of services provided	20.1	4.84	0.24
C4	Technical solutions applied	9.7	1.21	0.12
C5	Location of the logistic centre	22.6	5.17	0.23
Concordance ratio		0.717		
Criterion χ^2		48.788		
Table value χ^2		9.49		

Source: own study.

After multiplying the mean values (which are at the same time the value of the local priority) of the relevant Level II and Level III objectives, the system priority of Level III objectives was obtained, which will be the target weighting of a given factor for the functioning of the logistic centre:

Table 2.
Systemic priorities of the factors that have a decisive influence on the functioning of a logistic centre

Target name		System priority value [%]
C1 Cost of the services offered		
C11	Cost of warehouse space rental	14.57
C12	Maintenance fee	5.70
C13	Media costs (heating, electricity, water)	5.37
C14	Rent-free period	3.69
C15	Cost of additional services (e.g. security)	2.74
C2 Range of logistics services offered		
C21	Available storage space	4.26
C22	Possibility of comprehensive logistics service	4.28
C23	Having its own transport fleet	2.31
C24	Possibility of organising forwarding through the centre	2.49
C25	Operator's consultancy on logistics solutions in the centre	2.25
C3 Quality of service provided		
C31	Flexibility of operation	3.93
C32	Timely service	6.10
C33	Average level of damage to stored goods	3.19
C34	Customer service level	4.13
C35	Availability of additional services	2.73

Cont. table 2.

C4 Technical solutions applied		
C41	High-bay warehouse	3.31
C42	Automation of the storage process	1.63
C43	Presence of an intermodal transport terminal	1.73
C44	Quality assurance systems in place	1.55
C45	Safety systems used	1.48
C5 Location of the logistic centre		
C51	Availability of human resources	4.16
C52	Degree of connection with the international transport system	5.16
C53	Proximity to large urban centres	4.68
C54	Quality of road and telecommunications infrastructure	6.46
C55	Relations with public institutions	2.09

Source: own study.

By comparing the above results in the table according to the limits of the ranges, the following distribution of importance of the factors was obtained:

Table 3.

Distribution of factors in ranges

Distribution of factors in ranges				
No. of the range	**Boundaries of ranges [%]**	**Determination of factors**	**"Specific gravity" of the range (%)**	**Average value of the system priority of the factor in the range (%)**
1	11.49-14.80	C11	14.77	14.77
2	8.17-11.48	-	0	0
3	4.85-8.16	C12, C13, C32, C52, C53, C54	34.54	5.76
4	1.53-4.84	C14, C15, C21, C22, C23. C24, C25, C31, C33, C34, C35, C41, C42, C43, C44, C45, C51, C55	50.85	2.82

Source: own elaboration.

Therefore, according to the experts, the most important factors influencing the functioning of the logistic centre should be:

- C11 - Cost of leasing warehouse space: 14.77.
- C12 - Maintenance fee: 5.99.
- C13 - Media costs (heating, electricity, water): 5.12.
- C32 - Timely service: 5.63.
- C52 - Degree of connection to the international transport system: 5.53.
- C53 - Proximity to large urban centres: 5.20.
- C54 - Quality of road and telecommunications infrastructure: 7.06.

Based on the analysis of the research results, it was found that, according to the majority of experts, the effectiveness of the logistic centre's functioning is most strongly influenced by the costs of the services offered, including, first of all, the costs of renting warehouse space and the appropriately selected location of the logistic centre.

The operating costs in this case will be largely due to the proper organisation and proper operation of the centre, which will allow for the reduction of its own costs, which in turn will allow for a reduction in the prices offered to customers. This requirement was the most important point taken into account when developing the logistic centre's maturity model. The experts' choice of costs as the most important factor is not surprising, as the high importance of costs for a company's operations is emphasised both in management theory and practice.

The quality and scope of the logistics services offered by the centre were of lesser, although still of importance to experts. From this, we can conclude that according to most experts these elements are not important in themselves. Rather, they add value to other elements. Thus, during further analysis, they were mainly taken into account as elements which allow for a reduction of the centre's operating costs, not as decisive elements. However, they have not been overlooked because, although they are not an element determining the efficiency of the logistic centre, too low a level (in particular the quality of service) may lead to the loss of customers.

According to the experts, the technical solutions applied in the centre are the least important for the functioning of the logistic centre. This is an interesting fact, especially considering the opinion of many researchers concerning the importance of a reloading terminal for logistic centres. This means that, according to most experts, technical elements of advanced logistics, such as a high-bay warehouse or an intermodal terminal, are more added value than an important element determining the proper functioning of a logistic centre. During the development of the maturity model, these elements were therefore considered to be the final stages of the centre's development, not necessary for its proper functioning and rather the crowning achievement of the highest stages of its development.

The great importance of the location of the logistic centre emphasises the importance of using appropriate methods to determine the profitability of its location at the investment planning stage. It constitutes a confirmation of the correctness of the development of these methods in the world science of logistics. In this case, experts have a clear interest in the location of the centre close to significant flows of goods, which may be linked to international transport (e.g. transport corridors) or to the proximity of large urban centres that also offer significant flows of goods around the centre. The experts considered the high quality of road and telecommunications infrastructure to be even more important than the location of the centre in the vicinity of significant flows of goods, which is not surprising – high quality infrastructure in the vicinity of the centre is required for its proper functioning with significant transport flows. As in the case of costs, the high rating of these factors is not surprising when compared to the weight given to these criteria by the scientific community – the choice of the centre's location is a fundamental aspect when deciding on its establishment, and the ways of assessing the potential location have been carefully studied. During the development of the original version of the model, it took into account the significant importance of the location of the centre for the correctness of its functioning; however, in the modified version proposed in this paper,

it was abandoned, as centre's location is not something that can be influenced after its initial establishing.

4. Importance of reverse logistics and case for its inclusion in maturity model

As mentioned in the introduction, logistic processes have a strong and negative impact on the natural environment. According to existing estimates, logistic processes are responsible for up to 24% of greenhouse gas emissions, and it is widely accepted that reducing the carbon footprint of customers of large logistics companies can significantly contribute to overall CO2 emissions reduction (Paksoy, Kochan, Ali, 2021). Logistics as a discipline must therefore address challenges related to preventing further environmental degradation and create action patterns and solutions aimed at reducing ongoing emissions and destruction (Pichlak, 2024). The fundamental step taken by logistics in this regard is the implementation of reverse logistics processes and a strong emphasis on increasing sustainability in logistics.

Logistics' response to the need to reduce harmful gas emissions and increase sustainability is the creation of a new approach to supply chain management, known as Sustainable Supply Chain Management. This approach involves the joint and targeted improvement of logistic processes throughout the entire supply chain in collaboration with all partners, leading to increased energy efficiency in logistics, ecological production, and reduced environmental impact of supply chain flows, while simultaneously reducing generated waste (Chin, Keah-Choon, Suhaiza, 2015).

The second element of ecological logistics, often associated with Sustainable Supply Chain Management, is reverse logistics Reverse logistics refers to managing returns or waste in a closed-loop system to add value throughout the product life cycle by recovering usable material from the aforementioned returns or waste (Bag, Gupta, Luo, 2020). Reverse logistics processes are significantly more complex and costly than traditional logistics dealing with flows to the customer, especially since many companies have not yet developed adequate processes of this kind.

Its application, however, allows for the reuse of shortages, returned, or damaged goods according to an approach that prioritizes benefits: reuse, product upgrade, material recovery, waste management (Hazen, Hall, Hanna, 2012), with these options defined as:

- Reuse – (Hazen, Hall, Hanna, 2012, p. 248) "Direct reuse is an option that presents itself when a customer returns an unused product back to the place of purchase, thus inserting the product back into the supply chain for use. At the retailer level, once the product is no longer serviceable or requires some sort of upgrade (e.g. cleaning, replacing accessories, remanufacturing, repackaging, etc.) direct reuse is no longer an option.

Generally, this option exists only if the location in which the product resides in the supply chain possesses the capability to return the product to retail condition. This process includes products that are completely unused and products that are returned after such light use that upgrade is not required in order to return the product to new status".

- Product upgrade – involves improving the product from a withdrawn state to an acceptable condition for future use or sale. This method of product reuse involves (Hazen, Hall, Hanna, 2012, p. 249) "repairing, refurbishing, or remanufacturing an item in order to extend the life of and derive value from the original core unit". Product upgrade becomes an option when the possibility of direct reuse is either no longer available (e.g. the product is in used condition) or not economical (e.g. there is no longer a market requirement for the product). If executed properly, product upgrade can create profitable business opportunities through recapturing value that would otherwise have been lost".
- Material recovery – involves recovering any value from the returned product, for example by using individual functional parts or recycling materials for reuse.
- Waste management – involves directing the product to waste after the previous three options have been utilized. At this stage, no further value can be recovered from the product, but the waste must be disposed of in an appropriate, environmentally friendly manner.

Reverse logistics creates both material and intangible value for companies by helping them:

- extract additional value from used or returned goods instead of wasting manpower and time to procure more raw materials,
- create additional value through extending products' life cycles,
- improve customer satisfaction and increase their loyalty though paying more attention to faulty goods and merchandise repairs,
- obtain consumers' feedback to the product, which can suggest improvements and allow for better understanding of the real reasons for product returns, which can lead to future product improvements or new, improved product designs (Chin, Keah-Choon, Suhaiza, 2015).

Due to its nature, reverse logistics can be highly significant in any industry. Known examples of its use include diverse sectors such as the cosmetics company Estée Lauder (which reuses returned products within its logistics chain) and the heavy machinery manufacturer Caterpillar, which built a special factory dedicated to repairing, rebuilding, and renewing diesel engines (Morgan, Richey, Autry, 2016).

Combining Sustainable Supply Chain Management with appropriate reverse logistics usage allows for the creation of a closed-loop supply chain in logistics. In a closed-loop supply chain, a specific symbiosis between traditional logistics, associated with flows towards the customer,

and reverse logistics should be applied to create a self-sustaining loop of using worn-out products returned by customers—utilizing the four stages of value recovery from returned products. This way, worn-out and unnecessary products will become a significant element in the production of new items, reducing the need for acquiring new materials.

The utilization of a closed-loop supply chain is possible to varying degrees in different industries. One area where its use seems to have a high potential for positive impact is the fashion industry, particularly fast fashion, whose strong negative environmental impact and high level of threat are well known (Wren, 2022; Jamil, Kabiesz, Bartnicka, 2024). While the cited analysis indicates a strong negative environmental impact and suggests mainly Sustainable Supply Chain Management as a solution, a Closed-Loop Supply Chain appears to be a rational next step, allowing for an even greater elimination of negative effects – both in terms of environmental impact and in increasing worker safety.

A closed-loop supply chain is the logistics part of the so-called circular economy, an economic system where a closed loop of processes is created, in which waste from some processes is used as raw material in other processes. The version of a closed-loop supply chain fully adapted to the requirements of a circular economy is called a circular supply chain. The goal of circular supply chain is to expand the circulation of resources according to supply chain requirements. It integrates circular economy and supply chain management by extending the closed loop boundary and recovers value from primary and secondary supply chains. It even goes beyond the boundaries of closed-loop supply chain by including resources within supply chain systems to even higher reduce the use of virgin materials, enabling circular supply chain to achieve zero waste and facilitates end-of-life (EoL) or end-of-use (EoU) recovery, even for unwanted waste (Werner-Lewandowska, Golińska-Dawson, Cyplik, 2024).

As can be observed, reverse logistics and circular economy seem to be the future of logistics development, allowing for simultaneous cost reduction, process improvement, and reduction or, in an extremely optimistic scenario, elimination of the negative impact of logistics on the natural environment. The positive impact of reverse logistics on the stabilization and proper and effective functioning of supply chains that implement it cannot be overlooked – by reducing the risk of supply interruptions and ensuring a reliable source of materials for production. This is extremely important in the current turbulent times, where supply chains are particularly sensitive to possible disruptions. For these reasons, the inclusion of reverse logistics and circular economy elements in the developed maturity model of logistic centres is important, especially considering the strong stabilizing effect on supply chains exerted by logistic centres themselves.

The author's goal in this article was to include the discussed elements of reverse logistics and circular economy in the developed maturity model of logistic centres. These elements have been included in the areas "Capability of supporting reverse logistics processes" and "Sustainability and environmental impact", considering the capabilities and level of preparedness of logistic centres to support reverse logistics, as well as encouraging the assessment of the current environmental impact of the logistic centre.

5. The maturity model of logistics centers

The model of logistic centre maturity developed on the basis of the research results is presented in Table 4 below. It was based in its structure on the MZP (Productivity Management Model) models by A. Kosieradzka (Kosieradzka, 2012), as well as on the CMMI (Capability Maturity Model Integration) model, analysed on the basis of the works of T. Kasse (Kasse, 2008) and P. Taticchi (Taticchi, 2010). The model developed has five levels of maturity in fourteen subject areas and uses continuous representation (Kosieradzka, Smagowicz, 2016). Earlier versions of the maturity model were published in one of the author's monograph and previous article, while this article includes its modified version, more adapted to the analysis of the logistic centre in terms of ensuring operational reliability. The new version of the model includes additional areas: "The implementation of business continuity management systems", "The information security system level applied", "Capability of supporting reverse logistics processes" and "Sustainability and environmental impact". While the areas: "The implementation of business continuity management systems" and "The information security system level applied" mainly improve the previous version of the model, the areas "Capability of supporting reverse logistics processes" and "Sustainability and environmental impact" introduce new expectations regarding the maturity level of logistic centres, based on their ability to provide clients with services related to the rapidly developing, though not widely applied in Poland, field of logistics, and their own environmental responsibility.

The developed model is the authors' own input into logistics sciences.

Table 4.
Logistics centre maturity model

Area No 1: Level of excellence in logistics processes	
Level	Assessment criteria
1	• The Centre achieves the objectives set for it. • There are no highlighted processes, the centre benefits from employee involvement and hidden knowledge.
2	• The activity is formalised by distinguishing the processes, maps of main and auxiliary processes are created. • The processes critical to the functioning of the centre are distinguished.
3	• Detailed maps of processes in the centre are developed. • The implementation of processes is supervised and checked for compliance with the description.
4	• Developed quantitative measures for processes, implementation of a system for measuring the performance of processes by means of quantitative techniques. • Achievement of effects by the processes is constantly observed, improvements are made to the processes on an ongoing basis.
5	• Processes are continuously and innovatively improved. • Process improvement is based (in addition to quantitative methods) on benchmarking and qualitative methods, including measurement of customer service levels.

Cont. table 4.

Area No 2: Level of implementation of quality management systems	
Level	Assessment criteria
1	• The quality management system is non-formalised.
2	• The Centre endeavours to implement quality systems. • The formal quality requirements records are applied.
3	• Implementation of the ISO 9001 quality management system. • The Centre has formulated quality requirements.
4	• Implementation of other relevant ISO standards for the centre, including in particular ISO 14001 (environmental management), ISO-22000 (food safety management system), ISO-27001 (information security management), ISO-28000 (supply chain security management system). • The Centre constantly monitors the level of quality of service by means of appropriate measures.
5	• The Centre strives to achieve the highest possible quality and results, using appropriate quality management tools and strategies. • The Centre uses benchmarking and evaluation models to compare with other centres and to continuously improve based on best practice.
Area No 3: Implementation of business continuity management systems	
Level	Assessment criteria
1	• The business continuity management system does not exist or is not formalised.
2	• The Centre endeavours to implement business continuity management systems. • The formal provisions of the business continuity requirements are applied.
3	• Implementation of a business continuity management system based on e.g. ISO standards 22301 and 22313. • The Centre has formulated business continuity requirements, including a plan for a set of BCP instructions.
4	• The Centre continuously monitors the level of business continuity by means of appropriate measures. • High redundancy of required equipment and processes.
5	• Full implementation of BCMS and its embedding in the culture of the organisation. • The Centre uses benchmarking and evaluation models to compare with other centres and to continuously improve based on best practice.
Area No 4: Range of services offered by the centre	
Level	Assessment criteria
1	• The Centre offers basic logistic services, including primarily storage and transport.
2	• The Centre offers a wide range of logistic services, including, for example, complete organisation of forwarding and distribution, transport integration, organisation of freight streams, specialised warehouses.
3	• The Centre offers a basic package of support services in addition to logistic services.
4	• The Centre offers customers comprehensive logistic services. • The Centre supports its customers with its experience and expertise.
5	• The Centre offers a comprehensive package of additional services in addition to logistic services.
Area No 5: Information systems implemented	
Level	Assessment criteria
1	• The Centre has no structured IT systems.
2	• IT systems are implemented to facilitate the management of individual parts of the logistic centre's operations. • Implementation of IT systems managing the flow of goods and warehouse processes.
3	• Systematic implementation of IT systems in all areas of the logistic centre’s activity.
4	• The IT systems implemented in the centre work in a modular system, combining in a larger system managing the whole activity of the centre. • Advanced IT systems designed to track flows and manage warehouse processes, using the full potential of logistic technologies.
5	• Full unification of IT systems in a modular system. • Specialisation and selection of the best IT subsystems for individual modules.

Cont. table 4.

Area No 6: Degree of excellence of the warehouse organisation	
Level	Assessment criteria
1	• The warehouse meets the objectives set for it. • Storage organisation is not formalised.
2	• Detailed maps of warehouse processes are developed. • Processes critical to warehouse operation are distinguished.
3	• Developed methods to optimise the management of the flow and storage of goods based on formal flow management methods. • Warehouse processes use automatic identification capabilities to improve the management of the flow of goods. • The implementation of warehouse processes is constantly monitored and checked for compliance with the description.
4	• Developed quantitative measures for processes, implementation of a system for measuring the performance of processes by means of quantitative techniques. • Achievement of effects by the processes is constantly observed, improvements are made to the processes on an ongoing basis. • Implementation in the warehouse of IT systems based on process management and cooperating with automatic identification systems.
5	• The processes in the warehouse are continuously improved in a gradual and innovative way. • Warehouse processes make full use of available logistic technologies to optimise flow.
Area No 7: Degree of storage process mechanisation	
Level	Assessment criteria
1	• Manual organisation of warehouse work.
2	• Partially mechanised warehouse work organisation.
3	• Full mechanisation of warehouse operation.
4	• Introduction of basic automation in the warehouse.
5	• Fully automated warehouse.
Area No 8: Degree of technical advancement in the warehouse	
Level	Assessment criteria
1	• Lack of specialised technical solutions to facilitate warehouse work or reduce staff errors. • Lack of implementation of systems using automatic identification capabilities. • Use of basic storage and transport equipment.
2	• Basic systems implemented using automatic identification capabilities.
3	• Introduction of specialised technical solutions to facilitate warehouse work or reduce staff errors. • Implemented systems using automatic identification capabilities.
4	• Introduction of advanced technical solutions to facilitate warehouse work or reduce staff errors. • Implementation of advanced systems using automatic identification capabilities, use of RFID technology for automatic identification. • Use of specialised storage and transport equipment.
5	• The centre has a high-bay warehouse.
Area No 9: Physical security system level applied	
Level	Assessment criteria
1	• The centre has no formal systems of ensuring workers' safety, aside from the basic requirements of the Labour Code.
2	• The centre has introduced formal systems of ensuring workers' safety other than only the basic requirements of the Labour code. • The workers are provided with adequate Occupational Safety trainings.
3	• The centre has introduced formal systems of ensuring workers' safety other than only the basic requirements of the Labour code. • The basic technical safety measures, i.e. warning signs and mirrors, are employed in the centre.
4	• The centre has introduced formal systems of ensuring workers' safety other than only the basic requirements of the Labour code. The safety systems are constantly checked and updated. • Advanced technical safety measures, i.e. access control gates and forklift anti-collision systems, are employed in the centre.
5	• The centre uses advanced technical safety measures and employs modern safety technologies and research, i.e. proximity-aware, automatic forklift braking systems.

Cont. table 4.

Area No 10: Information security system level applied	
Level	Assessment criteria
1	• The centre has no formal systems of ensuring information security.
2	• The centre has introduced formal systems of ensuring information security. • The centre employs the basic organisational, physical and IT security measures to protect information.
3	• The centre has introduced formal systems of ensuring information security. • The centre employs the basic organisational, physical and IT security measures to protect information. • The workers are adequately trained in information security.
4	• The centre has introduced formal systems of ensuring information security and the systems are constantly checked and updated. • The centre employs advanced organisational, physical and IT security measures to protect information. • The workers are adequately trained in information security.
5	• The centre employs advanced organisational, physical and IT security measures to protect information. Modern technologies and research are employed to protect information.
Area No 11: Level of external transport solutions offered	
Level	Assessment criteria
1	• The Centre has access to one branch of external transport – road transport. • The Centre has no specialised equipment to handle external transport above the required minimum.
2	• The Centre has specialised facilities to facilitate unloading, handling and loading.
3	• The Centre has access to at least two branches of external transport. • The Centre has specialised facilities to facilitate unloading, handling and loading.
4	• The Centre has access to an intermodal terminal and supports intermodal transport.
5	• The Centre has its own terminal for intermodal transport.
Area No 12: Capability of supporting reverse logistics processes	
Level	Assessment criteria
1	• The centre does not offer reverse logistics services.
2	• The centre offers basic reverse logistics capabilities. • The centre can carry out processes for receiving and gathering returned or damaged goods for customers.
3	• The centre offers advanced reverse logistics capabilities. • The centre can carry out processes for receiving, gathering, and sorting returned or damaged goods.
4	• The centre offers advanced reverse logistics capabilities. • The centre can carry out processes for receiving, gathering, and sorting returned or damaged goods. • The centre offers services related to the implementation of circular economy aspects for customers.
5	• The centre offers comprehensive support for reverse logistics processes
Area No 13: Sustainability and environmental impact	
Level	Assessment criteria
1	• The centre does not analyse its environmental impact.
2	• The centre analyses and is aware of its environmental impact. • The centre strives to reduce its negative environmental impact at an advanced level.
3	• The centre analyses and is aware of its environmental impact. • The centre strives to reduce its negative environmental impact at an advanced level. • The centre applies Sustainable Development principles in its operations.
4	• The centre strives to reduce its negative environmental impact at an advanced level, exceeding legal requirements. • The centre applies Sustainable Development principles in its operations and can impart knowledge to customers. • The centre implements circular economy principles in its own operations. • The centre applies elements of corporate social responsibility.

Cont. table 4.

5	• The centre strives to reduce its negative environmental impact at an advanced level, significantly exceeding legal requirements. • The centre applies Sustainable Development principles in its operations and can impart knowledge to customers. • The centre implements circular economy principles in its own operations, achieving zero waste or a similar level. • The centre fully implements corporate social responsibility principles in its operations.
Area No 14: Level of connection with multinational transport	
Level	Assessment criteria
1	• No adequate methods have been employed in choosing the centre's placement.
2	• The centre is not located in proximity to major shipment routes.
3	• The basic methods of choosing the centre's placement have been employed.
4	• The centre is located in proximity to major shipment routes.
5	• The centre is located in proximity to major shipment routes, i.e. big city agglomerates, seaports or international transport canals.

Source: own elaboration.

The model developed is a universal one, meaning it can be utilised in any logistic centre, possibly with the requirement of small adjustments to better suit a specific logistic centre. The model does not limit the kinds of logistic centres it can be applied to, but it cannot be used to analyse distribution centres. In order to meet the requirement of effective functioning, the logistic centre should meet at least the conditions of the third level of maturity of the assessed areas. The introduction of the fourth and fifth levels of maturity at the centre is not necessarily required, but they are a crowning achievement and optimisation of its functioning.

6. Discussion

The Polish scientific literature does not generally address the problem of the correctness and effectiveness of logistic centres, which are among the most important facilities of point infrastructure in supply chains and have a significant and far-reaching impact on their functioning. To address the research gap concerning the efficiency and effectiveness of logistic centres, the author of this article has been working for several years on creating a maturity model of logistic centres.

Based on the analysis of the research results (done by broad literature review and expert (Delphic) studies), it was found that, according to the majority of experts, the effectiveness of the logistic centre's functioning is most strongly influenced by the costs of the services offered, including, first of all, the costs of renting warehouse space and the appropriately selected location of the logistic centre. The in-depth discussion of research results was included in Section 3: Methodology and results of research conducted.

Research results were then used to develop the maturity model of logistic centre. The model developed is a universal one, meaning it can be utilised in any logistic centre and allows for in-depth analysis of logistic centre and its weak and strong points. The model of logistic centre

maturity developed allows for the analysis and identification of weaknesses in the centre's development that could negatively affect its ability to smoothly implement logistic processes, allowing for the expansion and improvement of the centre's operations in aspects that are unreliable or ineffective at the current stage of development. The model developed is a universal one, meaning it can be utilised in any logistic centre, possibly with the requirement of small adjustments to better suit a specific logistic centre.

An additional, added value for the model developed is the relatively low popularity of research on maturity models in the Polish management science, which additionally contributes to the novelty of the solution. Even in the world scope literature, this topic is relatively rarely touched upon, as the majority of the publications which describe the maturity levels in logistics concentrate on the maturity models of enterprises in various branches (Battista, Schiraldi, 2013; Barbalho, de Faria Dantas, 2021; Tetik, Peltokorpi, Seppänen, Holmström, 2022), warehouses/storages (Wei Cao, Pingyu Jiang, 2013; Salhieh, Alswaer, 2021) or the supply chain (Helo, 2009; Reefke, Sundaram, Ahmed, 2010; Asdecker, Felch, 2018; Cheshmberah, Beheshtikia, 2020; Soares, Tortorella, Bouzon, Tavana, 2021) and not particularly on the logistics centre, which is a specific nodule of supply chains.

The author, then, concentrate on a relatively rarely described subject and develop their own, novel model of the logistic centre’s maturity. The developed model is, therefore, a research novelty and the authors’ own input into the reliability and logistics sciences, created in order to support the assessment of the logistic maturity of a supply chain, a very important research region, through developing the maturity model of one of the most important nodules of the chain. The maturity models applicable to business are especially important at the current time, as, as stated in Karolina Werner-Lewandowska’s article "Logistics maturity of the polish service sector - research results" (Werner-Lewandowska, 2020), the research of the logistics maturity is still relatively rare in Poland.

The author hopes the developed maturity model will become basis for other researchers to further study correctness and effectiveness of logistic centres, as in author's opinion these subjects should be developed further.

Unfortunately, because of lack of other models, which analyse maturity of logistic centres, it is impossible to compare developed model to other maturity models of logistic centre. However, the model meets all criteria that maturity model should include and was compared to models developed for other types of logistics enterprises.

The further research of the developed model itself should concentrate primarily on developing a set of good practices, which will be an element of the logistics centre’s maturity model. The author also plans to expand his research into reverse logistics and what role in closed-loop supply chain logistic centres can play, which will be used to further develop existing maturity model.

7. Summary

The paper presents expert research carried out and its results, and includes a model of the logistic centre's maturity developed on this basis. The model developed has five levels of maturity in fourteen areas. The developed model of logistic centre maturity can be used to analyse and determine the level of development of the centre in the most important areas of its operation, while allowing for a proper assessment of its effectiveness. As part of the model development, areas related to reverse logistics have been added. Reverse logistics is particularly important in today's times due to the ongoing environmental degradation

Thus, the presented maturity model is an advanced tool for studying and increasing the effectiveness of the logistics centre it will be used for the analysis of. Enabling the option of analysing the logistic centre is especially important at the present time, due to the logistic centres' high impact on the supply chains' functioning and to the relatively lacking analyses of the Polish service sector's logistic maturity (Werner-Lewandowska, 2020). Additionally, reverse logistics itself is a significant new element in increasing the resilience of supply chains to disruptions, which should lead to additional synergy effects with the same effect exerted by logistic centres.

The further research of the developed model should concentrate primarily on developing a set of good practices, which will be an element of the logistics centre's maturity model. Developing those, however, is a work far beyond the scope of the presented article.

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