

Article

Digital Maturity of Logistics Processes Assessed in the Areas of Technological Support for Performance Measurement, Employees, and Process Management

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Featured Application: Companies can implement the digital maturity assessment model to assess the digital maturity of their logistics processes. In turn, the results presented in the research can provide benchmarking data for companies that create digital transformation maps for their use.

Abstract: (1) Background: Industry 4.0 and the COVID-19 pandemic have resulted in an acceleration of digital transformation, primarily in production systems and logistics. This raises the need to assess where a company is in its digital transformation today and what measures must be taken to improve logistics processes. This article aims to present the results of a study assessing the digital maturity of logistics processes in a group of selected enterprises located in Poland. The research was conducted among companies that are business partners of the Poznań School of Logistics. (2) Methods: The DMM-OP digital process maturity assessment model was used in the study. Digital maturity was assessed on a five-point scale in four areas of company activity: process management, performance measurement, employee support, and technology. The research procedure included four stages. (3) Results: The results indicate that companies in the process management and performance measurement dimensions achieved the highest level of digital maturity. In commercial enterprises, the level of digital transformation is at the lowest level. Large enterprises achieved the best results, but there were also very good results in the group of small enterprises. (4) Conclusions: The results presented in the article can be used by industry and academia. The research was not statistical but can form the basis for benchmarking analyses.

Keywords: digital transformation; digital maturity model; process improvement; process audit



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1. Introduction

Digital transformation has been a phenomenon observed in industrial companies for many years to streamline business processes and support the operations of employees at different levels of the organization. Digital transformation, in its first implementation phase, was identified primarily with the transformation of documents available on paper to electronic versions [1]. However, current trends associated with digital transformation refer to the various sociological and technical changes accompanying the implementation of digital technologies in aspects of social life and industrial activity [2]. These changes are primarily based on developing information technologies that streamline the processes involved in collecting, processing, and distributing information from various sources so that decision-makers have access to comprehensive knowledge that facilitates their process planning and efficient use of resources [3].

Digital transformation is a critical trend for improving logistics processes and developing systems to support these processes. This is primarily due to the increasing popularity

of the Industry 4.0 concept and the demands placed on managing global supply chains. To achieve the expected effects of Industry 4.0 in manufacturing processes, it is also necessary to implement digital changes in logistical processes, which handle material flows in a company. Therefore, the digitalization and automation of manufacturing processes as part of implementing Industry 4.0 solutions necessitates the advancement of digital transformation, as well as logistics processes. Achieving ever-higher levels of digital maturity is also a result of participation in global supply chains and the need to obtain up-to-date information (ideally in real time) from cooperating counterparties to improve planning processes. Digital platforms are being developed for supply chain collaboration, bringing together knowledge from various sources and delivering it to partners through the results of multiple analyses that maximize the value of the established partnership [4]. At the same time, many authors emphasize in their research that digital transformation positively influences the integration of sustainable supply chains (e.g., [5,6]). Supply chain co-working creates particular needs for inter-organizational information exchange and data integration. Digitization enables vertical integration (from supply to consumer) and horizontal integration (with other business partners and competitors) to achieve end-to-end visibility [7]. Uninterrupted communication and a shared knowledge base increase trust between partners, fostering closer collaborative business relationships.

The COVID-19 pandemic has accelerated digital transformation processes in organizations in all areas by 3–4 years [8]. At the same time, the continuous development of IT technologies and Industry 4.0 solutions means that the potential to implement further improvements at the level of organizations and logistics processes is growing. Therefore, an important research issue is to assess the current level of digital maturity of logistics processes in companies and identify directions for further improvement. The aim of this article is to present the results of a study assessing the digital maturity of logistics processes in a group of selected enterprises located in Poland. The research was conducted among enterprises that are business partners of the Poznan School of Logistics. The main contributions of the presented results should be considered:

- Identification of the level of digital maturity of logistics processes in performance measurement and process support.
- Cross-analysis of the level of digital maturity of logistics processes, reflecting the diversified level of digital transformation in different types and sizes of companies.
- Identification of the leading areas of digital transformation in the audited companies and identification of the constraints they face related to the implemented Industry 4.0 solutions.
- Identification of the level of implementation of selected technological solutions in Polish enterprises.
- Identifying the leading groups of companies that achieve the highest share of implementation of advanced digital solutions in the area of logistics.

The structure of the article is presented in Figure 1.

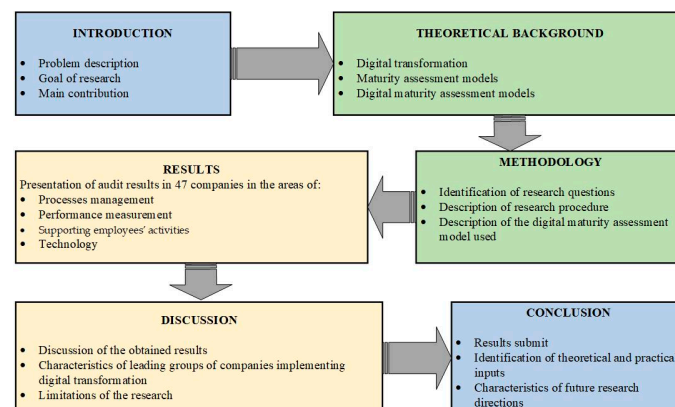


Figure 1. Structure of the article.

2. Theoretical Background

Through digital transformation, researchers typically understand companies' use of digital technologies to create new or modify existing processes and business models and to support changes in organizational structures, resource development, or linkages with internal and external process participants and stakeholders [9,10]. As noted in the Introduction, the digital transformation in industry has been evolving for many years and is taking on more developed forms as technology advances. Therefore, three trends of change related to digital transformation in organizations are currently distinguished in the literature. These trends are shown in Figure 2.

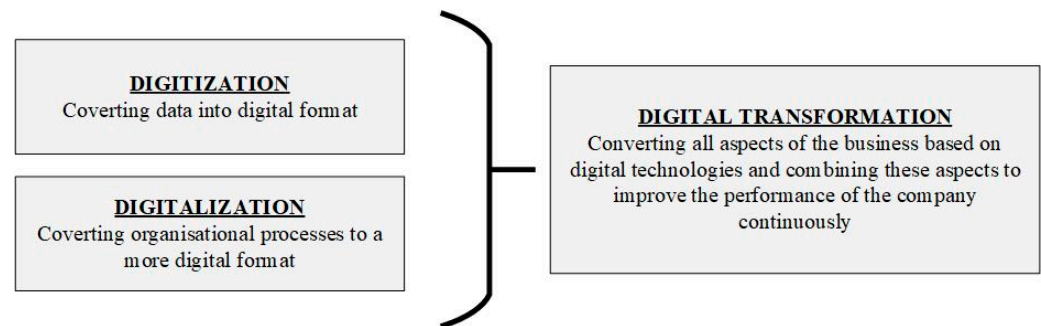


Figure 2. Digital terms (based on [11]).

Figure 2 indicates that digital transformation cannot be equated solely with equipping employees with IT-based tools. Indeed, its implementation in a company implies fundamental changes in the entire organization, encompassing strategy, organizational culture, and process execution in socio-technical systems [12]. Therefore, digital transformation is now recognized as an interdisciplinary field of research, including IT, entrepreneurship, strategic and operations management, organization science, personnel management, and many others [13].

Digital transformation affects almost all areas of modern organizations, including production, logistics, sales, organizational hierarchy, relationships with partners, suppliers, and customers [14–16]. Through the implemented internal transformations in the organization and in the relationships with the environment, it is possible to achieve the expected effect of digitalization in the form of improved performance of the entire enterprise [17]. However, to ensure a sustainable competitive advantage and continuous company development, the implemented digital transformation must have a multidisciplinary dimension and concern various enterprise levels [18,19]. For this reason, many researchers and consultancies are developing digital maturity assessment models that enable companies to assess the level of digital maturity in different areas of their business and to set directions for further development.

Maturity assessment models (MAMs) are a tool for analyzing the level of maturity status achieved concerning a selected development process [20]. Their primary purpose is to assess the maturity status of a specific factor regarding a specific domain of interest based on a set of criteria in a comprehensive manner [21]. However, assessing the current level of fulfillment of the requirements of a specific maturity level is one of many areas of application of MAMs. The models also enable [22,23]:

- Measurement for audit and benchmarking purposes.
- Supporting transformation processes based on the guidelines of successive maturity levels—measuring progress between current and target levels.
- Benchmarking and positioning the company in the market served.
- Understanding the strengths and weaknesses of the enterprise and the opportunities arising from a given development trend.

Several maturity models are currently described in the literature and business, which relate to different business areas and management levels. Characteristic features of the

MAM are the dimensions and maturity levels, which provide the framework for the assessment procedure. The rules and modes of assessment adopted are also important. The characteristics describing most MAMs presented in research and industry are shown in Figure 3.

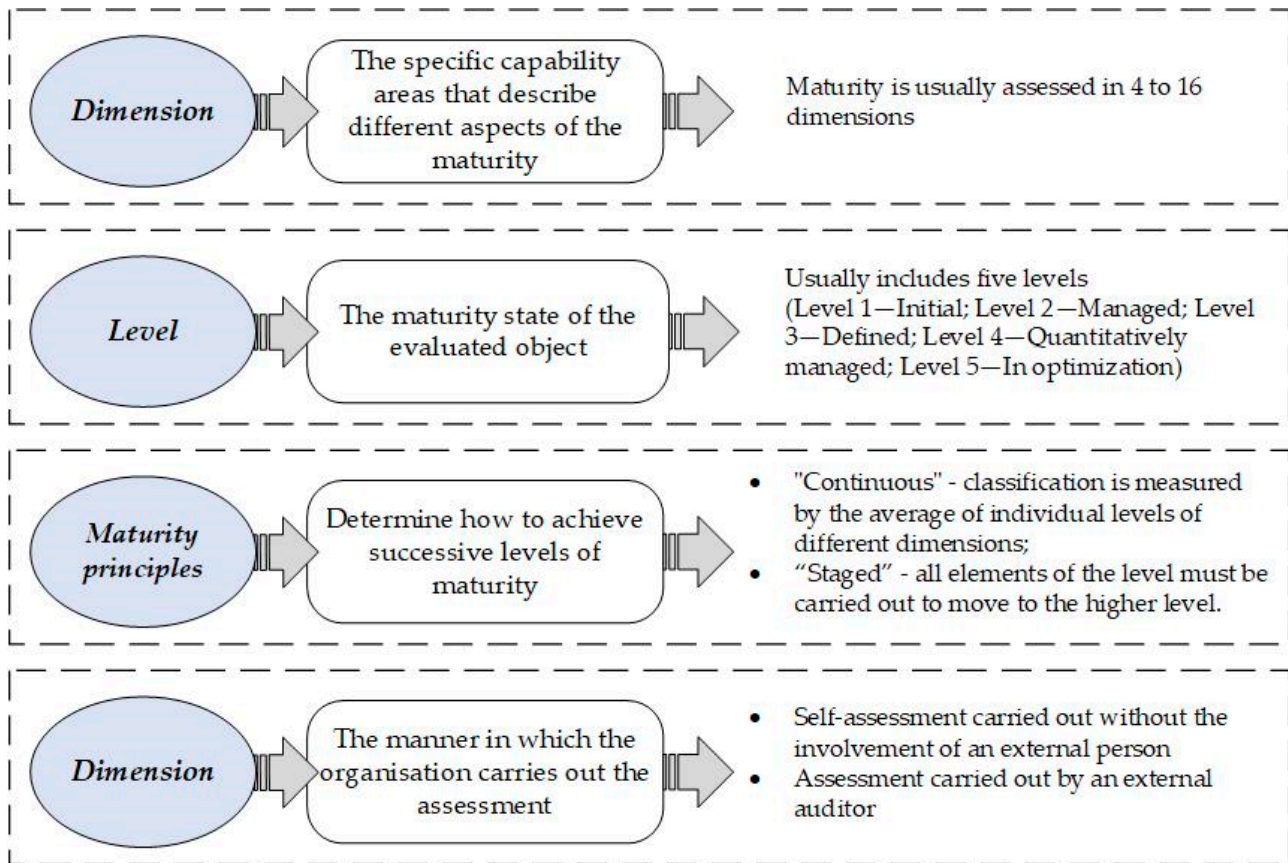


Figure 3. Characteristics of the maturity assessment model (based on [24–26]).

The growing importance of digital transformation has generated demand for developing digital maturity assessment models (DMMs) for businesses. Digital maturity models (DMMs) help companies determine where they stand in digital development. Numerous examples of such approaches can be found in the literature, which research teams, consultancies, and Market Research Companies create [27]. A critical analysis of many DMMs developed by academics and consultancies can be found in [25]. Most of the models described in the literature are holistic [24]. However, some authors present DMMs in which the area of maturity assessment is strictly defined, for example, assessing maturity knowledge-intensive business processes [28], big data usage [29], digital information systems [26], but also logistics 4.0 [30–32].

Research findings in [33] indicate that most DMMs are built on the same principles as traditional CMMIs (Capability Maturity Model Integrations). The assessment of digital maturity areas most commonly concerns [34] strategy, leadership, customers, products, operations, culture, people, governance, and technology. Digital maturity models are used to benchmark and position companies in the served market and to determine digital transformation paths in such a way as to move from the current state to the desired level of maturity [22,30]. However, it should be noted that the pace of digital transformation depends on the sector and the level of supply chain representation by the company. Research findings indicate that customer-oriented organizations operating in the B2C (business-to-customer) market are subject to a faster and stronger impact of digital transformation than an organization operating in the B2B (business-to-business) model [25]. Therefore,

this should be considered when conducting a digital maturity audit of each assessed organization.

3. Methodology

Many academic and industry publications and reports emphasize that Industry 4.0 and the COVID-19 pandemic have significantly accelerated digital transformation processes in many countries, sectors, and global supply chains. This is also confirmed by the authors' observations during their research projects and study visits to partner companies. However, in their research, the authors noticed, as did other researchers (e.g., [35]), that the primary attention of managers in modern organizations is focused primarily on digital transformation concerning production processes. Meanwhile, as noted in the introduction, to achieve the full benefits of the digital transformation being implemented, it is necessary to extend it not only to manufacturing processes but also to other operational processes, including logistics. For this reason, the authors of this article posed the following research questions:

- Q1: How does digital transformation support managing logistics processes in companies?
- Q2: How are companies using digital technologies in performance measurement of logistics processes?
- Q3: What tools do enterprises use to support logistics professionals in their operational activities?
- Q4: Which technological solutions are used in logistics systems, and to what extent?

For questions formulated in this way, the research's aim was defined, which is to determine the level of digital maturity of logistics processes in enterprises in Poland after the COVID-19 pandemic. A 4-step research procedure was adopted to achieve this aim. The procedure is presented in Figure 4.

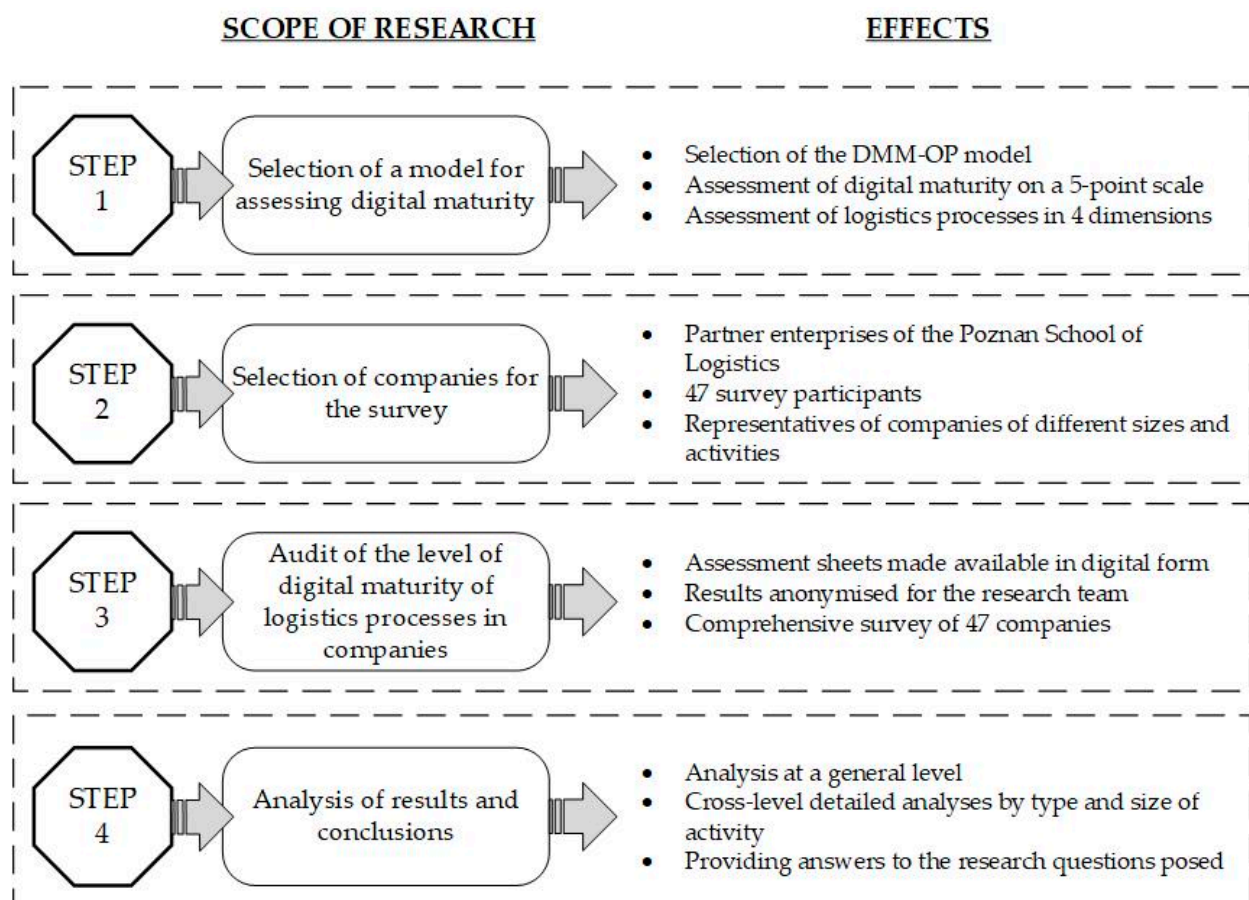


Figure 4. Research procedure.

The starting point for answering the underlying research questions was selecting a suitable digital maturity assessment model whose assessment areas relate to logistics processes. The DMM-OP model, developed by Tubis and described in [36], was used for the research. The model performs maturity assessment at two levels—organization and processes. At the organization level, three areas are assessed: Strategy, Corporate Culture, and Data. The assessment at the organization level refers to the central digital transformation covered by the entire enterprise and is expressed in the mandatory corporate culture and management strategy. At the process level, four areas are assessed: Processes, Business Partners, Employees, and Technology. The process level refers to the specific business area of the company and the digital transformation targeted at specific operational processes related to this area. The object of the analysis carried out in this article is to assess the level of digital transformation of the surveyed companies only in the area of the internal logistics system. For this reason, the results presented refer only to the selected three areas examined in the DMM-OP model: Processes, Employees, and Technology.

- **Processes**—This includes the creation of a framework for value-adding processes for the company and their organization. The level of digitalization, automation, and optimization of operations is assessed in relation to these processes. The analysis includes not only how processes are performed but also the systematization and automation of measurements. It is also essential to use the results of the measurements for analyses aimed at optimizing and proactively managing the implemented processes. Two sub-areas are distinguished in Processes: (1) performance management and (2) process management.
- **Employees**—Digital maturity assessment models focus primarily on developing an employee's digital competence. However, an equally critical issue is the resistance to change and the reluctance of people to work with machines, which can effectively block any action aimed at digitalization processes. Employees' attitudes are influenced by the perceived benefits of the support they receive in their ongoing operations provided by the digital solutions implemented. Therefore, the rationale and scope of the implementation and the potential benefits achieved by the employee using digital technologies in his/her daily duties will determine his/her acceptance of the implemented changes. In the Employees area, the DMM-OP model distinguishes three sub-areas: (1) support of employee activities by digital solutions, (2) employee attitudes, and (3) employee competence development.
- **Technology** is considered a critical area of digital transformation, focusing primarily on the technical infrastructure, including machine automation, information and communication systems, and network services integration. Due to the assessment of the level of automation and self-driving, many researchers have also included cyber-security management issues in their analyses. However, in the DMM-OP model, this area is restricted to infrastructure issues only.

In the case of the Employee area, the analysis only covered the supporting employees' activities level, as only system readiness was assessed. The analysis of the development of digital competencies and employee behavior will be the subject of further research by the authors, the results of which will be published in subsequent articles. The different areas are assessed on a 5-point scale, where level 1 is the baseline (very low level of digitization, lack of systemic, centrally controlled solutions). In contrast, level 5 is the peak stage of digital transformation (Leadership), where the company applies the latest technologies and good practices in digitization and automation of processes and knowledge management. The model assumes that the lowest level of 1 is the so-called base level, from which the enterprise starts its digital transformation. However, assigning a score of level 0 is also possible in exceptional cases. This will be the case if the assessed area is not supported by any ICT tool (no systemic use of even PCs) and the organization's employees report solid resistance to implementing digital transformation.

The second stage of the research procedure was the selection of companies to conduct the research. The research was not intended to be a statistical study depicting the global

level of digitalization of Polish enterprises in the post-pandemic period. Conducting such a study would have been very difficult because the research tool consists of 105 questions, so conducting a comprehensive audit requires a significant time commitment. A critical challenge in this case would be to obtain an adequate representation of companies to agree to take an active part in the survey. The research aimed to provide a fragmented diagnosis of the state of digital transformation in Polish companies and answer the underlying research questions. It was more important for the research team to ensure a high level of quality in the answers provided by the respondents than their statistical sectoral representation. For this reason, enterprises that are business partners of the Poznan School of Logistics were invited to participate in the research, which conducts different industrial activities; they belong to different enterprise groups and represent different sectors of the economy. A total of 47 enterprises took part in the study. The structure of the enterprises taking part in the study by type of activity and size is shown in Figures 5 and 6.

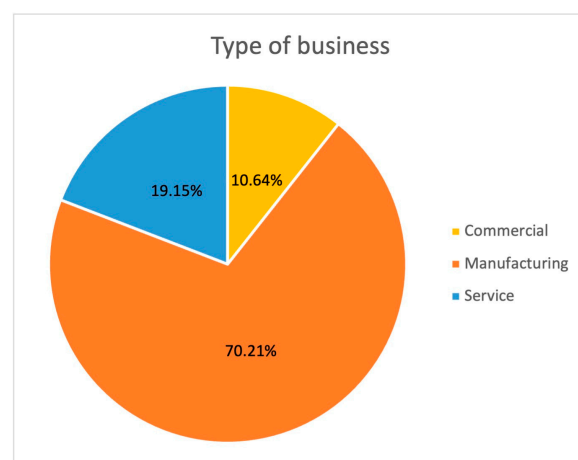


Figure 5. Percentage of different types of companies in audit work.

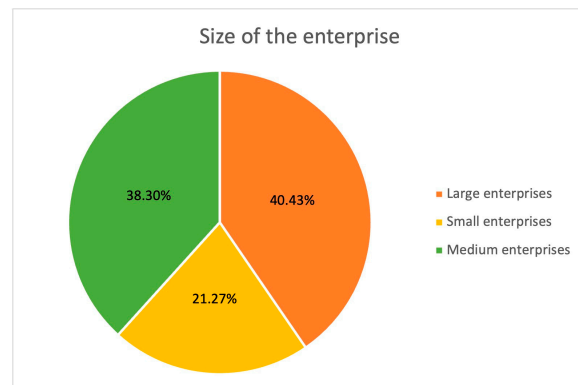


Figure 6. Percentage of companies of different business sizes.

Stage three concerned the implementation of an audit assessing the level of digital maturity of logistics processes in the surveyed companies. To ensure the required level of anonymity of the responses, a self-assessment sheet was used for the research, which was developed for the DMM-OP model and made available to respondents in an electronic survey version that does not record the address of the person responding. However, before respondents completed the self-assessment, they were allowed to speak directly with members of the research team, who explained the purpose of the survey, the terms used in the DMM-OP model, the recommended way of answering, and the interpretation of selected questions on the assessment sheet. Audit data were collected by the research team from January to May 2024. All evaluation forms were completed correctly and

comprehensively by the respondents so that all the results of the audit surveys could be accepted for analysis.

The fourth stage of the research work was the quantitative and qualitative analyses of the responses provided by the respondents, which were carried out at the overall level (considering the entire surveyed group of respondents) and in the individual groups of companies distinguished for the analyses. Percentages at the overall level were calculated for all survey participants (Formula (1)). At the same time, analyses for individual groups of enterprises were related to the size of the given set of enterprises (Formula (2)).

$$\% \text{ responses} = \frac{NoR}{NoC}, \quad (1)$$

where:

% responses—percentage of responses;

NoR—number of responses;

NoC—number of all companies surveyed.

$$\% \text{ responses} = \frac{GNoR}{GNoC} \quad (2)$$

where:

% responses—percentage of responses;

GNoR—number of responses provided by respondents from the distinguished enterprise group;

GNoC—number of respondents representing the enterprise group.

Section 4 presents selected results of the analyses carried out, the interpretation of which allows answers to the questions formulated in Section 3. Other results obtained in the audited organizations are the subject of further analyses, and the results obtained will be presented in subsequent publications.

4. Results

The research questions relate primarily to digitalizing internal logistics processes and focus on the digital transformation supporting the operational management process. Therefore, the audit of the level of digital maturity carried out in the surveyed companies referred to four areas related to the implementation of logistics processes: (a) process management, (b) performance management, (c) employee operational support, and (d) technology solutions used.

4.1. Process Management

The first stage of the digital transformation implemented in the process management dimension should be the documentation of processes and the execution of projects related to document management on digital solutions. The audit indicates that not all surveyed organizations achieve even this basic level of digital maturity; only 53.19% responded positively to the first questions (Figure 7). These are primarily large enterprises, among which only about 26% of enterprises do not apply digital support in the area under analysis. Notably, the lowest level of fulfillment of this condition concerns medium-sized enterprises. Even small enterprises in 50% of cases have digital solutions supporting process documentation management. The analysis of the answers provided according to the activity area indicates a similar level of fulfilment; a slightly lower level of digitalization of this sphere was recorded primarily in service companies, but the disproportions occurring are insignificant.

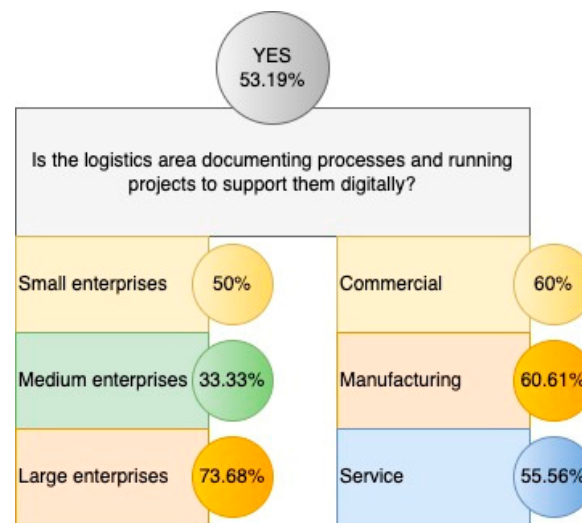


Figure 7. Percentage of positive responses to the question on digital support for document management processes.

An important step in the development of process management should be the digitalization of core and supporting processes. Digitalization of core processes constitutes an organization's first level of digital maturity, while digitization of supporting processes is a prerequisite for reaching the second level. This is due to the methodology of implementing digital solutions, which assumes that core processes should be digitalized first and supporting processes only afterwards. This is also confirmed by the results of the conducted audits—Figure 8. Core processes are digitalized in almost 64% of the analyzed companies, while only half have implemented digitalization at the level of supporting processes. What is noteworthy about the answers is that an average of 20% of the respondents answered, "I do not know". This signals to the auditors that digital transformation has not been embedded in the organizational culture of the surveyed company since people in managerial positions cannot answer such a question.

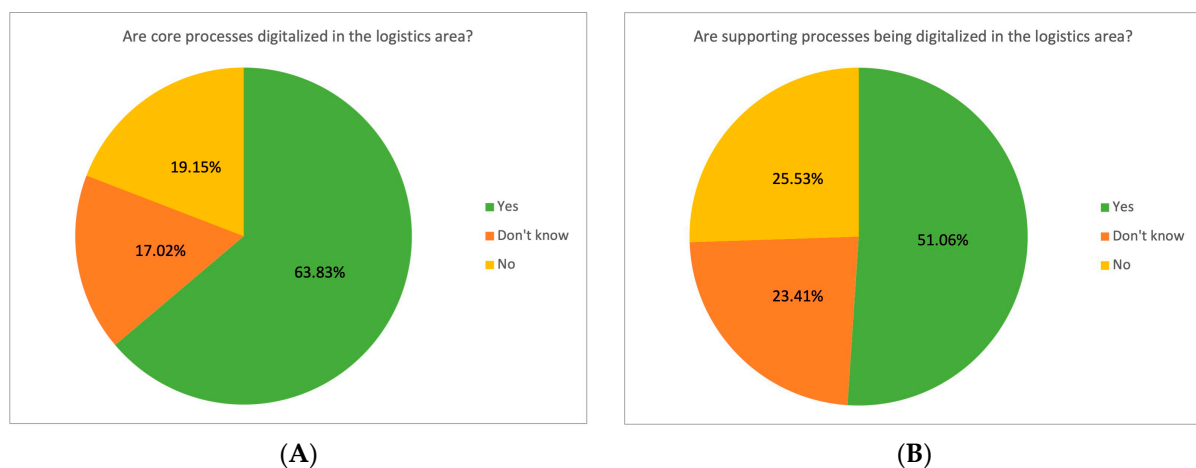


Figure 8. Digitalization of (A) core processes and (B) supporting processes.

The most comprehensive implementations concern large enterprises, where digitization of core and supporting processes is at the same level—see Figure 9. The most significant disparity in this area appears among small enterprises. As many as 70% of the surveyed enterprises have digitized their core processes, while only 40% have implemented digitization in supporting processes. Analyzing the answers, the research team noted that in the case of manufacturing and service enterprises, the digitization of core and

supporting processes is proceeding at a similar pace (with a difference of 10 percentage points). However, in the case of trading companies, the disparity in the areas analyzed is the most significant (40 percentage points).

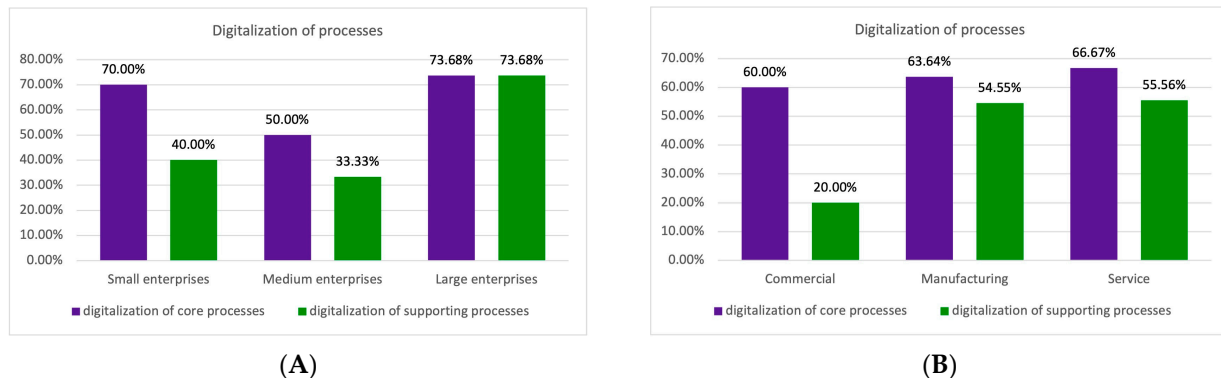


Figure 9. The digitalization of basic and supporting processes according to (A) organization size and (B) type of activity.

An enterprise reaches the next level of digital maturity if logistics process management is geared towards integration, digitalization, and automation. Implementing such solutions for internal processes means reaching the third level of digital maturity in the process management dimension. On the other hand, if the logistics processes, not only the internal ones but also those implemented at the interface with business partners, are digitalized, automated, and optimized, then the company has reached the fourth level of digital maturity. A comparison of the achievement of these two maturity levels in the distinguished groups of enterprises is presented in Figure 10.

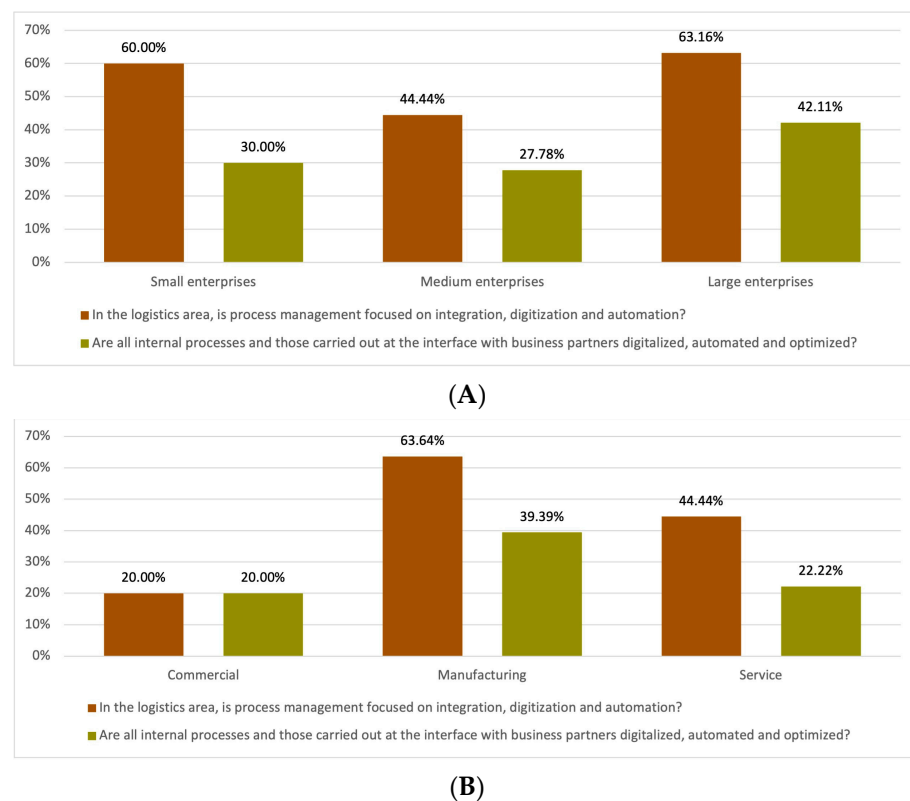


Figure 10. Percentage of companies reaching level three and four of digital maturity by (A) organization size (B) type of business conducted.

The analysis of the results obtained shows that the highest percentage of enterprises achieving the third and fourth levels of digital maturity still concerns large companies. Noteworthy, however, is the fact that small enterprises are still in second place, whose percentage of enterprises reaching the third level of maturity is only three percentage points lower. The worst performers in this set are medium-sized enterprises, among which less than 50 percent reach the next level of digital maturity, and the fourth level is only reached by around 28 percent of respondents.

The third level of digital maturity in the process management dimension is achieved primarily by manufacturing companies—almost 64% of respondents from this group of companies. The group of trading companies recorded the smallest share of respondents achieving both maturity levels. However, it is worth noting that in this group, the percentage of companies reaching both levels of digital maturity is balanced (there was no enterprise recorded whose development was behind at level 3).

The highest level of digital maturity is reached by enterprises implementing best process management practices in their logistics service, including interdepartmental and interdisciplinary collaboration and integrating external stakeholders. The share of such organizations in the surveyed groups of enterprises is shown in Figure 11. Notably, the highest rate of reaching the fifth level of maturity was recorded for small enterprises. A comparison of the responses given to the last two levels indicates that small enterprises that have reached maturity level 4 understand the importance of digital transformation in the process management dimension and are, therefore, taking steps to implement best practices in this area. The smallest percentage was found in the group of medium-sized enterprises. Only around 17% of the companies in this group reached level 5 of digital development in the analyzed dimension. The analysis of the degree of achievement of the highest level of maturity by type of business conducted by the respondents shows significant similarity. In all groups of audited enterprises, the share of companies reaching level 5 of maturity was around 20–25%.

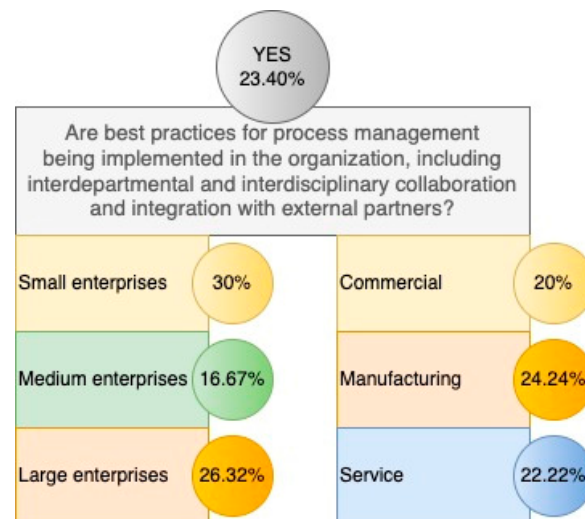


Figure 11. Percentage of companies reaching level 5 of digital maturity in the area of process management.

A summary of the maturity levels in the distinguished groups of enterprises is presented in Tables 1 and 2. A noteworthy phenomenon observed in the group of small and medium-sized enterprises is that a higher percentage of enterprises reached level 3 of digital maturity than level 2. An analysis of the other answers given by this group of respondents indicates that some enterprises are implementing integration, digitalization, and automation, but only concerning core processes. Supporting processes are still implemented in a traditional way and represent the potential for further improvement. However, it is worth pointing out that this phenomenon primarily concerns manufacturing companies.

Table 1. Percentage of companies reaching particular levels of digital maturity in the process management area by company size.

	Small Enterprise	Medium Enterprise	Large Enterprise
Level 1—Basic	70.00%	50.00%	73.68%
Level 2—Discovery	40.00%	33.33%	73.98%
Level 3—Developed	60.00%	44.44%	63.16%
Level 4—Integrated	30.00%	27.78%	42.11%
Level 5—Leadership	30.00%	16.67%	26.32%

Table 2. Percentage of companies achieving particular levels of digital maturity in the area of process management by type of activity.

	Commercial	Manufacturing	Service
Level 1—Basic	60.00%	63.64%	66.67%
Level 2—Discovery	20.00%	54.55%	55.56%
Level 3—Developed	20.00%	63.64%	44.44%
Level 4—Integrated	20.00%	39.39%	22.22%
Level 5—Leadership	20.00%	24.24%	22.22%

4.2. Performance Management

In publications on digital transformation in logistics processes, many authors emphasize its significant impact on performance management processes. By having access to data from various sources, integrated in Big Data, companies are better able to monitor the results obtained and analyze them for better process management. Therefore, the second area of maturity assessment in the process area is to determine the level of digitalization of performance management operations.

The first level of maturity in the performance management area concerns the implementation of measurement systems in the company, which are based on defined procedures and indicators. Defined measurement systems form the basis for performance monitoring and logistics process management. If the performance analysis of logistics processes is measured in a systematic manner and, in addition, this measurement is supported by digital tools, it is possible to speak of a company reaching the second level of digital maturity in the analyzed area. The percentage of companies that have reached levels 1 and 2 in the analyzed dimension in the surveyed groups of companies is shown in Tables 3 and 4.

Table 3. Percentages of companies achieving levels 1 and 2 of digital maturity in the area of performance management by company size.

	Response “YES” (Total)	Small Enterprise	Medium Enterprise	Large Enterprise
Does the enterprise measure process performance based on defined procedures, indicators and targets in the logistics area?	66%	60.00%	55.56%	78.95%
Does the company use digital technologies to measure process performance in the logistics area?	51%	50.00%	27.78%	73.68%

Table 4. Percentages of companies reaching levels 1 and 2 of digital maturity in the area of performance management by business type.

	Response “YES” (Total)	Commercial	Manufacturing	Service
Does the enterprise measure process performance based on defined procedures, indicators and targets in the logistics area?	66%	60.00%	63.64%	66.67%
Does the company use digital technologies to measure process performance in the logistics area?	51%	60.00%	54.55%	33.33%

The largest share of enterprises reaching levels 1 and 2 of digital maturity is, of course, for large organizations, among which more than 70% reach both of the first levels of development. The greatest disparity is found in the case of medium-sized enterprises, among which only around 50% of respondents who have achieved maturity level 1 report having also achieved level 2. This is also the group of enterprises that has the lowest percentage of organizations that have achieved both level 1 and level 2 digital maturity in the area of performance management. When analyzing the results obtained by type of business, it can be seen that the proportion of organizations achieving level 1 and level 2 digital maturity in the performance management area is comparable for manufacturing and trading companies. The greatest variation is found in the case of service companies, among which only half of the organizations at baseline also reach maturity level 2.

The next level of maturity is reached by a company when digital solutions are implemented to measure the performance of logistics processes automatically, and the analytical solutions used enable proactive process management. Figure 12 shows the share of companies reaching the third level of digital maturity in the area of performance measurement by distinguished groups of companies.

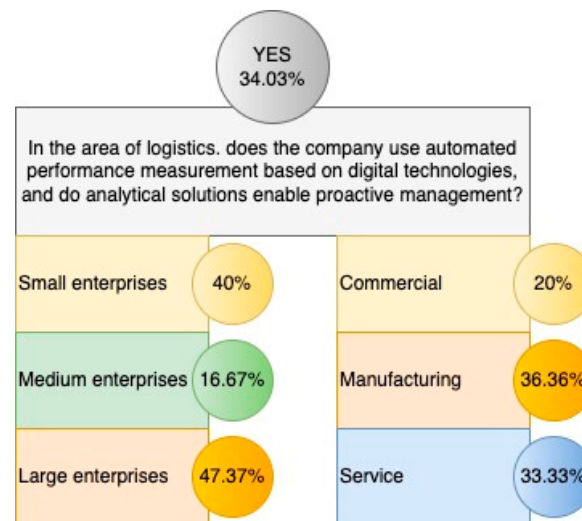


Figure 12. Percentages of companies reaching level 3 of digital maturity in performance measurement dimension.

The results show that only around 34% of the companies surveyed achieve the third level of digital maturity. This result is underestimated primarily by respondents representing medium-sized companies. Only about 17% meet the requirements of level 3 of digital transformation for the analyzed dimension. Large and small organizations at this level of maturity account for around 40–50% of the companies in their group. When broken down by type of business, the level of the different groups of enterprises is more convergent. More than 30% of manufacturing and service enterprises reach the third level of maturity. The lowest rate is characterized by commercial enterprises, among which this level is reached by the same respondents who have reached level 3 in digitalization of process management.

An interesting phenomenon occurred for the following two levels of digital maturity assessment. Level 4 refers to companies that use real-time data from various sources to measure process performance. Level 5 maturity, on the other hand, refers to companies that implement best practices for digitalization and automation of the organization's process performance management but also optimize performance measurement based on digital technologies and data from business partners. When asked about implementing best practices in organizational process performance management, around 36% of respondents responded positively—Figure 13. This is a higher percentage than the companies whose answers indicated that they had reached digital maturity level 3. However, analyzing their

responses concerning meeting the conditions for achieving levels 4 and 5 of digital maturity indicates that many enterprises do not meet the expected requirements. This relationship is shown in Figure 14. This phenomenon is primarily the case for large manufacturing companies. In this case, it can be concluded that these enterprises are focused on continuous development and digital transformation in performance measurement but have not yet reached the desired level of maturity.

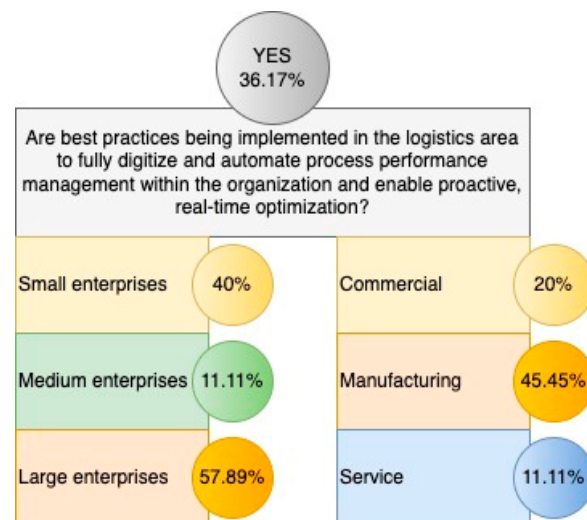


Figure 13. Percentages of companies responding positively to the question on the implementation of best practices related to the digitalization of performance measurement in logistics processes.

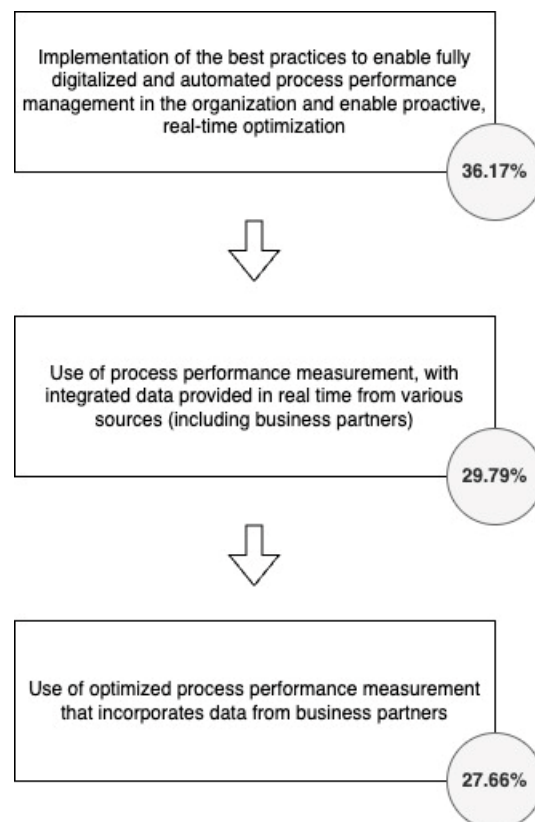


Figure 14. Discrepancies in responses regarding meeting the conditions for achieving levels 4 and 5 of digital maturity in the performance measurement dimension.

Tables 5 and 6 show the percentages of companies achieving levels 4 and 5 of digital maturity. The breakdown shows the discrepancies related to the uneven digital development in medium-sized commercial enterprises. The selected representatives of this group are more likely to focus on optimizing performance measurement based on business partner data rather than integrating real-time data from different sources. It is also worth noting that most large companies, primarily manufacturers, comparably achieve the maturity levels shown in Tables 5 and 6. In contrast, there is a discrepancy of 20 percentage points between levels 4 and 5 for small enterprises.

Table 5. Percentage shares of companies reaching levels 4 and 5 of digital maturity in performance measurement dimension by company size.

	Response “YES” (Total)	Small Enterprise	Medium Enterprise	Large Enterprise
Does the company use process performance measurement with integrated data provided in real-time from various sources (including business partners) in the area of logistics?	29.79%	50.00%	11.11%	36.84%
Does the company use optimized process performance measurement that incorporates data from business partners in the area of logistics?	27.66%	30.00%	22.22%	31.58%

Table 6. Percentage shares of companies reaching levels 4 and 5 of digital maturity in performance measurement dimension by type of activity.

	Response “YES” (Total)	Commercial	Manufacturing	Service
Does the company use process performance measurement with integrated data provided in real-time from various sources (including business partners) in the area of logistics?	29.79%	20.00%	30.30%	33.33%
Does the company use optimized process performance measurement that incorporates data from business partners in the area of logistics?	27.66%	40.00%	27.27%	22.22%

A summary of the maturity levels in the distinguished groups of enterprises in performance measurement is presented in Tables 7 and 8. Due to the above-described phenomenon of the inconsistency of achieving successive maturity levels, the percentage for level 5 was adopted based on the identified implementation of solutions optimizing the performance measurement process based on business partners’ data and not on implemented good practices. The analysis of the results obtained indicates the occurrence of commercial enterprises that arbitrarily implement digital performance measurement solutions. There is no standard order of implementation, which means that the highest level of maturity was reported by as many as 40% of respondents from this group, while only 20% reached levels 3 and 4. It should also be noted that while the first two maturity levels are reached by more than 70% of large enterprises, their share at levels 3–5 is already comparable to that of small enterprises. The most significant differentiation was observed in the group of service enterprises, in which about 67% reached the baseline level, while only half (33.33%) reached level 2.

Table 7. Percentage shares of companies reaching particular levels of digital maturity in performance measurement dimension, broken down by company size.

	Small Enterprise	Medium Enterprise	Large Enterprise
Level 1—Basic	60.00%	55.56%	78.95%
Level 2—Discovery	50.00%	27.78%	73.68%
Level 3—Developed	40.00%	16.67%	47.37%
Level 4—Integrated	50.00%	11.11%	36.84%
Level 5—Leadership	30.00%	22.22%	31.58%

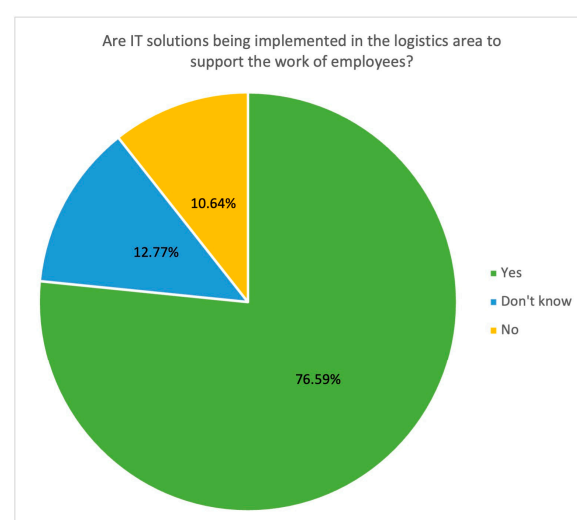
Table 8. Percentage shares of companies reaching particular levels of digital maturity in performance measurement dimension, broken down by type of activity.

	Commercial	Manufacturing	Service
Level 1—Basic	60.00%	63.64%	66.67%
Level 2—Discovery	60.00%	54.55%	33.33%
Level 3—Developed	20.00%	36.36%	33.33%
Level 4—Integrated	20.00%	30.30%	33.33%
Level 5—Leadership	40.00%	27.27%	22.22%

4.3. Supporting Employees' Activities

Industry 4.0 and related digital solutions are being implemented to improve the efficiency and agility of logistics process execution. Therefore, an important area of digital transformation is using IC technology and automation to support the operational activities of employees. Therefore, the third dimension of the audit is the extent to which digital transformation supports employee operations.

The first question referred to the general use of IT solutions by employees in the logistics area. More than 76% of the companies surveyed declared that they equip logistics employees with IT tools, as seen in Figure 15. However, it is worth noting that more than 10% of companies do not even achieve this basic level of digital support for employees involved in logistics processes. An in-depth analysis of the responses indicates that this group is primarily made up of small enterprises, but concerning manufacturing companies, this indication also occurred among medium-sized organizations.

**Figure 15.** Respondents' responses regarding the support of logistics employees by IT solutions.

The basic level of digital support for employees is to equip them with simple digital solutions such as a digital assistant and other mobile devices. Further defined maturity levels refer to the implementation of specific Industry 4.0 solutions like systems to support

the operational work of logistics employees. For level 2, digital maturity is assigned to virtual/augmented reality tools in the day-to-day support of logistics staff operations, while the implementation of autonomous and automated solutions such as UAVs and AGVs appears at level 3. Implementing digital twins and autonomous solutions that support the provision of goal-oriented information to operational staff and support the development of organizational intelligence (the collective ability of an enterprise to collect, process and act on big data) means that the assessed entity has reached level 4 of digital maturity. The percentage of surveyed enterprises that have reached successive levels of digital maturity is shown in Figure 16.

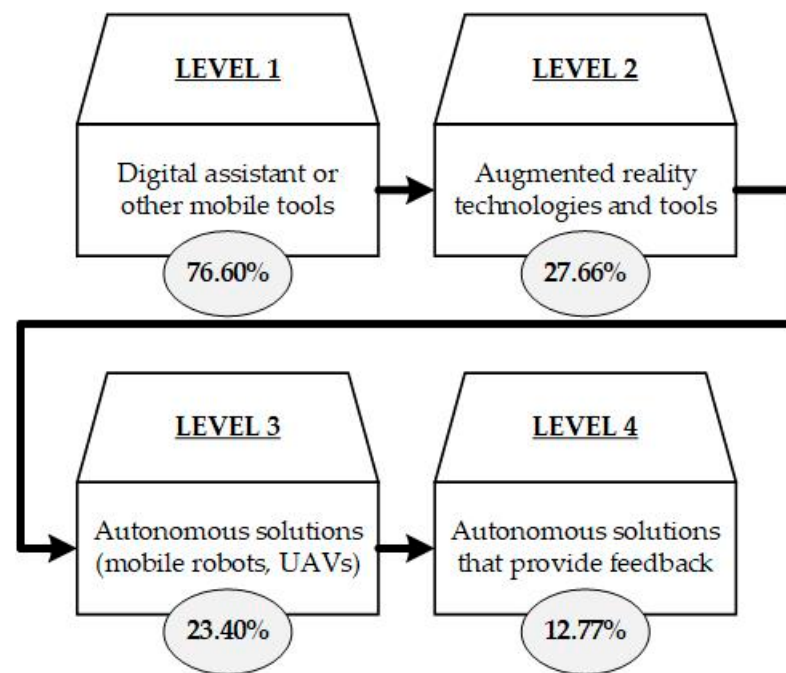


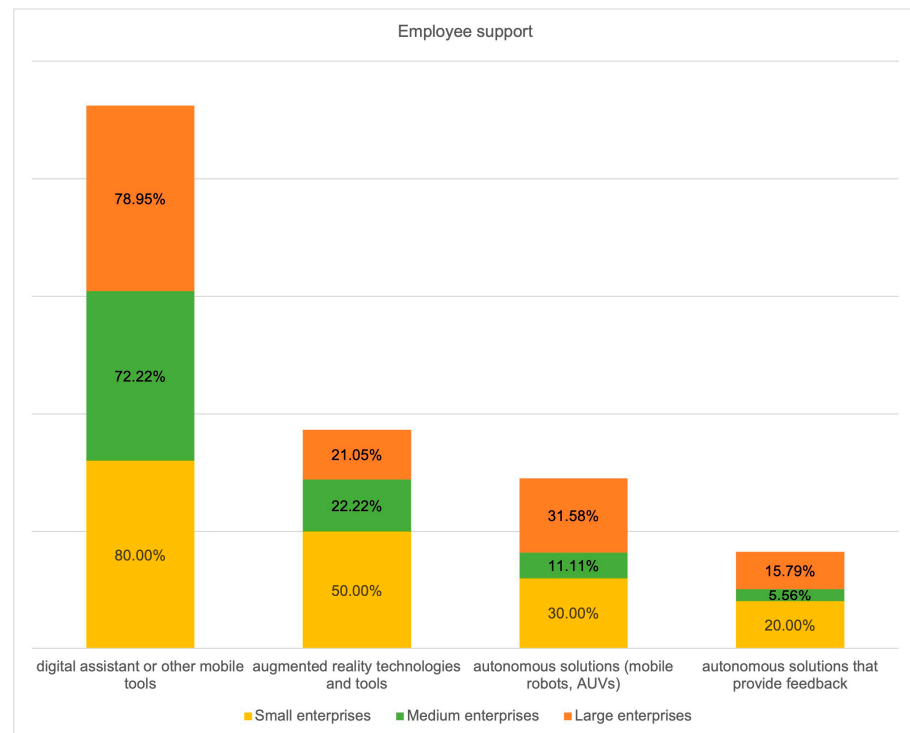
Figure 16. Percentage share of surveyed enterprises that have reached the defined levels of digital maturity in the dimension of support for logistics staff activities.

Figure 17 shows the percentage of enterprises in each of the distinguished groups that have implemented particular solutions to support the operational activities of logistics staff. An analysis of the results for each group of enterprises shows that augmented reality tools are more popular in small enterprises than in the other two groups. It is also worth noting that more large enterprises use automated and autonomous vehicle systems than augmented reality-based tools. Few enterprises are implementing autonomous solutions that provide them with feedback to support the development of organizational intelligence. However, it is noteworthy that the highest percentage of enterprises that have achieved maturity level 4 is found in the group of small enterprises.

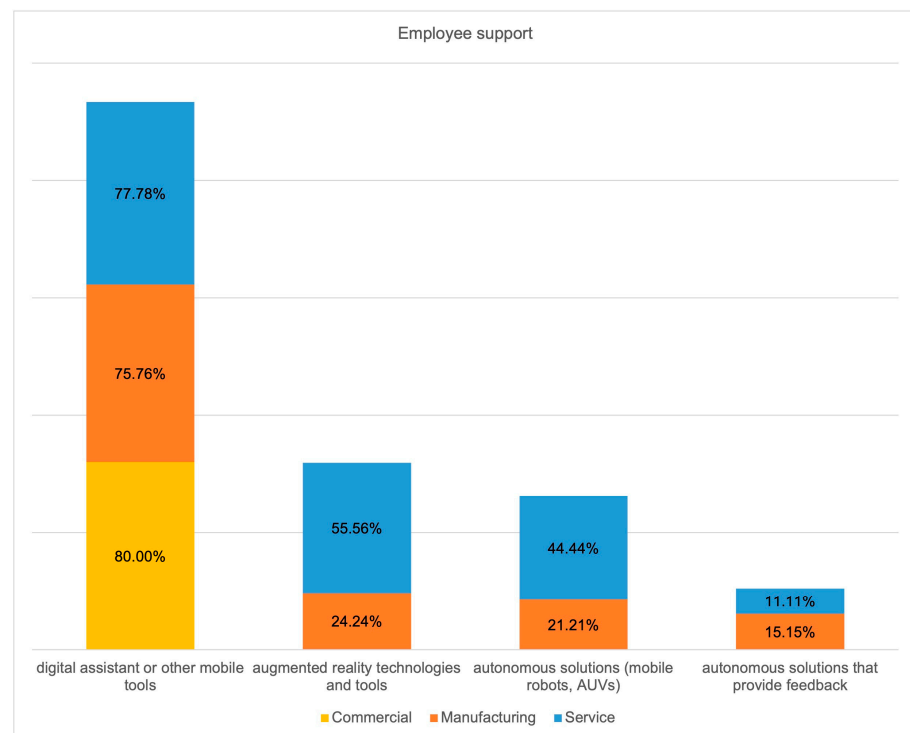
One notable result is that commercial enterprises only achieve the baseline level of digital maturity and do not invest in other solutions to support logistics staff, only in digital assistants or mobile tools. However, it is noteworthy that this level was reached by 80% of the surveyed retail companies. It should also be noted that Industry 4.0 solutions supporting logistics employees in their daily activities are implemented more often by service companies than by manufacturers. Levels 2 and 3 of digital maturity were reached by around 50% of service companies and just over 20% of manufacturers.

As in the previous dimensions, the last level of organizational development is the implementation of best practices, whereby employees are supported by the latest technological developments that optimize and automate the activities they perform and analytical tools that make full use of the organization's intelligence. Only 4.26% of the audited companies implement best practices in this area. An analysis of the results presented in Figure 18

shows that only manufacturers achieve the highest level of digital maturity. It is also worth noting that, despite the highest share of implementations for levels 2–3, none of the audited small enterprises have reached level 5 of digital maturity.



(A)



(B)

Figure 17. Percentage share of companies using the indicated Industry 4.0 tools to support the operational activities of logistics employees by (A) organization size and (B) type of business.

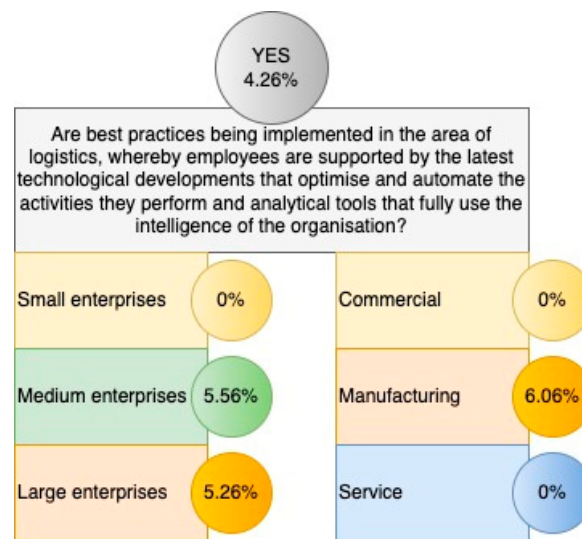


Figure 18. Percentages of enterprises achieving the highest level of digital maturity in supporting logistics employees' activities.

A summary of the maturity levels in the dimension of support of employee activities in the distinguished groups of enterprises is presented in Tables 9 and 10. The analysis of the obtained results shows that this maturity area is the least developed in the surveyed enterprises. First of all, it should be pointed out that commercial enterprises only reach the first level of digital maturity. This means that these organizations are not investing in developing the more advanced tools of Industry 4.0. It is also worth noting that large and medium-sized enterprises record a huge jump between the first and second levels of digital maturity. This may mean that moving beyond traditional IC technologies is a significant challenge for these companies. The process is more even in small companies, but the scale of the invested resources is also much smaller due to the number of employees. At the same time, none of the audited small enterprises have reached the fifth level of digital maturity.

Table 9. Percentages of companies reaching each level of digital maturity in the area of support for employee activities by company size.

	Small Enterprise	Medium Enterprise	Large Enterprise
Level 1—Basic	80.00%	72.22%	78.95%
Level 2—Discovery	50.00%	22.22%	21.05%
Level 3—Developed	30.00%	11.11%	31.58%
Level 4—Integrated	20.00%	5.56%	15.79%
Level 5—Leadership	0.00%	5.56%	5.26%

Table 10. Percentages of companies reaching each level of digital maturity in the area of support for employee activities by company size.

	Commercial	Manufacturing	Service
Level 1—Basic	80.00%	75.76%	77.78%
Level 2—Discovery	0.00%	24.24%	55.56%
Level 3—Developed	0.00%	21.21%	44.44%
Level 4—Integrated	0.00%	15.15%	11.11%
Level 5—Leadership	0.00%	6.06%	0.00%

4.4. Technology

Digital transformation is all about harnessing the potential offered to organizations by the ongoing development of technology. Therefore, the last area audited is the technological solutions companies implement in logistics. The simplest form of digital transformation implemented uses ICT for vertical and horizontal integration along the internal value chain. This means applying the support of IT tools to improve the integration of information flows within the organization and improving communication between employees through mobile devices. According to the results in Figure 19, almost 83% of the surveyed companies achieve the baseline level of digital maturity defined in the Technology dimension. An in-depth analysis shows that this is up to almost 90% of respondents among large enterprises, with the remaining 10% answering, ‘Do not know’.

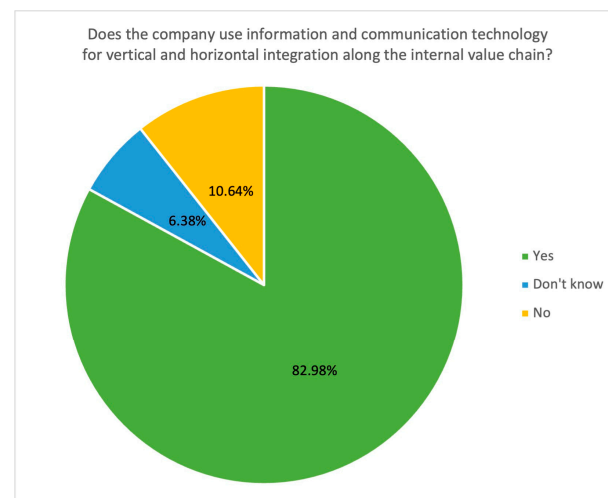


Figure 19. Share of enterprises using IT for vertical and horizontal integration.

The different levels of digital maturity are associated with using specific Industry 4.0 solutions. Figure 20 shows the technologies analyzed and their assignment to the corresponding level of digital maturity assessed. Mobile devices assigned to level 1 of digital maturity in the analyzed area are the most common solutions audited companies use. They are used by more than 68% of audited enterprises to improve communication. The second level of digital transformation is the deployment of cloud-based solutions for storing and sharing knowledge within the organization and sensor systems to monitor the operation of devices and the execution of logistics processes. As shown in Figure 20, cloud computing solutions are gaining more popularity than sensor systems. Therefore, around 28% of the audited companies meet the requirements of the second level completely, while around 25% meet them only partially. The third level of digital maturity is characterized by using solutions based on the Internet of Things to connect and exchange data between devices and systems. This level was reached by more than 25% of the organizations surveyed. Companies reaching level 4 of digital maturity are expected to use autonomous devices in logistics processes and solutions using artificial intelligence to optimize planning processes. On the other hand, for level 5, a machine-to-machine collaboration system should be implemented, which allows devices to communicate without human intervention when performing autonomous activities. However, the results obtained from the study indicate that more companies reach maturity level 5 by implementing solutions based on autonomous machine-to-machine collaboration than fully reach level 4 related to the use of artificial intelligence.

A detailed analysis of the share of different groups of companies with selected Industry 4.0 solutions implemented is shown in Figure 21. The two most popular technologies—mobile devices and cloud computing—are implemented proportionally across the distinguished groups of enterprises. There is some deviation in commercial enterprises’ use of

cloud computing technologies. Only 20% of these enterprises use this solution, while more than 50% of service and manufacturing enterprises declare their use in logistics processes. Trading companies also do not use the other five technologies, so their digital maturity currently reaches a maximum of level 2, and this is an incomplete achievement (no use of sensors is indicated as a level 2 digital maturity technology). It is also worth noting that companies implementing autonomous devices also consider it reasonable to implement machine-to-machine collaboration systems, which allow devices to communicate without human intervention (for both questions, positive answers were given by the same companies—percentage share agreement).

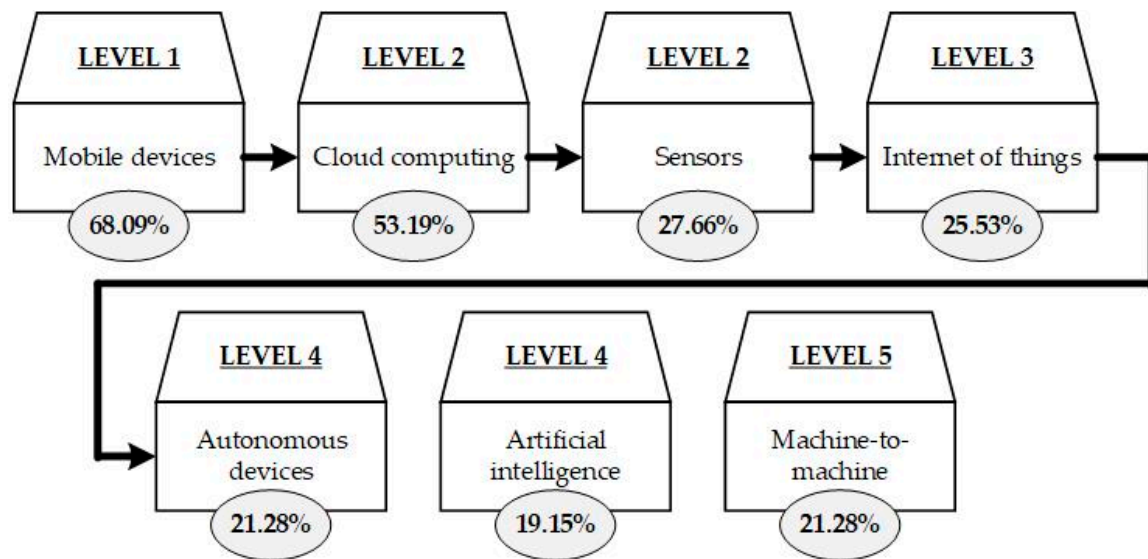
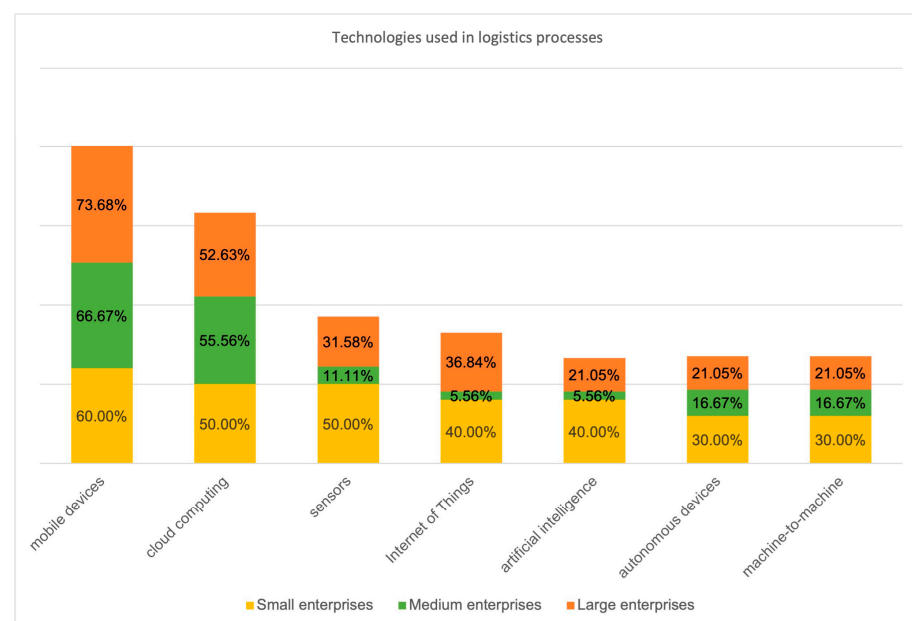
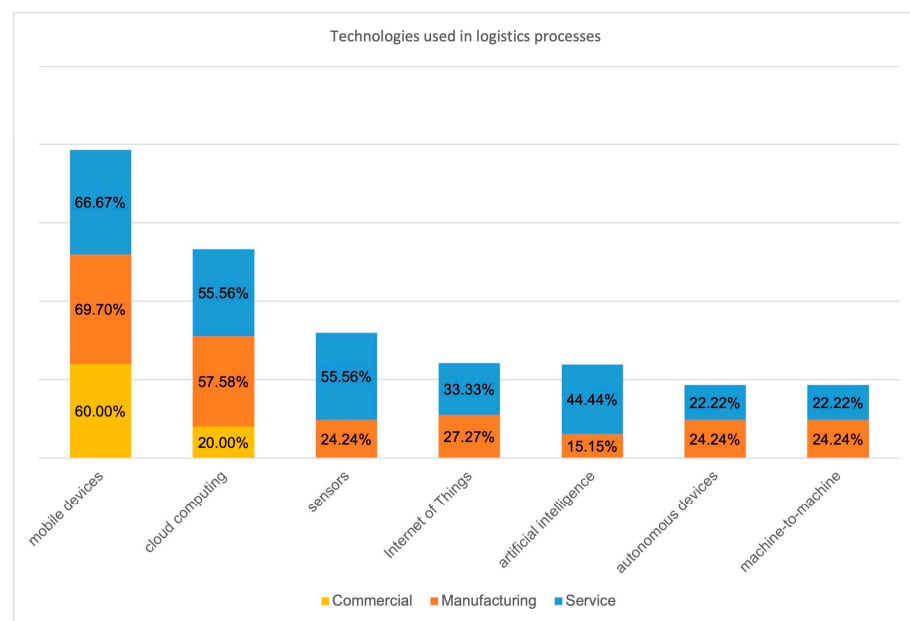


Figure 20. Percentage of companies adopting the technologies analyzed, together with their assignment to successive levels of digital maturity.



(A)

Figure 21. Cont.



(B)

Figure 21. Percentage share of companies using the analyzed technologies by (A) organization size and (B) type of business.

A summary of the maturity levels in the distinguished groups of enterprises in the Technology area is presented in Tables 11 and 12. Due to the partial fulfillment of the requirements of levels 2 and 4, in indicating the percentage shares of enterprises achieving both levels, the values for those that fulfill them at least partially were adopted. Notably, small and large enterprises take on the challenges of digital transformation evenly—the differences in the shares of enterprises reaching levels 3, 4, and 5 of digital maturity are insignificant. Therefore, it can be assumed that with the implementation of more Industry 4.0 solutions, their use is becoming a natural need for businesses. In the case of medium-sized enterprises, there is a clear jump between level 2 and level 3. It should also be noted that commercial enterprises do not reach a higher level of digital maturity than level 2, which they only partially meet (no use of sensors in logistics processes). This is the second dimension that indicates the audited trading companies' low level of digital maturity.

Table 11. Percentages of companies achieving each level of digital maturity in the Technology dimension by company size.

	Small Enterprise	Medium Enterprise	Large Enterprise
Level 1—Basic	60.00%	66.67%	73.68%
Level 2—Discovery	50.00%	55.56%	52.63%
Level 3—Developed	40.00%	5.56%	36.84%
Level 4—Integrated	40.00%	5.56%	21.05%
Level 5—Leadership	30.00%	16.67%	21.05%

Table 12. Percentages of companies achieving each level of digital maturity in the Technology dimension by type of activity.

	Commercial	Manufacturing	Service
Level 1—Basic	60.00%	69.70%	66.67%
Level 2—Discovery	20.00%	57.58%	55.56%
Level 3—Developed	0.00%	27.27%	33.33%
Level 4—Integrated	0.00%	15.15%	44.44%
Level 5—Leadership	0.00%	24.24%	22.22%

5. Discussion

The research conducted among the selected enterprises made it possible to visualize the levels of digital maturity of the logistics processes implemented in different groups of enterprises. Although the measurements carried out were not statistical, and they aimed to audit different types of enterprises using the developed DMM-OP model, the results obtained are, in many cases, in line with previous studies by the authors [37] and other researchers (e.g., [27]). Large companies mainly achieve the highest levels of digital transformation in the studied dimensions and are most often manufacturers. However, it was a big surprise that small companies performed equally well in most assessed dimensions. For areas such as ‘Support of employee activities’ or ‘Technology’, small companies had a higher proportion at maturity levels 3 and 4 than large organizations. This may be due to the greater flexibility of operation and openness to new solutions of small enterprises, but also to lower global investment costs (small scale of implementation) and greater availability of EU funding for innovation (numerous competitions directed mainly at small enterprises—a higher level of funding). It should be noted that small enterprises in Poland can obtain up to 80% co-financing from EU funds for innovative projects (including, above all, those aimed at digital transformation). This makes these organizations more open to emerging technological trends and overcomes the problem of their own limited financial resources. The second reason for the results obtained in this group of companies is the respondents’ characteristics. The research involved enterprises cooperating with the Poznan School of Logistics. Thus, these organizations are focused on development and knowledge exchange and are open to emerging new technological trends. This is confirmed by their involvement in cooperation with research units in knowledge exchange and experience, as well as the implementation of joint research and development projects. Therefore, their digital maturity level may differ from that of the average small enterprise. Thanks to their cooperation with the university, these companies have a greater awareness of changing market trends and more excellent knowledge of innovations emerging in logistics. Above all, they can achieve maximum funding when obtaining external funding. The smallest share of respondents achieving higher maturity levels was recorded in the group of medium-sized enterprises. This may be due to a larger scale of required investments due to the size of the business (in comparison to small organizations) and, at the same time, smaller economies of scale than in large enterprises, which would allow for increased implementation efficiency and negotiate more favorable conditions with the supplier of new technologies.

The audit results show that trading companies are less committed to digital transformation. In the ‘Processes management’ and ‘Performance measurement’ dimensions, companies in this group recorded the lowest percentage of organizations achieving higher levels of digital maturity. In the ‘Technology’ group, the highest maturity level achieved by representatives of trading companies was two, and in the ‘Supporting employees’ activities’ area, these companies achieved the first level of digital maturity. These results are surprising, as many retail companies base their competitive advantage on excellently managed logistics processes. The digitalization of this area may be a critical issue in improving their operations. Therefore, the research team hypothesized that this group of companies’ lack of commitment to digital transformation may be due to their membership in the small business set. Indeed, the observations made by the team members indicate that the demand for digitalization and digitization is at a lower level in small commercial enterprises than in, for example, production companies. This is mainly due to the characteristics of these organizations, which are based on small teams of employees performing simple operations on a small site. However, an in-depth study of the responses received from respondents has shown that there are more medium-sized enterprises in this group than small ones. Therefore, it must be assumed that a low level of digital maturity characterized the representatives of the commercial enterprises taking part in the research. However, these results cannot be used as a basis for defining conclusions about the sector as a whole.

In the area of ‘Technology’, the greatest surprise was the low proportion of companies using sensor-based solutions. This technology is widely used for measuring and monitoring the execution of operations in logistics systems. Given the rate of companies achieving high levels of digital transformation in the ‘Performance Measurement’ area, one would have expected this technology to be used extensively by these organizations. Meanwhile, less than 28% of respondents declared the implementation of sensors in logistics processes. It should also be noted that in the area of “Supporting employees’ activities”, the most significant disparity was registered in the share of companies reaching the various levels of digital maturity. Between level one (76.60%) and level two (27.66%), there was a decrease of almost 50 percentage points in the share of companies reaching both levels. It can also be considered that this area of digital transformation is particularly critical for commercial enterprises that have only reached level one of maturity at most.

A critical limitation of the results presented is the lack of a statistical survey nature. As highlighted in Section 3, the survey instrument consists of 105 companies. This makes it challenging to obtain an adequate representation of individual groups of companies that would allow general conclusions to be drawn from the responses obtained. Therefore, the presented results can be analyzed in the context of an audit conducted in a selected group of companies rather than as phenomena specific to a particular type of company. However, the important conclusion is that the DMM-OP model can be used as a research tool to assess a set of organizations or as an audit questionnaire for companies wishing to determine their level of digital maturity. Some phenomena observed in the obtained results require further research and a description of why they occur in the surveyed companies. However, due to the required anonymity of the measurements, conducting additional analyses in interesting cases was impossible. This constitutes a limitation for the inference carried out by the authors, which has to be based only on top-down answers indicated by the respondents. However, this limitation does not exist in the case of audits carried out directly at the company, where the study participants can develop their conclusions based on additional discussion (knowledge exchange).

6. Conclusions

This article presents the results of audit research carried out in 47 companies in Poland, representing different sizes of enterprises conducting various types of activity in different sectors. The research aimed to assess the digital maturity of logistics processes implemented in the surveyed organizations based on the DMM-OP model presented in [36]. The research focused on four areas of managing and supporting internal logistics processes. Based on the results obtained, it is possible to identify those dimensions characterized by a high level of digital maturity in the surveyed companies, as well as those areas where digital transformation is only in the initial implementation stage.

The results obtained are essential source material for representatives of science. They show specific trends in enterprises in Poland, which can be a reference point for their research. Also, for industry representatives, the presented results will be a valuable source of information. They can form part of a benchmarking analysis to assess their own level of digital transformation. The results are a good point of reference in the benchmarking analysis, as they relate to the levels of transformation in growth-oriented enterprises, including through cooperation with universities. This fact highlighted in the Discussion is important from the point of view of the analytical inference carried out. At the same time, the maturity model levels described can be used by managers to assess the digital transformation process in their logistics processes. The results obtained, as well as the guidelines of the subsequent maturity levels, make it possible to determine the potential for further development of enterprises. Of course, the implication in the company’s operations must be supported by analyzing the organization’s potential and needs. The results of the interviews with managers indicate that not all digital technologies are justifiable for implementation in their logistics processes. For this reason, the managerial implications of this study need to be further developed.

One of the critical areas of digital maturity turned out to be the ‘Supporting employees’ activities’ dimension. Therefore, in future research, the authors of this article will focus on assessing the level of digital competence of logistics employees and other aspects of digital transformation relating to the activities of logistics teams and their management.

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