
Digitalisation and Technological Development in the Transport and Warehousing Sector: A Comparative Analysis of the EU-27

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Abstract:

Purpose: The purpose of this study is to assess and compare the level of digital and technological development in the transport and warehousing sector across the EU Member States. The study focuses on cross-country differences in the adoption, development and use of selected digital technologies and solutions supporting the technological transformation of enterprises.

Design/Methodology/Approach: The study employs a multidimensional comparative approach based on Hellwig's pattern development method. Six diagnostic variables were selected to capture different aspects of digital and technological development in the transport and warehousing sector: the use of artificial intelligence technologies, the internal development of AI technologies, enterprises' consideration of AI adoption, the use of enterprise resource planning (ERP) systems, the use of paid cloud computing services, and the share of turnover generated through online sales. The analysis uses secondary data for EU-27 Member States and applies a synthetic measure to rank countries and identify differences in their level of technological development.

Findings: The results reveal substantial disparities between the EU Member States. Denmark and Malta achieved the highest values of the synthetic measure of digitalisation and technological development, while Romania, Bulgaria and Poland recorded the lowest values. Poland ranked 25th among the 27 analysed countries, with a value considerably below the EU-27 average. The findings indicate that the level of digital and technological development in the transport and warehousing sector remains highly differentiated across the European Union.

Practical Implications: The findings highlight the need for further investment in digital technologies and the development of technological and organisational capabilities in the transport and warehousing sector. Particular attention should be given to countries with lower levels of technological development, where targeted measures supporting technology adoption, digital competence development and organisational transformation may contribute to reducing disparities between EU Member States and strengthening the competitiveness of the sector.

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Originality/Value: *The study contributes to the literature by providing a multidimensional comparative assessment of digital and technological development in the transport and warehousing sector across the EU Member States. The application of the Hellwig synthetic measure enables the simultaneous consideration of several dimensions of digitalisation and technological development and provides a comprehensive basis for identifying differences between countries.*

Keywords: *Artificial intelligence, enterprise resource planning, cloud computing, digital innovation, technology adoption, transport economics.*

JEL codes: *O33, L91, R40.*

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1. Introduction

Between 2015 and 2025, logistics ceased to be perceived solely as an operational support function of an enterprise. It became an area integrating technologies, data, competencies and decisions made across the entire supply chain. The growing popularity of e-commerce, pressure to shorten order fulfilment times and the experience of the COVID-19 pandemic increased the importance of flow visibility and process resilience.

The literature describes this change using the concepts of Logistics 4.0 and the digital supply chain. Winkelhaus and Grosse indicate that the new logistics model requires combining technology with work organisation and data analysis, rather than merely automating selected activities (Winkelhaus and Grosse, 2020, pp. 18-22).

The aim of the article is to assess and compare the level of digitalisation and technological development in the transport and warehousing sector across the EU-27 Member States and to identify the spatial differences between countries.

The research problem addressed in this study concerns the extent and spatial differentiation of digitalisation and technological development in the transport and warehousing sector across the European Union.

In order to address the research problem, the following research questions were formulated:

RQ1: *What is the level of digitalisation and technological development in the transport and warehousing sector across the EU Member States?*

RQ2: *To what extent do EU Member States differ in terms of the use and development of selected digital technologies, including artificial intelligence, ERP systems and cloud services?*

RQ3: *Which EU Member States demonstrate the highest and lowest levels of digitalisation and technological development based on the synthetic measure?*

RQ4: *What is the position of Poland compared with the other EU Member States in terms of the analysed dimensions of digitalisation and technological development?*

The study combines a review of the literature on Logistics 4.0 and technological transformation with an empirical analysis based on secondary statistical data. The theoretical part provides the conceptual background for the analysis, while the empirical part applies Hellwig's pattern development method to construct a synthetic measure of technological development.

The theoretical analysis is based on Polish- and English-language scientific literature concerning Logistics 4.0, digital transformation, Industry 4.0 technologies, logistics performance and the organisational conditions of technological implementation. The empirical analysis uses secondary statistical data, primarily from Eurostat, for the EU-27 Member States.

2. Digitalisation and Logistics 4.0 – Conceptual Framework

Logistics innovation means a change in the way material, information and decision flows are designed, coordinated and controlled. It is therefore not equivalent to purchasing a single device. Barreto, Amaral and Pereira describe Logistics 4.0 as a consequence of integrating cyber-physical systems, the Internet of Things, radio-frequency identification and communication tools that make it possible to track operations and reduce uncertainty (Barreto *et al.*, 2017, pp. 1246-1249). El Hamdi and Abouabdellah additionally mention cloud computing, big-data analytics, blockchain, warehouse management systems and intelligent transport systems (El Hamdi and Abouabdellah, 2022, pp. 1-3).

An important supplement to this approach is the concept of the digital supply chain. Büyüközkan and Göçer indicate that its characteristics include speed, flexibility, collaboration, transparency and the use of information from multiple sources (Büyüközkan and Göçer, 2018, pp. 159-163). Frederico *et al.* emphasise that Supply Chain 4.0 covers not only technologies, but also strategy, processes, organisational structure and performance measurement (Frederico *et al.*, 2020, pp. 264-270). This means that implementation should lead to a redesign of relations between network participants rather than the creation of isolated islands of automation.

The literature distinguishes digitisation, process digitalisation and digital transformation. The first means converting analogue data into digital form, the

second means using data to improve tasks, and the third means changing the way an enterprise operates. Frank *et al.* (2019, pp. 16-18) indicate that practical solutions require a coherent infrastructure, including the Internet of Things, the cloud and analytics.

Assessing innovation requires organisational maturity to be taken into account. Facchini *et al.* analyse it in the dimensions of management, material flow and information flow. Their model comprises five levels: from a lack of awareness of technological possibilities to the full integration of solutions (Facchini *et al.*, 2020, pp. 1, 7-9). Dallasega *et al.* propose a Logistics 4.0 measurement model based on empirically verified dimensions, enabling the diagnosis of the current state and comparison of enterprises (Dallasega *et al.*, 2022, pp. 1387-1393). In practice, a roadmap is needed that combines business needs, data readiness and the sequence of investments.

The perspective of small and medium-sized enterprises requires particular attention. Tubis and Grzybowska show that the literature on the application of Logistics 4.0 in the SME sector is fragmented, while barriers include costs, limited resources, competencies and integration difficulties (Tubis and Grzybowska, 2022, pp. 2-5, 16-18). Khan *et al.* point out that the determinants of adoption also depend on the level of infrastructure, work culture, environmental uncertainty and management support (Khan *et al.*, 2022, pp. 2-4, 11-13). There is therefore no single universal transformation scenario for all organisations.

Automation does not eliminate the importance of people but changes the scope of their tasks and requires competencies, ergonomics and safety to be taken into account (Cimini *et al.*, 2019, pp. 2183-2187). The effectiveness of implementations also depends on decision-making responsibility, training and matching solutions to the management level (Hadaś *et al.*, 2023, pp. 47-50).

3. Technologies, Process Efficiency and Digital Transformation in Logistics

In recent years, the development of logistics has been based on combining complementary technologies. Sensors, RFID and cyber-physical systems create an identification and monitoring layer. The cloud and integration platforms enable information exchange, while artificial intelligence and analytics support demand forecasting, route selection, inventory management and anomaly detection.

Efthymiou and Ponis show that Industry 4.0 technologies affect transport, warehousing, inventory management and information flow (Efthymiou and Ponis, 2021, pp. 2-5, 14-16). Da Silva *et al.* emphasise that similar changes apply to logistics service providers, which must adapt their processes, competencies and collaboration models (da Silva *et al.*, 2023, pp. 2-6, 20-22).

Warehousing demonstrates that the effectiveness of Logistics 4.0 depends on both technology and process organisation. Automated storage systems, mobile robots and real-time data can reduce errors and improve resource utilisation, but they require proper design, infrastructure maintenance and information quality control (Perotti *et al.*, 2022, pp. 197-205).

Empirical studies show that efficiency is not limited to cost reduction. In a group of 31 Polish manufacturing enterprises using logistics trains or AGVs, as many as 97% of respondents indicated transport optimisation as a reason for implementation, 84% indicated improved workstation organisation, 77% increased safety, and 90% improved flow continuity (Płaczek and Osieczko-Potoczna, 2025, pp. 350-352). Woschank and Dallasega, meanwhile, indicate that smart and lean solutions affect logistics performance, while autonomous technologies are not yet fully utilised (Woschank and Dallasega, 2021, pp. 487-490).

A Polish case study of a manufacturing enterprise confirms the importance of a contextual approach. Rut *et al.* indicate that the integration of IT systems, real-time machine monitoring, RFID and warehouse automation can reduce downtime, improve inventory accuracy and increase competitiveness. At the same time, they list risks such as cyberattacks, failures, high costs and a lack of system integration (Rut *et al.*, 2024, pp. 114-116, 124-130). The example shows that an investment decision should result from a diagnosis of problems rather than from a technology trend.

The development of e-commerce and omnichannel sales has increased the number of smaller and more frequent orders, requiring more efficient picking and greater flexibility in last-mile delivery. The implementation of Industry 4.0 also requires the identification of enabling factors, barriers and successive stages of transformation (Ghadge *et al.*, 2020, pp. 672-680).

The assessment of innovation effects should combine quantitative measures, such as order fulfilment time, costs and the number of errors, with qualitative indicators covering safety, resilience and customer satisfaction. Such an approach reduces the risk of apparent optimisation and makes it possible to assess the impact of changes on the entire supply chain.

Statistical analysis requires methodological caution. Data on the number of implementations, order fulfilment times, the share of online sales, warehouse productivity or transport costs can be compared only when similar definitions and observation scopes have been maintained.

A change in an indicator is not always a direct result of the use of technology. It may result from an increase in the scale of operations, changes in energy prices, labour shortages, supply disruptions or a different order structure. For this reason, innovation research should combine time-series analysis with process interpretation.

Quantitative data show the direction and pace of change, while case studies make it possible to explain the mechanisms, limitations and side effects of implementations. Such an approach is consistent with the concept of maturity, in which not only the presence of a tool is assessed, but also its integration with information flow and managerial responsibility.

Sustainable development remains an important assessment criterion. Route optimisation, reducing empty runs, more accurate forecasting and monitoring energy consumption can reduce environmental pressure. At the same time, automation generates infrastructure costs, demand for competencies and new cybersecurity risks. The calculation of effects should therefore cover the entire life cycle of a solution, its resilience to failures and its impact on employees. Logistics innovation is valuable when it improves results without shifting costs to other links in the supply chain.

From a managerial perspective, the phased implementation of innovation is particularly important. An enterprise should begin by identifying the problem, defining the expected result and selecting measures, and then conduct a pilot in a limited area. After assessing data quality, maintenance costs, employee reactions and the impact on customers, the solution can be scaled up. This approach reduces the risk of investing in tools that do not match the organisation's real needs.

It also makes it possible to identify dependencies between transport, warehousing, production and order handling. In the longer term, the advantage is gained not by enterprises with the greatest number of systems, but by organisations capable of consistently integrating, updating and using them in everyday decision-making.

Documenting results also remains important, because comparable data make it possible to assess changes occurring in subsequent years and identify areas requiring further improvement. A reliable assessment also requires maintaining measurement continuity, describing the adopted definitions and clearly separating technological effects from business-cycle changes. As a result, statistics from recent years can form a basis for comparisons rather than merely a set of unrelated observations. Such an approach increases the credibility of the analysis and the usefulness of recommendations for contemporary business practice.

This perspective shows a shift from point improvements to the integration of logistics ecosystems. The most important direction of development is not automation treated as an end in itself, but the responsible combination of data, technologies, processes and competencies. The value of an implementation is determined by matching tools to the problem, organisational readiness and the ability to learn. The available statistics make it possible to analyse the dynamics of change before the pandemic, during the period of disruption and during the subsequent adaptation. Conclusions from the literature indicate that logistics innovation should be assessed simultaneously in economic, operational, social and environmental dimensions.

4. Research Methodology and Study Design

The empirical objective of the study is to assess and compare the level of digitalisation and technological development in the transport and warehousing sector across the EU-27 Member States. The analysis focuses on the extent to which enterprises employ selected digital technologies and solutions that support data integration, automation, information exchange and the digital transformation of business processes. Poland's position is also examined in relation to the other EU Member States.

The study is based on secondary statistical data obtained primarily from Eurostat. The analysis covers enterprises in the transport and warehousing sector employing at least 10 persons. The selection of indicators was determined by data availability, comparability between EU Member States and their relevance to the technological transformation of logistics processes. Six diagnostic variables were included in the analysis:

X_1 – percentage of enterprises in the transport and warehousing sector employing at least 10 persons and using at least one artificial intelligence technology;

X_2 – percentage of enterprises in the transport and warehousing sector employing at least 10 persons in which artificial intelligence technologies were developed by their own employees;

X_3 – percentage of enterprises in the transport and warehousing sector employing at least 10 persons that have ever considered using at least one artificial intelligence technology;

X_4 – percentage of enterprises in the transport and warehousing sector employing at least 10 persons using an enterprise resource planning (ERP) system to exchange information between different functional areas of the enterprise;

X_5 – percentage of enterprises in the transport and warehousing sector employing at least 10 persons using paid cloud services available over the internet;

X_6 – share of turnover generated through online sales conducted via enterprises' own websites or applications in the transport and warehousing sector.

All variables were treated as stimulants, as higher values indicate a greater degree of technological advancement and digitalisation. Due to differences in the availability of statistical observations, the time periods covered by individual indicators vary. The analysis therefore takes into account the longest periods for which comparable data are available. Missing observations were retained as unavailable data and were not replaced by estimated values, in order to avoid introducing additional assumptions into the comparative analysis.

To obtain a multidimensional assessment of the analysed phenomenon, Hellwig's pattern development method was applied. The method enables several diagnostic variables expressed in different units to be transformed into a synthetic measure and used to rank the analysed countries according to the level of the phenomenon under

investigation. The procedure consists of several stages, including the selection and verification of diagnostic variables, their normalisation, determination of a development pattern and calculation of the synthetic measure.

The normalisation procedure was applied to eliminate differences in measurement units and scales. Since all variables were identified as stimulants, their normalisation was performed so that higher normalised values corresponded to more favourable levels of technological development. Subsequently, a pattern representing the hypothetical country characterised by the most favourable values of all diagnostic variables was determined. The distance of each country from this pattern was then calculated, and the resulting distances were transformed into a synthetic measure of development. Higher values of the synthetic measure indicate a higher level of digitalisation and technological development.

The resulting synthetic measure, denoted as M1, represents the level of digitalisation and technological development captured by the selected diagnostic variables. It was used to rank the EU-27 Member States and identify groups of countries characterised by different levels of digital and technological advancement. The classification provides a basis for identifying spatial disparities and assessing Poland's position relative to the EU-27.

The methodological approach combines a descriptive analysis of individual indicators with a multidimensional synthetic assessment. This makes it possible to consider both the dynamics of selected technologies and the overall level of technological development. The approach should nevertheless be interpreted as a comparative assessment of selected dimensions of digitalisation rather than as a direct measure of innovation performance or the economic efficiency of enterprises. The results may also be affected by differences in data availability and by the relatively limited number of indicators for which comparable observations are available across all Member States.

5. Analysis of the Level of Digitalisation and Technological Development in the Transport and Warehousing Sector in the EU-27

An analysis of the level of digitalisation and technological development in the transport and warehousing sector makes it possible to assess the extent to which modern technologies are used and developed by enterprises operating in the EU-27 Member States. The study takes into account indicators concerning, among other things, the use of artificial intelligence, ERP systems, cloud services and online sales. Comparing the values of individual indicators and the synthetic measure makes it possible to identify differences between countries and determine Poland's position against the other Member States.

Table 1 presents the annual share of enterprises in the EU-27 and individual Member States that used at least one artificial intelligence technology in the transport and

warehousing sector in 2021-2025. At the EU-27 level, a clear upward trend is visible: the share of such companies increased from 5.22% in 2021 to 11.15% in 2025, i.e. by 5.93 pp. This means that the use of AI in the sector under study is still not widespread, but the pace of adoption is high.

The highest values in 2025 were recorded in Luxembourg (27.90%), Denmark (26.90%), Belgium (22.36%), Lithuania (20.02%) and the Netherlands (19.65%). Particularly dynamic changes occurred in Romania, Estonia and Lithuania, although it should be remembered that very high growth rates are partly due to a low initial value. Poland remains below the EU average. The share of enterprises using AI increased from 1.85% to 2.97%, representing an increase of 1.12 percentage points (pp).

The standard deviation for Poland is only 0.54, meaning that changes occurred gradually and without sharp jumps. The median for Poland, equal to 2.16%, also confirms the persistently low level of AI use. Declines were recorded in several countries, including Croatia, Cyprus and Slovenia. The data therefore indicate strong spatial differentiation. The countries with the highest results are not always those that recorded the greatest growth, because the level of technological advancement depends both on current investment and on the earlier level of enterprise digitalisation.

Table 1. X_1 - Percentage of enterprises in the transport and warehousing sector employing at least 10 persons and using at least one artificial intelligence technology annually in 2021–2025 [%]

	2021	2023	2024	2025	Mean	Median	Kurtosis	Stand dev.	Change between 2021 and 2025 [percentage points (pp)]
EU-27	5.22	5.26	8.13	11.15	7.44	6.70	-1.10	2.82	5.93
Belgium	5.69	14.94	23.03	22.36	16.05	18.65	-0.51	8.09	16.67
Bulgaria	1.92	1.90	4.40	5.71	3.4825	3.16	-3.75	1.89	3.79
Czechia	3.34	4.42	5.65	6.06	4.8675	5.04	-2.17	1.23	2.72
Denmark	21.28	15.16	21.10	26.90	21.11	21.19	1.50	4.79	5.62
Germany	6.14	7.05	11.48	12.22	9.2225	9.27	-5.29	3.07	6.08
Estonia	2.36	5.61	10.13	13.99	8.0225	7.87	-1.89	5.10	11.63
Ireland	4.98	6.07	7.87	16.76	8.92	6.97	2.99	5.36	11.78
Greece	5.43	5.91	11.64	9.56	8.135	7.74	-3.60	2.98	4.13
Spain	9.02	7.04	8.59	14.69	9.835	8.81	2.96	3.35	5.67
France	4.24	2.35	5.28	8.96	5.2075	4.76	1.33	2.78	4.72
Croatia	7.52	7.58	7.83	4.83	6.94	7.55	3.83	1.41	-2.69
Italy	3.03	3.45	5.24	11.62	5.835	4.35	2.73	3.97	8.59
Cyprus	7.14	7.01	7.28	5.52	6.7375	7.08	3.65	0.82	-1.62

Latvia	3.45	4.10	5.19	5.90	4.66	4.65	-2.63	1.09	2.45
Lithuania	3.84	4.97	4.96	20.02	8.4475	4.97	3.91	7.73	16.18
Luxembourg	10.09	10.04	14.54	27.90	15.6425	12.32	2.60	8.44	17.81
Hungary	3.32	2.23	3.95	5.86	3.84	3.64	1.04	1.52	2.54
Malta	15.00	16.45	20.63	18.55	17.6575	17.50	-1.60	2.46	3.55
Netherlands	11.48	9.06	10.99	19.65	12.795	11.24	3.18	4.69	8.17
Austria	6.98	8.31	13.48	19.37	12.035	10.90	-1.14	5.64	12.39
Poland	1.85	1.84	2.46	2.97	2.28	2.16	-2.08	0.54	1.12
Portugal	7.38	8.26	4.90	14.81	8.8375	7.82	2.33	4.23	7.43
Romania	0.31	0.36	2.73	3.07	1.6175	1.55	-5.73	1.49	2.76
Slovenia	12.52	7.50	18.97	8.51	11.875	10.52	0.27	5.20	-4.01
Slovakia	6.23	3.32	8.22	15.78	8.3875	7.23	1.72	5.32	9.55
Finland	5.70	8.37	6.95	12.93	8.4875	7.66	1.80	3.16	7.23
Sweden	3.71	4.74	15.54	12.17	9.04	8.46	-4.22	5.74	8.46

Source: Own elaboration based on Eurostat data.

Table 2. *X₂ - Percentage of enterprises in the transport and warehousing sector employing at least 10 persons in which artificial intelligence technologies were developed by their own employees, annually in 2021–2025 [%]*

	2021	2023	2024	2025	Mean	Median	Kurtosis	Standard deviation	Change between 2021 and 2025 [pp]
UE-27*	1.42	1.61	2.05	2.40	1.87	1.83	-2.37	0.44	0.98
Belgium	2.01	5.45	2.89	5.35	3.93	4.12	-4.75	1.74	3.34
Bulgaria	N/A	N/A	N/A	0.72	0.72	0.72	N/A	N/A	N/A
Czechia	0.50	1.01	0.51	N/A	0.67	0.51	N/A	0.29	N/A
Denmark	5.19	N/A	5.27	N/A	5.23	5.23	N/A	0.06	N/A
Germany	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Estonia	0.52	1.10	4.18	N/A	1.93	1.10	N/A	1.97	N/A
Ireland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Greece	0	0.30	1.33	2.22	0.96	0.82	-2.22	1.01	2.22
Spain	3.12	1.52	0.64	2.19	1.87	1.86	-0.40	1.05	-0.93
France	0.69	N/A	0.14	N/A	0.42	0.42	N/A	0.39	N/A
Croatia	2.71	1.65	3.01	1.55	2.23	2.18	-5.11	0.74	-1.16
Italy	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyprus	0.46	1.71	1.81	0.82	1.20	1.27	-4.49	0.66	0.36
Latvia	2.08	0.67	0.79	0.81	1.09	0.80	3.84	0.66	-1.27
Lithuania	0.16	1.42	1.98	5.38	2.24	1.70	2.23	2.23	5.22
Luxembourg	N/A	N/A	1.72	2.88	2.30	2.30	N/A	0.82	N/A
Hungary	0.17	0.85	0.12	0.38	0.38	0.28	1.50	0.33	0.21
Malta	3.06	3.92	4.97	5.95	4.48	4.45	-1.57	1.26	2.89

Netherlands	1.16	2.85	2.41	3.78	2.55	2.63	0.82	1.09	2.62
Austria	2.57	1.95	1.90	3.53	2.49	2.26	0.41	0.76	0.96
Poland	0.24	0.45	0.67	0.71	0.52	0.56	-1.78	0.22	0.47
Portugal	0.96	0.47	0.88	2.10	1.10	0.92	2.62	0.70	1.14
Romania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Slovenia	2.66	N/A	4.80	1.09	2.85	2.66	N/A	1.86	-1.57
Slovakia	0	0.77	1.37	1.50	0.91	1.07	-0.59	0.68	1.50
Finland	0.87	1.44	0.85	1.83	1.25	1.16	-2.91	0.48	0.96
Sweden	0.74	1.41	2.76	2.86	1.94	2.09	-3.99	1.04	2.12

Note: N/A - data not available.

Source: Own elaboration based on Eurostat data.

Table 2 concerns enterprises in which artificial intelligence technologies were developed by their own employees. This indicator measures not only the use of AI, but also an organisation's capacity to independently create technological solutions. For the EU-27, the value increased from 1.42% in 2021 to 2.40% in 2025, representing an increase of 0.98 pp. The level nevertheless remains low, because most companies probably use ready-made solutions supplied by external providers. In 2025, the highest values were recorded in Malta (5.95%), Lithuania (5.38%) and Belgium (5.35%).

Poland reached 0.71%, compared with 0.24% in 2021. Despite the relatively high growth rate of 0.47 pp, the absolute level remains clearly below the EU average. The standard deviation for Poland is 0.22, indicating stable, gradual growth, while the median of 0.56% confirms the small scale of the phenomenon. The interpretation of some results is hindered by numerous missing data, especially for Germany, Ireland, Italy and Romania.

Growth rates should also not be directly compared in countries where the initial value was zero. In such cases, percentage growth is not meaningful. The most important conclusion is that the development of in-house AI competencies in the logistics sector still has a limited scope. Developing technology independently requires financial resources, specialised staff and appropriately developed IT infrastructure.

Table 3 presents the percentage of enterprises that have ever considered using at least one artificial intelligence technology. This indicator can be treated as a measure of interest in AI and the potential for future implementations. For the EU-27, the available data indicate an increase from 5.44% in 2023 to 8.92% in 2025. The lack of a value for 2021 makes it impossible to calculate the full dynamics of change for the Union as a whole.

In 2025, the highest results were achieved by Denmark (19.10%), Finland (17.72%), Malta (16.16%), Lithuania (16.04%) and Belgium (12.67%). Poland was among the

countries with the lowest levels: the indicator increased from 1.36% in 2021 to 2.43% in 2025, i.e. by 1.07 pp. The average for Poland was 1.96%, and the standard deviation was 0.44, confirming the small scale of changes. High increases were recorded, among others, in Austria, Croatia and Bulgaria, but in each of these cases the starting point was relatively low. Table 3 also shows that interest in AI alone is higher in many countries than the actual use of this technology. This means that a gap exists between considering an implementation and carrying it out. The reasons may include costs, a shortage of competencies, a lack of data of adequate quality or uncertainty about the profitability of the investment.

Table 4 presents the annual share of enterprises in the EU-27 and individual Member States that used ERP systems to exchange information between different functional areas of the enterprise in the transport and warehousing sector in 2019–2025. Unlike AI technologies, ERP systems are a much more widespread and mature solution. For the EU-27, the share of enterprises using ERP increased from 26.79% in 2019 to 37.30% in 2025.

The highest values in 2025 were recorded in Greece (61.23%), Denmark (59.53%), Spain (55.56%) and Luxembourg (54.47%). In many countries, growth was systematic, although not everywhere. Declines occurred, among others, in Austria, Croatia, Slovakia and Sweden. Poland recorded an improvement from 18.99% in 2019 to 27.03% in 2025, representing an increase of 8.04 percentage points. Despite the improvement, the result remains below the EU average.

The standard deviation for Poland is 4.20, confirming moderate variability, while the median of 25.76% indicates stable growth over the period under analysis. ERP systems are particularly important for logistics because they integrate data on orders, inventories, transport and enterprise resources. Their high level of use can be regarded as a foundation for further digitalisation. Without efficient information integration, it becomes more difficult to implement more advanced solutions, such as data analytics, process automation or artificial intelligence.

Table 3. *X₃ - Percentage of enterprises in the transport and warehousing sector employing at least 10 persons that have ever considered using at least one artificial intelligence technology, annually in 2021–2025 [%]*

	2021	2023	2024	2025	Mean	Median	Kurtosis	Standard deviation	Change between 2021 and 2025 [pp]
UE-27*	N/A	5.44	8.34	8.92	7.57	8.34	N/A	1.86	N/A
Belgium	5.69	4.86	6.28	12.67	7.38	5.99	3.50	3.58	6.98
Bulgaria	0.91	2.27	1.32	3.24	1.94	1.80	-1.64	1.04	2.33
Czechia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Denmark	8.67	N/A	13.11	19.10	13.63	13.11	N/A	5.23	10.43
Germany	N/A	9.26	13.62	10.57	11.15	10.57	N/A	2.24	N/A

Estonia	7.93	3.65	1.41	N/A	4.33	3.65	N/A	3.31	N/A
Ireland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Greece	8.44	7.81	7.16	11.82	8.81	8.13	2.81	2.08	3.38
Spain	3.21	4.95	5.85	8.83	5.71	5.40	1.14	2.35	5.62
France	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Croatia	1.45	4.95	8.05	5.74	5.05	5.35	1.33	2.74	4.29
Italy	N/A	2.31	N/A	7.26	4.79	4.79	N/A	3.50	N/A
Cyprus	6.08	3.83	8.13	12.25	7.57	7.11	0.32	3.58	6.17
Latvia	4.42	4.73	5.63	8.94	5.93	5.18	2.69	2.07	4.52
Lithuania	7.04	5.19	7.72	16.04	9.00	7.38	3.16	4.82	9
Luxembourg	N/A	N/A	10.42	12.35	11.39	11.39	N/A	1.36	N/A
Hungary	3.64	4.22	2.26	5.96	4.02	3.93	0.87	1.53	2.32
Malta	9.18	16.36	9.53	16.16	12.81	12.85	-5.95	3.99	6.98
Netherlands	5.76	4.66	6.16	6.93	5.88	5.96	0.79	0.95	1.17
Austria	2.21	5.06	12.13	10.41	7.45	7.74	-3.61	4.61	8.20
Poland	1.36	2.03	2.01	2.43	1.96	2.02	1.87	0.44	1.07
Portugal	1.14	2.88	15.16	N/A	6.39	2.88	N/A	7.64	N/A
Romania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Slovenia	3.29	5.33	1.28	9.28	4.80	4.31	0.26	3.42	5.99
Slovakia	2.04	3.90	3.77	5.01	3.68	3.84	1.75	1.23	2.97
Finland	10.19	11.87	N/A	17.72	13.26	11.87	N/A	3.95	7.53
Sweden	6.65	3.84	6.34	10.86	6.92	6.50	1.86	2.91	4.21

Note: *Average based on available data; N/A - data not available.

Source: Own elaboration based on Eurostat data.

Table 4. X_4 - Percentage of enterprises in the transport and warehousing sector employing at least 10 persons and using an ERP system to exchange information between different functional areas of the enterprise, annually in 2019–2025 [%]

	2019	2021	2023	2025	Mean	Median	Kurtosis	Standard deviation	Change between 2019 and 2025 [pp]
EU-27	26.79	29.22	34.33	37.30	31.91	31.78	-3.11	4.77	10.51
Belgium	49.83	N/A	59.72	N/A	54.78	54.78	N/A	6.99	N/A
Bulgaria	17.89	16.50	17.48	19.22	17.77	17.69	0.98	1.13	1.33
Czechia	23.47	22.35	16.08	31.48	23.35	22.91	1.44	6.32	8.01
Denmark	27.09	34.87	62.95	59.53	46.11	47.20	-4.90	17.81	32.44
Germany	17.95	23.25	31.20	31.12	25.88	27.19	-2.93	6.47	13.17
Estonia	16.84	14.88	16.66	25.47	18.46	16.75	3.42	4.75	8.63
Ireland	20.12	17.11	21.50	25.61	21.09	20.81	0.88	3.53	5.49
Greece	N/A	53.77	56.66	61.23	57.22	56.66	N/A	3.76	N/A
Spain	41.68	47.66	47.64	55.56	48.14	47.65	1.64	5.69	13.88

France	45.94	42.34	37.92	49.32	43.88	44.14	-0.90	4.89	3.38
Croatia	21.39	21.27	20.45	13.06	19.04	20.86	3.77	4.01	-8.33
Italy	N/A	20.49	34.62	45.20	33.44	34.62	N/A	12.40	N/A
Cyprus	33.87	37.39	44.05	45.43	40.19	40.72	-3.78	5.48	11.56
Latvia	28.19	39.57	31.31	27.83	31.73	29.75	2.17	5.46	-0.36
Lithuania	42.45	44.40	39.05	40.77	41.67	41.61	-0.93	2.29	-1.68
Luxembourg	39.88	33.48	45.69	54.47	43.38	42.79	-0.37	8.92	14.59
Hungary	10.77	13.74	32.32	22.50	19.83	18.12	-1.27	9.70	11.73
Malta	32.28	41.53	50.82	46.61	42.81	44.07	0.15	7.98	14.33
Netherlands	34.92	32.67	40.55	43.26	37.85	37.74	-3.64	4.90	8.34
Austria	33.02	30.59	26.57	20.66	27.71	28.58	-0.43	5.40	-12.36
Poland	18.99	24.49	28.55	27.03	24.77	25.76	0.92	4.20	8.04
Portugal	36.65	N/A	N/A	N/A	36.65	36.65	N/A	N/A	N/A
Romania	13.28	12.09	18.86	23.35	16.90	16.07	-2.46	5.22	10.07
Slovenia	13.27	21.62	25.74	15.18	18.95	18.40	-3.18	5.77	1.91
Slovakia	14.76	22.64	17.44	13.73	17.14	16.10	0.80	3.98	-1.03
Finland	26.78	28.50	40.96	38.79	33.76	33.65	-5.27	7.15	12.01
Sweden	19.58	22.44	45.84	17.41	26.32	21.01	3.51	13.18	-2.17

Note: N/A - data not available.

Source: Own elaboration based on Eurostat data.

Table 5. X_5 - Percentage of enterprises in the transport and warehousing sector employing at least 10 persons and using paid cloud services available over the internet, annually in 2020–2025 [%]

	2020	2021	2023	2025	Mean	Median	Kurtosis	Standard deviation	Change between 2020 and 2025 [pp]
EU-27	29.39	35.17	38.76	46.57	37.47	36.97	0.41	7.19	17.18
Belgium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bulgaria	6.42	9.46	16.54	9.21	10.41	9.34	2.57	4.31	2.79
Czechia	20.81	41.27	34.79	42.11	34.75	38.03	1.54	9.85	21.30
Denmark	57.89	56.83	61.15	59.18	58.76	58.54	-0.38	1.86	1.29
Germany	26.10	33.25	36.42	43.02	34.70	34.84	0.53	7.03	16.92
Estonia	50.12	50.16	56.91	54.84	53.01	52.50	-4.25	3.42	4.72
Ireland	48.06	62.11	66.18	72.48	62.21	64.15	1.43	10.35	24.42
Greece	N/A	N/A	26.55	30.79	28.67	28.67	N/A	3.00	N/A
Spain	21.24	26.97	25.38	37.48	27.77	26.18	2.21	6.91	16.24
France	24.65	26.39	18.77	34.07	25.97	25.52	1.23	6.31	9.42
Croatia	25.11	N/A	40.75	70.34	45.40	40.75	N/A	22.97	45.23
Italy	N/A	52.87	57.86	74.14	61.62	57.86	N/A	11.12	N/A
Cyprus	46.56	55.82	63.94	53.17	54.87	54.50	0.89	7.19	6.61
Latvia	13.13	18.04	28.74	33.11	23.26	23.39	-3.69	9.25	19.98

Lithuania	26.03	30.81	29.38	54.06	35.07	30.10	3.56	12.82	28.03
Luxembourg	29.79	29.24	34.32	42.56	33.98	32.06	0.96	6.16	12.77
Hungary	22.76	21.56	41.68	45.57	32.89	32.22	-5.48	12.50	22.81
Malta	60.41	65.29	65.07	65.90	64.17	65.18	3.65	2.53	5.49
Netherlands	42.66	58.13	57.63	66.73	56.29	57.88	1.97	10.00	24.07
Austria	22.96	33.88	35.33	41.43	33.40	34.61	1.80	7.69	18.47
Poland	21.71	23.81	43.46	41.50	32.62	32.66	-5.69	11.45	19.79
Portugal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Romania	13.81	8.84	16.01	17.95	14.15	14.91	0.78	3.92	4.14
Slovenia	38.21	32.28	41.74	33.98	36.55	36.10	-2.31	4.26	-4.23
Slovakia	17.46	26.81	28.89	23.96	24.28	25.39	0.95	4.98	6.50
Finland	67.69	61.99	63.48	66.88	65.01	65.18	-4.17	2.72	-0.81
Sweden	60.66	65.69	61.73	58.48	61.64	61.20	1.32	3.02	-2.18

Note: N/A - data not available.

Source: Own elaboration based on Eurostat data.

Table 5 presents the percentage of transport and warehousing enterprises using paid cloud services available over the internet. At the EU-27 level, the indicator increased from 29.39% in 2020 to 46.57% in 2025, confirming the rapid spread of cloud solutions. The highest values in 2025 were achieved by Italy (74.14%), Ireland (72.48%), Croatia (70.34%), the Netherlands (66.73%) and Malta (65.90%). Poland also recorded a significant increase: from 21.71% in 2020 to 41.50% in 2025.

Between 2020 and 2025, the indicator increased by 19.79 percentage points. It should be noted, however, that Poland's result in 2025 was slightly lower than in 2023, when it reached 43.46%. The standard deviation of 11.45 indicates substantial variability in the series, while the median of 32.66% illustrates the rapid increase in cloud use well. The most stable results were recorded in Denmark, Finland and Sweden, where cloud services were already widely used at the beginning of the period under analysis. High growth rates in Croatia, Latvia and Lithuania are partly due to a lower initial base.

From a logistics perspective, the cloud is strategically important because it enables remote access to data, ongoing information exchange and the scaling of IT systems. It also facilitates the integration of different locations, operators and supply-chain partners. Missing data for Belgium and Portugal limit the full comparison, but the overall direction of change remains unambiguous.

The growing popularity of the cloud indicates that enterprises are moving from local IT systems towards more flexible digital models. For Polish enterprises, further development in this area may improve operational resilience, information availability and the speed of response to changes in demand in real time.

Table 6 presents the share of turnover from online sales carried out through enterprises' own websites or applications in the transport and warehousing sector. In the EU-27, the indicator remained relatively stable: it amounted to 7.11% in 2020, 7.27% in 2021 and 6.97% in 2025. The change between 2020 and 2025 was slightly negative, at -0.14 pp. This means that the importance of enterprises' own online sales channels in the sector's turnover did not grow as quickly as the use of digital technologies.

The highest values in 2025 were recorded in Ireland (26.10%), Sweden (17.88%), Malta (14.04%), Spain (13.13%) and Denmark (12.90%). The largest increases occurred in Ireland, Lithuania and Romania, although some of them resulted from a low initial level. Poland has data available only for 2020, when the share of turnover amounted to 6.32%. The lack of subsequent observations makes it impossible to assess the trend and compare the dynamics with other countries.

In some countries, enterprises use their own websites and applications more frequently, while in others sales may be carried out through external platforms or be of limited importance to the sector's activity. The indicator should therefore be interpreted as a measure of the share of a specific sales channel, not of the overall level of digitalisation of logistics enterprises.

The stable EU-27 result does not mean that there were no technological changes but may indicate that some sales shifted to other digital channels, including intermediary platforms. The analysis should also take into account that missing data for some countries, including Poland, limit the possibility of drawing far-reaching comparative conclusions.

Table 7 presents the values of the diagnostic variables, their standardised values and the synthetic measure M used to assess the level of digitalisation and technological development in the transport and warehousing sector across the EU-27 countries. The calculated values of the synthetic measure provide the basis for the classification of countries presented in Table 8.

Table 6. *X₆ - Share of turnover from online sales carried out through enterprises' own websites or applications in the transport and warehousing sector employing at least 10 persons, annually in 2020–2025 [%]*

	2020	2021	2023	2025	Mean	Median	Kurtosis	Standard deviation	Change between 2020 and 2025 [pp]
EU-27	7.11	7.27	6.46	6.97	6.95	7.04	1.88	0.35	-0.14
Belgium	5.82	7.63	12.62	9.90	8.99	8.77	-1.04	2.94	4.08
Bulgaria	1.50	1.65	1.43	6.02	2.65	1.58	3.97	2.25	4.52
Czechia	7.59	8.98	7.02	8.57	8.04	8.08	-3.23	0.90	0.98
Denmark	15.69	11.96	9.40	12.90	12.49	12.43	0.87	2.60	-2.79
Germany	1.97	1.50	3.89	1.66	2.26	1.82	3.36	1.11	-0.31

Estonia	17.77	8.78	14.23	14.36	13.79	14.30	1.86	3.72	-3.41
Ireland	7.37	44.62	28.95	26.10	26.76	27.53	1.38	15.28	18.73
Greece	4.50	4.62	4.65	3.08	4.21	4.56	3.85	0.76	-1.42
Spain	10.57	7.53	10.95	13.13	10.55	10.76	1.54	2.30	2.56
France	12.85	14.61	2.00	5.31	8.69	9.08	-4.17	6.01	-7.54
Croatia	10.40	7.38	6.02	9.07	8.22	8.23	-1.88	1.92	-1.33
Italy	N/A	N/A	N/A	6.43	6.43	6.43	N/A	N/A	N/A
Cyprus	1.45	2.17	1.79	2.67	2.02	1.98	-0.77	0.52	1.22
Latvia	11.03	4.54	8.67	9.52	8.44	9.10	2.06	2.78	-1.51
Lithuania	4.12	4.05	5.66	11.81	6.41	4.89	3.10	3.68	7.69
Luxembourg	2.03	N/A	N/A	3.52	2.78	2.78	N/A	1.05	1.49
Hungary	18.68	19.08	11.40	13.70	15.72	16.19	-4.18	3.78	-4.98
Malta	N/A	4.33	N/A	14.04	9.19	9.19	N/A	6.87	N/A
Netherlands	4.19	6.01	5.11	4.83	5.04	4.97	0.98	0.76	0.64
Austria	4.19	7.32	5.93	8.12	6.39	6.63	-0.96	1.72	3.93
Poland	6.32	N/A	N/A	N/A	6.32	6.32	N/A	N/A	N/A
Portugal	10.08	6.70	11.42	10.67	9.72	10.38	2.75	2.09	0.59
Romania	3.47	3.37	4.13	10.77	5.44	3.80	3.81	3.57	7.3
Slovenia	1.79	N/A	2.70	1.35	1.95	1.79	N/A	0.69	-0.44
Slovakia	4.39	7.80	3.33	2.55	4.52	3.86	1.95	2.31	-1.84
Finland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sweden	13.63	9.95	14.20	17.88	13.92	13.92	1.35	3.25	4.25

Note: N/A - data not available.

Source: Own elaboration based on Eurostat data.

Table 7. Statistical characteristics of diagnostic variables and synthetic measures of innovation in the transport and warehousing sector in the EU-27

Country	Values of diagnostic variables						Standardisation						d _i	Synthetic measure M
	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	t ₁	t ₂	t ₃	t ₄	t ₅	t ₆		
Belgium	16.505	3.93	7.38	54.78	N/A	8.99	1.64	1.61	0.07	1.89	-2.50	0.17	5.75	0.3947
Bulgaria	3.4825	0.72	1.94	17.77	10.41	2.65	-1.15	-0.91	-1.56	-1.20	-1.86	-1.02	9.07	0.0462
Czechia	5.0	0.67	N/A	23.35	34.75	8.04	-0.86	-0.95	-2.14	-0.74	-0.35	-0.01	8.10	0.1477
Denmark	21.0	5.23	13.63	46.11	58.76	12.49	2.63	2.63	1.94	1.16	1.14	0.84	2.88	0.6970
Germany	9.2225	N/A	11.15	25.88	34.70	2.26	0.08	-1.48	1.20	-0.52	-0.35	-1.10	7.47	0.2142
Estonia	8.0	1.93	4.33	18.46	53.01	13.79	-0.18	0.04	-0.84	-1.14	0.79	1.08	6.27	0.3399
Ireland	9.0	N/A	N/A	21.09	62.21	26.76	0.01	-1.48	-2.14	-0.92	1.36	3.53	7.03	0.2601
Greece	8.135	0.96	8.81	57.22	28.67	4.21	-0.15	-0.72	0.50	2.09	-0.72	-0.73	6.66	0.2995
Spain	9.835	1.87	5.71	48.14	27.77	10.55	0.21	-0.01	-0.43	1.33	-0.78	0.47	5.81	0.3888
France	5.2075	0.42	N/A	43.88	25.97	8.69	-0.78	-1.15	-2.14	0.98	-0.89	0.12	7.83	0.1760

Croatia	6.94	2.23	5.05	19.04	45.40	8.22	-0.41	0.28	-0.63	-1.10	0.31	0.03	6.73	0.2918
Italy	5.835	N/A	4.79	33.44	61.62	6.43	-0.65	-1.48	-0.70	0.11	1.32	-0.31	7.31	0.2312
Cyprus	6.7375	1.20	7.57	40.19	54.87	2.02	-0.45	-0.53	0.13	0.67	0.90	-1.14	6.86	0.2778
Latvia	4.66	1.09	5.93	31.73	23.26	8.44	-0.90	-0.62	-0.36	-0.04	-1.06	0.07	7.18	0.2443
Lithuania	8.4475	2.24	9.00	41.67	35.07	6.41	-0.09	0.28	0.56	0.79	-0.33	-0.31	5.90	0.3795
Luxembourg	16.0	2.30	11.39	43.38	33.98	2.78	1.46	0.33	1.27	0.94	-0.39	-1.00	5.72	0.3981
Hungary	3.84	0.38	4.02	19.83	32.89	15.72	-1.08	-1.18	-0.93	-1.03	-0.46	1.45	7.39	0.2227
Malta	17.6575	4.48	12.81	42.81	64.17	9.19	1.89	2.04	1.69	0.89	1.48	0.21	3.67	0.6141
Netherlands	12.795	2.55	5.88	37.85	56.29	5.04	0.85	0.53	-0.38	0.47	0.99	-0.57	5.72	0.3977
Austria	12.0	2.49	7.45	27.71	33.40	6.39	0.68	0.48	0.09	-0.37	-0.43	-0.32	6.05	0.3636
Poland	2.28	0.52	1.96	24.77	32.62	6.32	-1.41	-1.07	-1.55	-0.62	-0.48	-0.33	8.28	0.1290
Portugal	8.8375	1.10	6.39	36.65	N/A	9.72	0.00	-0.61	-0.22	0.37	-2.50	0.31	7.19	0.2434
Romania	1.6175	N/A	N/A	16.90	14.15	5.44	-1.55	-1.48	-2.14	-1.27	-1.62	-0.50	9.41	0.0101
Slovenia	11.875	2.85	4.80	18.95	36.55	1.95	0.65	0.76	-0.70	-1.10	-0.24	-1.16	7.05	0.2581
Slovakia	8.3875	0.91	3.68	17.14	24.28	4.52	-0.10	-0.76	-1.04	-1.25	-1.00	-0.67	7.94	0.1644
Finland	8.4875	1.25	13.26	33.76	65.01	N/A	-0.08	-0.50	1.83	0.13	1.53	-1.53	6.83	0.2819
Sweden	9.04	1.94	6.92	26.32	61.64	13.92	0.04	0.05	-0.07	-0.49	1.32	1.11	5.48	0.4238
EU-27	7.44	1.87	7.57	32	37.47	7	-0.30	-0.01	0.13	-0.02	-0.18	-0.21	6.35	0.3323
Arithmetic mean	8.85	1.88	7.14	32.17	40.34	8.07	0.0	-0.2	-0.3	0.0	-0.2	-0.1	6.71	0.2938
Standard deviation	4.66	1.27	3.34	11.98	16.13	5.29	1.0	1.1	1.2	1.0	1.2	1.0	1.40	0.1469
Coefficient of variation	53%	68%	47%	37%	40%	66%							21%	50%
Max	21.11	5.23	13.63	57.22	65.01	26.76	2.63	2.63	1.94	2.09	1.53	3.53	9.41	0.6970
Min	1.62	0.38	1.94	16.90	10.41	1.95	-1.55	-1.48	-2.14	-1.27	-2.50	-1.53	2.88	0.0101

Note: N/A - data not available.

Source: Own elaboration.

Table 8. Classification of EU-27 countries by the level of innovation in the transport and warehousing sector

Country	Synthetic measure M ₁	Synthetic measure M ₁	Level of digitization and technological development
Denmark	0.69702754	0.69702754	HIGH
Malta	0.61410061	0.61410061	
Sweden	0.423758707	0.423758707	
Luxembourg	0.398082613	0.398082613	MODERATE
Netherlands	0.39772326	0.39772326	
Belgium	0.394682741	0.394682741	
Spain	0.388766339	0.388766339	
Lithuania	0.379509884	0.379509884	
Austria	0.363601773	0.363601773	

Estonia	0.339897357	0.339897357	
Greece	0.299477025	0.299477025	
Croatia	0.291778148	0.291778148	LOW
Finland	0.281924395	0.281924395	
Cyprus	0.277759946	0.277759946	
Ireland	0.260086999	0.260086999	
Slovenia	0.258094776	0.258094776	
Latvia	0.244290387	0.244290387	
Portugal	0.243380963	0.243380963	
Italy	0.231244524	0.231244524	
Hungary	0.222713589	0.222713589	
Germany	0.214175166	0.214175166	
France	0.175971701	0.175971701	VERY LOW
Slovakia	0.164403785	0.164403785	
Czechia	0.147710049	0.147710049	
Poland	0.129005285	0.129005285	
Bulgaria	0.046211517	0.046211517	
Romania	0.010073556	0.010073556	

Source: Own elaboration.

Table 8 presents a classification of EU-27 countries according to the level of digitalisation and technological development in the transport and warehousing sector, based on the value of the synthetic measure M1. The higher the value of the measure, the higher the level of digitalisation and technological development of a given country.

The highest level of digitalisation and technological development was recorded in Denmark, for which the synthetic measure was 0.6970. Malta, with a value of 0.6141, was also included in the group of countries with a high level of digitalisation and technological development. The results of these countries clearly exceed the EU-27 average of 0.3323. The group of countries with a moderate level of digitalisation and technological development includes Sweden, Luxembourg, the Netherlands, Belgium, Spain, Austria and Estonia, among others. The values of the measure in this group generally range from 0.2995 to 0.4238. It is worth noting that Estonia achieved a result slightly above the EU average.

Poland, with an M1 value of 0.1290, was included in the group of countries with a very low level of digitalisation and technological development. It ranked 25th among the 27 countries analysed, ahead only of Bulgaria and Romania. Poland's result is approximately 61% lower than the EU-27 average. This may indicate the

limited scale of implementation of modern digital solutions in domestic transport and warehousing enterprises.

The comparison confirms that the differences between EU countries are significant. The value of the measure for Denmark was approximately 70 times that recorded for Romania. The results justify the need to further support investment in digitalisation, automation and the development of technological competencies in countries achieving the lowest values of the measure.

6. Conclusion

The analysis confirms that the level of digitalisation and technological development in the transport and warehousing sector varies substantially across the EU-27. Between 2021 and 2025, the use of artificial intelligence increased, while the use of cloud services grew clearly between 2020 and 2025. ERP systems remain a more widespread foundation for data integration than AI solutions.

Poland improved its results in ERP, cloud and AI use; however, its synthetic measure MI amounted to 0.1290, placing the country 25th among the EU-27 Member States and indicating a very low level of technological development.

The results obtained are consistent with the literature. Hadaś *et al.* (2023, pp. 47-50) emphasise that contemporary logistics trends include digitalisation, automation and decisions made at different management levels. Rokicki *et al.* (2022, pp. 1-3) indicate that the pandemic accelerated the development of e-commerce, omnichannel sales, automation and AI.

At the same time, the mere presence of technology does not determine efficiency. Perotti *et al.* (2022, pp. 193-205) show that Logistics 4.0 implementations in warehouses depend on benefits, barriers and organisational conditions. Tubis and Grzybowska (2022, pp. 2-5, 16-18) draw attention to financial, competency and integration constraints, which are particularly important for SMEs.

The results should nevertheless be interpreted with caution, because data are missing for some countries and very high growth rates may result from a low initial base. The stable share of online sales through enterprises' own websites or applications does not undermine the importance of digitalisation but suggests the development of other sales channels and intermediary platforms.

The low share of AI technologies created by enterprises' own employees also indicates that the maturity of the sector depends on enterprises' ability to develop internal competencies, and not solely on the purchase of ready-made tools and cooperation with technology providers and partners across the entire regional supply chain.

The findings provide clear answers to the research questions formulated in the study.

RQ1: *What is the level of digitalisation and technological development in the transport and warehousing sector across the EU Member States? The analysis indicates that the level of digitalisation and technological development varies considerably across the EU Member States. The results confirm that digital transformation in the transport and warehousing sector is progressing across the European Union, but its intensity remains highly differentiated between countries.*

RQ2: *To what extent do EU Member States differ in terms of the use and development of selected digital technologies, including artificial intelligence, ERP systems and cloud services?*

The results demonstrate substantial differences in the adoption and development of the analysed technologies. Cloud services and ERP systems are considerably more widespread than artificial intelligence, while the development of AI technologies by enterprises' own employees remains relatively limited. The differences between countries are particularly visible in the use of AI and cloud services, indicating varying levels of technological readiness and digital maturity across the EU-27.

RQ3: *Which EU Member States demonstrate the highest and lowest levels of digitalisation and technological development based on the synthetic measure? Denmark achieved the highest value of the synthetic measure ($MI = 0.6970$), followed by Malta ($MI = 0.6141$). At the opposite end of the ranking were Romania, Bulgaria. The results therefore confirm a clear spatial differentiation in the level of digitalisation and technological development within the European Union.*

RQ4: *What is the position of Poland compared with the other EU Member States in terms of the analysed dimensions of digitalisation and technological development? Poland occupies a relatively weak position compared with most EU Member States.*

Although improvements were observed in the use of AI, ERP systems and cloud services, the levels recorded in Poland remain below the EU-27 average for several of the analysed indicators. The synthetic measure places Poland 25th among the 27 Member States, indicating a very low overall level of digitalisation and technological development in the transport and warehousing sector.

This position suggests that further progress requires not only investment in digital technologies, but also the development of internal competencies, data integration capabilities and organisational capacity to implement and effectively use advanced technological solutions.

Overall, the answers to the research questions confirm that the digital transformation of the transport and warehousing sector in the EU-27 is characterised by substantial spatial differentiation. Although the general direction of change is positive, the pace and scale of technological development vary considerably between Member States.

The results also indicate that technological advancement cannot be assessed solely through the adoption of individual technologies, as effective digital transformation depends on the integration of technological infrastructure, organisational capabilities and human competencies.

Practical conclusions:

1. Cloud services and ERP systems constitute an important technological foundation for further digital transformation in the logistics sector.
2. AI adoption is developing dynamically across the EU-27; however, the share of enterprises using AI in Poland remains substantially below the EU-27 average.
3. Cross-country differences indicate that technological modernisation requires not only financial investment, but also appropriate competencies, data integration and effective change management.
4. Polish enterprises should consider a phased approach to digital transformation, progressing from data organisation and system integration to AI pilot projects and systematic evaluation of their operational, economic and qualitative effects.

The study has several limitations. First, the analysis relies on secondary data, and missing observations for selected countries and years limit the comparability of some indicators. Second, the selected variables capture specific dimensions of technology adoption and digital business activity and therefore should not be interpreted as a comprehensive measure of innovation or digital maturity. Third, the synthetic measure provides a relative ranking of EU Member States within the selected set of diagnostic variables and should not be interpreted as a direct causal measure of technological performance.

Future research should extend the analysis in several directions. First, subsequent studies could incorporate a broader set of indicators covering not only technology adoption, but also the intensity of technology use, organisational readiness, employee competencies, cybersecurity and the environmental effects of digital transformation.

Second, longitudinal analyses could be conducted to examine whether differences between EU Member States are decreasing or becoming more pronounced over time.

Third, future research could combine country-level indicators with enterprise-level data to identify the organisational factors that determine the successful implementation of digital technologies in the transport and warehousing sector. Finally, comparative studies could examine the relationship between technological development and selected economic and operational outcomes, such as productivity, employment, logistics performance and competitiveness. Such research would make it possible to move beyond assessing the level of technological development towards

identifying the mechanisms through which digital transformation affects the performance and resilience of logistics organisations.

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