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Digitalization in Logistics for Competitive Excellence: Case Study of Estonia

Aurelija Burinskienė*, Diana Daškevič

Abstract: Logistics is presently undergoing a transformative phase driven by rapid digitalization. This trend has spurred an in-depth exploration of the industry's theoretical potential and practical challenges. This comprehensive review focuses on practical applications, delving deeply into the increasing interest in digital technologies within logistics. The primary objective of this study is to conduct a bibliometric analysis to unravel the growth and academic development of the concept of logistic digitalization. The investigation examines academic literature from the Web of Science database spanning 2020-2024. Using VOS Viewer, an intellectual structure and bibliographic analysis are performed on selected articles. The cluster that concentrates on articles about the Internet of Things (IoT) technology and its impact on the logistics economy (the fourth cluster) is most closely related to the digital theme. The study combines theoretical framework, including Michael Porter's and the Resource-Based View, to illustrate the connections that improve business competitiveness. The examination of investments in digital technology sheds light on the logistics sector's experiences during the years when these investments impact labor productivity. Descriptive analysis results suggest that companies implementing technology can achieve a workforce productivity increase of up to 20%, underscoring the significance of technology investments for enhancing business competitiveness. These findings shed light on how various logistics sub-sectors respond to investments in software and computers and the rate at which these technologies influence labor productivity metrics. These empirical findings substantially reinforce the theoretical framework, providing practical implications and emphasizing the critical necessity for logistics firms to integrate digital technologies into their operational frameworks seamlessly. In conclusion, as the logistics landscape hovers on the brink of a digital revolution, businesses must adeptly navigate and wholeheartedly embrace digital solutions to ensure competitiveness.

Keywords: digitalization; investments; labor productivity; logistic sector

1 INTRODUCTION

The logistics sector is rapidly transforming through digitalization, becoming crucial in securing competitive advantages in today's dynamic global market. The move to digitalization comes with various advantages, like better access to information, streamlined logistics, real-time data collection, improved inventory management, and increased transparency [1, 2].

In the constantly changing world of logistics, with the rise of Smart Logistics and Smart Supply Chain, technologies like artificial intelligence, blockchain, cloud computing, and the Internet of Things work together to automate processes and planning. This leads to a level of partial autonomy and promotes the sharing of information across organizations [3]. Nevertheless, optimizing the advantages of integrated systems necessitates organizations synchronizing their internal technology implementation with the tempo of external stakeholders. Achieving success in this transformative process requires organizations to allocate resources toward emerging technologies, meticulously oversee the integration of digital tools, and gain a comprehensive understanding of the opportunities and interconnections within logistics processes [4].

This literature review explores the increasing interest in digitalization within logistics, focusing on its profound impact on supply chain management and its integration to enhance competitiveness. Integrating digital technologies into logistics remains pivotal for industry growth [5]. 3PL companies have to provide services to customers. Additionally, retail companies always seek to improve operational efficiency in warehouses due to fierce competition. The outcomes reported by the companies outlined, such as Bltron, Pierre's Ice Cream, and Anacapri Foods, reveal a notable 20% surge in workforce productivity [6]. Warehouse operations, particularly material handling (e.g., storage, picking, etc.), are significantly bolstered by IoT solutions. For instance, "smart" sensors can maintain continuous inventory monitoring, generate replenishment alerts [7], aiming to subsequently reduce operational costs stemming from unmet customer needs or increasing unwanted items. Additionally, autonomous picking and packing robots, as well as collaborative robots working alongside humans, help reduce error rates and increase efficiency [8]. However, these technologies can transform standard processes, make supply chain operations more efficient, and contribute to the success of businesses [9]. Embracing digitalization is vital for logistics firms to ensure they deliver effective and responsive customer services [10, 11].

The study aims to understand how digital transformation is changing the logistics sector and plays a crucial role in gaining a competitive advantage in today's dynamic market [12, 13]. The change propelled by digital technologies brings several benefits, such as improved access to information, streamlined practices, real-time data collection, enhanced inventory management, and greater transparency [14].

The paper aims to bridge theoretical concepts with real-world applications in the logistics sector, exploring the growing significance of digital technologies and their transformative potential. It outlines the empirical study's objective, which focuses on how software and computer investments impact logistics productivity.

This paper aims to address the following research questions:

1) What topics are emphasized in the research paper?
2) What are the specific applications of digital technologies?
3) What is the effect of implementing digital technologies seeking to increase competitive advantage?

The paper is divided into five chapters. It starts with an introduction and a literature review. In the second chapter, bibliometric analysis is conducted, classifying digital

technologies used in logistics based on their functional capabilities. This chapter also discusses theories relevant to the application of digital technologies for enhancing logistics competitiveness. In the third chapter, the authors present the research design, methods, materials, and results, which include descriptive, statistical, and regression analysis. Finally, the paper concludes with discussions and conclusions in the fourth and fifth chapters.

2 LITERATURE REVIEW

Analyzing the current and future state of the logistics sector underscores the crucial need to quickly adopt and seamlessly integrate new market demands for a competitive edge. Achieving business efficiency is closely tied to understanding the evolving trends in digital technologies and how they directly impact logistics management operations. [15, 16]. In the current sector, integrating digital technologies becomes a significant challenge. Digitization includes adopting new technologies and converting traditional processes into digital formats [17]. These new digital advancements represent the latest innovations anticipated to significantly reshape corporate strategies and societal environments.

Researchers [18] studied how introducing new digital technologies opens up valuable business opportunities for logistics centers in supply chains. The study's results serve as a basis for proposing alternative strategic options to innovate logistics chains and improve competitiveness.

Studies show that incorporating information technology in a collaborative approach significantly boosts productivity and efficiency in warehouse operations [19]. The impact of information technology on productivity and competitive advantage in logistics is underscored. Productivity, a widely used indicator for performance evaluation [20, 21], remains a key focus. Adopting integrated logistics systems also enables firms to implement lean production methodologies characterized by dependable order cycles and reduced inventory levels [22]. Overall, logistics integration empowers companies and their supply chain partners to operate as a cohesive unit, leading to enhanced performance across the entire chain [23]. Numerous studies have highlighted the manifold logistics advantages of sharing information with supply chain partners, particularly in inventory management [24, 25]. For instance, Vendor-Managed Inventory (VMI) integration with suppliers has been demonstrated to reduce the bullwhip effect [26].

As evident from various sources, information technologies unmistakably reshape the logistics sector and bring strategic value to companies. Their integration into collaborative processes improves productivity and efficiency within warehouse operations [27]. These technologies have become essential tools for gaining a competitive edge in logistics. Supporting productivity, efficiency, and innovation becomes a cornerstone of competitiveness in logistics [28]. Effectively managed information technologies optimize current operations and set the stage for future development and competition.

2.1 The Bibliometric Analysis

This study used a bibliometric approach to understand the academic landscape of digital technologies in logistics competitiveness.

The data collection framework is depicted in Fig. 1.

Web of Science is highlighted as a crucial database, covering a substantial portion of accessible academic literature. The study employs a multi-stage approach to gain a conceptual understanding of the phenomena. Information is gathered from publications on the subject, employing various methods to accomplish this objective. Firstly, a bibliometric analysis is conducted to examine and assess the chosen literature using statistical techniques. The Web of Science is the primary database housing a significant amount of academic literature.

Bibliometric analysis involves exploring and analyzing selected literature using various statistical and mathematical methods. We employed VOS Viewer for bibliometric analysis, covering the period from 2020 to March 2024, comprehensively exploring the concept's evolution.

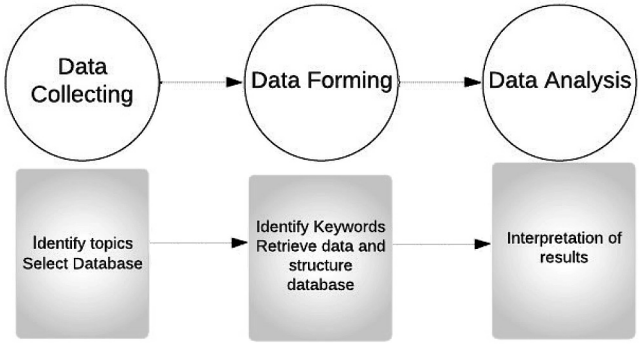

Figure 1 The research process adopted in the study (Author's compilation)

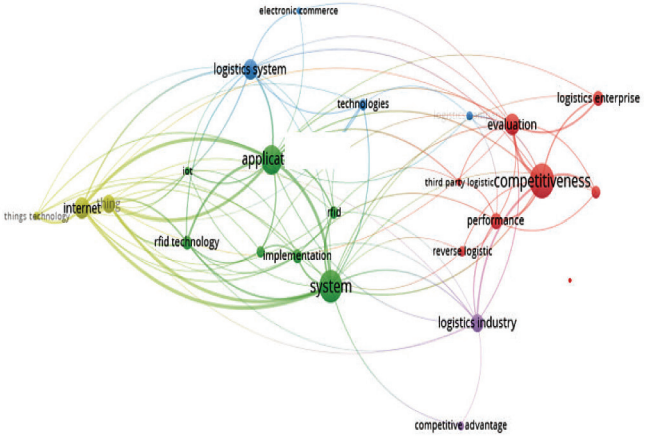

Figure 2 Keyword analysis of authors' keywords (Author's compilation)

VOS Viewer helps create a graphical representation of the dataset, making it easier to interpret extensive data. The generated bibliographic map highlights the articles' most frequently mentioned authors and words. Different colors of circles on bibliometric maps separate clusters to show the keywords 'logistics', 'digitalization', 'technologies', and selected authors in management theory. Circle sizes indicate

the importance of the word, with brighter colors signifying greater importance. Lines on the map represent relationships, with brightness indicating the strength of the connection, and different distances define the intensity of the interface.

The constructed bibliometric map consists of five clusters, as illustrated in Fig. 2.

The keywords associated with each cluster, formed through the algorithm, are also presented in the figure.

The first cluster primarily focuses on articles related to competitiveness, evaluation, logistic performance, and logistic enterprise.

The second cluster features articles discussing application, implementation, and logistic information systems.

The third cluster revolves around the common theme of logistics systems, technologies, and logistics companies.

The fourth cluster includes articles discussing Internet of Things (IoT) technology and logistic economy things technology.

The cluster focusing on articles about the Internet of Things (IoT) technology and its impact on the logistics economy (the fourth cluster) appears to be most closely related to the theme of digital technologies in logistics competitiveness.

2.2 Classification of Digital Technologies Used in Logistics

Digitization is how information technologies and digital systems are used to optimize and modernize logistics operations.

It is a field in constant evolution, where new technological solutions are developed to manage the supply chain, warehouses, transportation, information flows, and various aspects of logistics more efficiently. Tab. 1 provides an overview of the integration of digital technologies in various logistics operations.

Digitization in logistics permeates all aspects of operations, from receiving and warehousing goods to optimizing transportation routes and conducting real-time data analytics [10].

These technologies contribute to the digital transformation of logistics operations, making them more efficient and responsive to market demands. Warehousing: This area is related to asset inventory and storage. The technologies include the use of Warehouse Management Systems (WMS), Positioning Systems, RFID (Radio-Frequency Identification) or barcode scanning systems, Augmented Reality (AR), electronic data interchange (EDI), integration with advanced picking systems, and other technologies [29 , 30].

Each business area employs various technologies to enhance operational efficiency, from warehousing and transport management to data analysis and security. This helps optimize the supply chain, reduce time and resource wastage, and increase overall business benefits [18, 32].

Data analysis technologies in logistics and supply chain management provide numerous advantages. These benefits include improved decision-making, cost reduction, enhanced customer satisfaction, and the ability to adapt to changing market conditions, ultimately leading to increased competitiveness in the industry [27, 33].

Table 1 Classification of digital technologies used in logistics

Logistic functional areas	Operations	Technology
Warehousing	Inventory and Warehousing	Warehouse Management System (WMS)
		Positioning System and Augmented Reality (AR)
		Handling Management and Picking Route Optimization
		Storage identification technology
		Cross-Docking Systems
		Internet of Things (IoT) Technology
		RFID (Radio-Frequency Identification) and Barcode Scanning Technologies
		Electronic Data Interchange (EDI)
		Integration with advanced picking systems
Automated Material Handling	Automated Guiding	Automated Storage and Retrieval Systems (AS/RS)
		Automated Guided Vehicles (AGVs)
		Autonomous Mobile Robots (AMRs)
		Guiding Control Software
		IoT Sensors and Data for Decision-Making
Picking and Packing	Automated Picking	Automated picking solutions
		Automated Sortation Systems
		Automated Labeling and Packaging Systems
		Weight Measurement Technology
		Voice Picking Systems
		Real-time data Management Systems (DMS)
Transport Management	Route Planning and Optimization	Global Positioning System (GPS)
		Fleet Management and Route Optimization
		Workload balancing
		Electronic Bill of Lading (eBOL)
		Big Data Analytics
Safety and Security	Safety-oriented transportation	Intelligent transport systems
		AI-driven analytics and warnings (road works, in-vehicle signage, signalized intersections, etc.)
Data Analysis, Interpretation and Exploitation	Demand Forecasting	Big Data Analytics
	Data Collection	Automated Data Collection and Integration
	Labor Augmentation	Robotic Process Automation (RPA)
	Tracking and Monitoring	Real-time IoT Tracking and Monitoring Technology
	Asset Tracking	RFID Asset Tracking, GPS-based asset tracking
	Document Management	Blockchain Technology
	Traceability	Supply Chain Traceability technology
	Real-time decision making	Real-time data and Predictive Modeling, Big data analytics

As we progress in this digital era, logistics professionals and businesses must remain agile and adapt to the evolving landscape. Embracing these digital solutions is no longer an option but a necessity to stay competitive and deliver a seamless logistics experience to customers.

Integrating digital technologies in logistics operations is a game-changer with great promise for the industry. By adopting these innovations, logistics operations can become more efficient and responsive, ultimately contributing to the success of businesses and the entire supply chain.

2.3 Theories that Are Actual for the Application of Logistic Competitiveness

In logistics, the quest for competitiveness is a constant endeavor. Logistics companies must draw upon various theories and models to gain a competitive edge in today's global marketplace. These theories provide an essential framework for understanding and improving logistics operations. In this context, we will explore several competitiveness theories and how they can be applied in logistics, considering the role of digital technologies to enhance efficiency, reduce costs, and provide superior services to customers.

Tab. 2 illustrates the application of various competitiveness theories in the logistics sector and the utilization of digital technologies. Each theory is presented with its application context, highlighting the role of digital technologies in enhancing efficiency, reducing costs, and improving customer service in logistics.

Table 2 Theories that are actual for the application of digital technologies for logistics

Theory	Application in logistics	Role of digital technologies
Michael Porter's Competitive Advantage Theory	Selecting cost leadership or differentiation strategies.	Enhancing differentiation through tracking, data analysis, and customer service, supporting cost leadership.
Michael Porter's Diamond Model	Assessing competitiveness factors in logistics operations.	Improving infrastructure, efficiency, cost reduction, and customer service.
Competitive Strategy Theory	Providing insights into optimal strategies for competitive contexts.	Making data-driven decisions, identifying optimal strategies, and achieving long-term competitive advantages.
Resource-Based View (RBV) Theory	Evaluating unique resources and competencies for a competitive advantage.	Optimizing resources, reducing costs, enhancing efficiency, and improving customer service.
Dynamic Capabilities Theory	Building flexibility, learning from experience, and innovating supply chains.	Enabling real-time adaptation, continuous learning, innovative processes, agile decision-making, and competitive resilience.
Digital Transformation Theory	Adapting to digital trends and excelling in the digital age.	Real-time data collection, enhanced supply chain visibility, efficient inventory management, predictive analytics, improved customer experiences, data-driven decision-making, and sustainable operations.

Michael Porter's competitive advantage theory aids in crafting competitive logistics business models. Digital technologies enhance differentiation through tracking, data analysis, and customer service.

Michael Porter's Diamond Model offers a comprehensive framework for assessing logistics competitiveness, focusing on infrastructure, supplier industries, demand conditions, and supporting industries.

Integrating digital technologies enhances infrastructure, efficiency, cost reduction, and customer service [28]. Competitive Strategy Theory aids in strategic decisions with insights into competitive advantages. Digital technologies provide essential data for data-driven decisions. The Resource-Based View (RBV) theory evaluates unique logistics resources. Digital technology integration optimizes resources, reduces costs, and enhances efficiency and customer service [21].

The Dynamic Capabilities Theory empowers logistics companies to adapt and innovate their supply chains with digital technologies for real-time adaptation, learning, and agile decision-making [34]. Digital Transformation Theory guides logistics companies in adopting digital trends [35].

Logistics companies can leverage a range of competitiveness theories to refine their strategies and operations.

The studies on technologies and business competitiveness were formed as two separate streams. However, integration among these two streams is required to expand the concepts of technology application and increase business competitiveness.

In this research, the authors analyzed the different aspects of applying technologies and business competitiveness by delivering general and more specific investigations.

Theories, such as Michael Porter's Competitive Advantage Theory, Resource-Based View (RBV), and others, play a pivotal role in navigating the logistics industry's digitalization landscape. These theories offer frameworks for understanding market dynamics, competitive forces, and strategic positioning in a digital context [28].

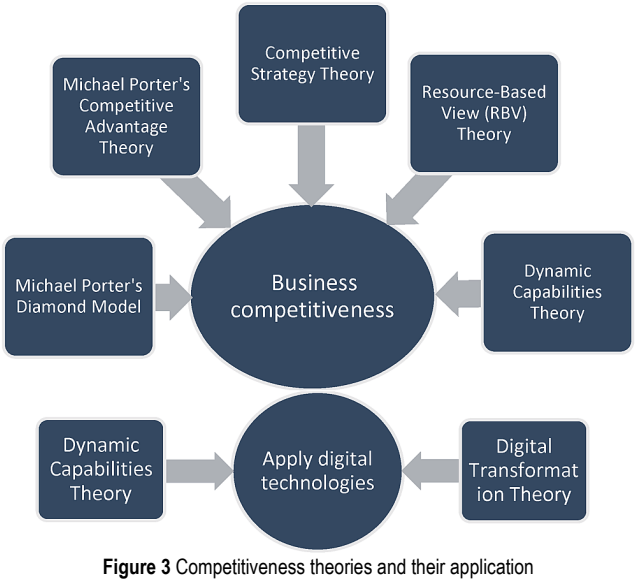

Figure 3 Competitiveness theories and their application

In Fig. 3, theories related to logistics are classified into two categories: those associated with business competitiveness, various competitive strategies, resource

evaluation, and identifying unique advantages. The other category comprises strategies focused on applying digital technologies in logistics, such as digital transformation, real-time data collection, supply chain visibility, etc. This emphasizes the significance of these theories in enhancing business competitiveness.

Understanding these theories is crucial in logistics as they aid in strategic planning, decision-making, and optimizing operations. Companies can use these frameworks to assess market dynamics, identify competitive threats and opportunities, allocate resources effectively, and develop strategies to enhance competitiveness. In the digital era, applying these logistics theories helps leverage technology effectively, optimize supply chains, and adapt to changing market conditions to achieve sustained success.

By applying these theories and incorporating these technological advancements, they can achieve improved efficiency, reduced costs, and, most importantly, better meet the ever-evolving needs of their customers in a highly competitive global market.

2.4 The Application of Digital Technologies in Logistics

The evaluation of productivity is commonly assessed by comparing a firm's, an industry's, or a country's performance over time. Indicators linked to the application of digital technologies can generally be categorized into three groups: (1) indicators related to the input application of digital technologies, (2) indicators related to the process of applying digital technologies, and (3) indicators related to the output resulting from the application of digital technologies. These indicators, measured at the firm or sectoral level, affect individual firm productivity. The increasing availability of data and its transformation into economically valuable insights usable for decision-making creates new possibilities for structuring manufacturing within value chains [5].

Digital technologies within the logistics sector can be classified according to their productivity levels, which distinctly shape their impact on operational efficiency. They fall into three productivity categories: low, medium, and high, each exerting a different influence on the logistics industry. Low-productivity digital technologies typically encompass basic systems with restricted functionality. Conversely, high-productivity digital technologies offer sophisticated analysis and optimize logistics activities. For instance, basic data collection and tracking systems, typical of low-productivity technologies, provide essential information on goods' routes but lack advanced analytical capabilities [27].

On the other hand, medium-productivity digital technologies, like certain data analysis platforms, enable in-depth information analysis and decision-making based on analytical data. Customized logistics management systems enhance warehouse operations, route planning, and goods movement, yet may have limitations in functionality. High-productivity digital technologies, such as artificial intelligence and big data analytics, substantially impact logistics sector productivity. They facilitate comprehensive data analysis, market trend forecasting, efficient inventory management, and timely goods delivery. Leveraging artificial intelligence can address intricate logistics challenges, streamline logistics activities, and automate processes, significantly enhancing overall productivity and efficiency [31].

The impact of these technologies on logistics sector productivity varies based on their scope, adaptation, and utilization. Research has demonstrated that utilizing information technologies in logistics can effectively address current and potential future problems, enhance service quality, optimize logistics flows, improve safety standards, reduce resource and product supply costs, enhance information exchange efficiency, and introduce innovative customer support tools [16].

Understanding these distinct productivity levels guides the future direction of digital technologies and empowers businesses to strategically integrate and optimize their technological investments, customizing approaches to augment efficiency and effectiveness within the logistics sector.

3 RESEARCH DESIGN AND RESULTS

3.1 Research Design

The study follows a step-by-step approach to grasp the concepts involved. Initially, the researchers gathered knowledge from data describing advancements in implementing digital application technologies.

The authors use a three-stage methodology. In the first stage, statistical analysis is applied to express and interpret collected data using statistical measures. This method helps understand trends, data distribution, and relationships between variables, providing a foundational basis for subsequent research.

Moving on to the second stage, the authors employ descriptive analysis. This research approach aims to establish facts and describe an object or phenomenon without delving into in-depth explanations or assumptions about causes and effects.

For the third stage, the authors incorporate regression analysis and use heteroscedasticity and autocorrelation-consistent (HAC) standard errors defining the method. Regression analysis explores the relationship between two or more variables, examining the relationship line between a dependent variable and independent variables, enabling the prediction of the dependent variable based on the independent ones.

During the statistical analysis, the authors compare labor productivity across EU logistics sectors and identify productivity gaps between them, with the productivity index taken from Estonia, a leading investor in digital technologies in the Baltic region. In the regression analysis, the authors present regression equations formulated for seven logistics sub-sectors, illustrating diverse effects resulting from the application of digital technologies.

Empirical data from 2011-2020 is used to emphasize the growing emphasis on digitalization within the logistics domain, particularly concerning labor productivity.

In applying the descriptive method, the authors identified nine studies that exemplify the implementation of high-productivity digital technology, specifically voice-picking technology, to enhance logistics management efficiency.

3.2 Review of the EU Logistic Sector

The statistical analysis confirmed that advanced digital technology greatly improves operational efficiency, productivity, and accuracy in logistics across different industries. Companies adopting this technology experienced enhanced workforce performance, shorter training periods, and decreased error rates in logistics operations. This highlights the transformative power of cutting-edge digital technology for effective logistics management in various business settings.

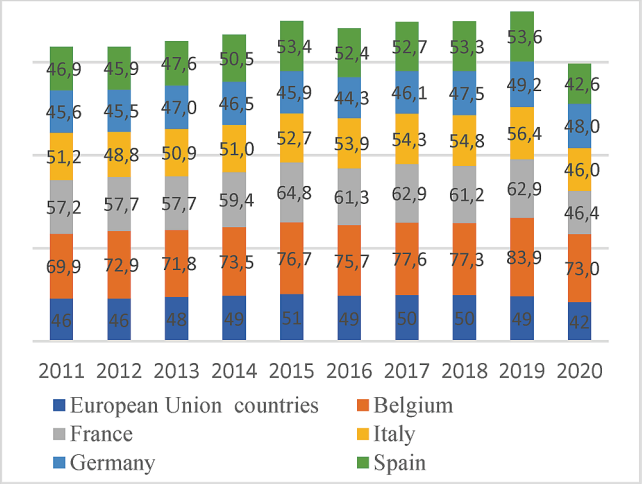

Figure 4 Labor productivity in the logistics sectors of European Union countries [36]

Fig. 4 shows labor productivity in the logistics sector of European Union countries from 2011 to 2020. The percentages indicate the efficiency of generating output relative to the resources used in the logistics domain. For example, Belgium's metrics fluctuate from 69.9% to 83.9%, Germany's from 45.6% to 49.2%, and so on for each country. These percentages reveal the output produced per unit of resources within the logistics sector. The observed fluctuations across countries indicate distinct trends in labor productivity within the logistics industry.

Belgium consistently maintains high logistics labor productivity levels, exceeding 70% for a significant portion of the assessed period. However, looking at the entire European Union, the overall average labor productivity within the logistics sector is approximately 50%. Belgium's exceptional labor productivity suggests they may have implemented various measures to achieve such outstanding indicators. This might involve investments in advanced digital logistics technologies, such as voice picking systems, automated warehouses, or sophisticated inventory management systems, to optimize operational processes and increase efficiency. Large logistics companies and warehouses in various countries, including Germany, France, Spain, and others, have integrated voice-picking technology into their operations. This implementation streamlined order preparation and enhanced warehouse efficiency through voice-controlled digital technology, enabling employees to pick items efficiently. Undoubtedly, this technology has undergone significant changes.

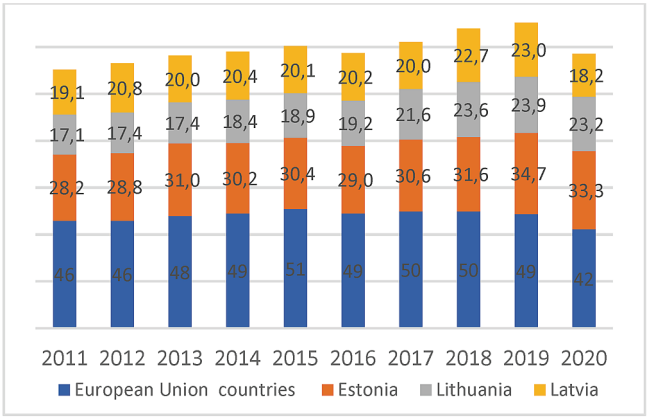

Figure 5 Labor productivity in the logistics sectors of Baltic countries [36]

Fig. 5 delineates labor productivity metrics within the logistics sector across the Baltic States. These metrics represent the percentage scale of productivity levels pertinent to logistics operations. Estonia exhibits a productivity range of 28.2% to 34.7% over the specified duration, Lithuania demonstrates productivity spanning from 17.1% to 23.9%, and Latvia showcases productivity levels oscillating between 18.2% and 23%.

The fluctuations in labor productivity across the Baltic nations uncover distinct trends within the logistics industry. Estonia steadily enhances its performance, maintaining productivity above 30% for most of the analyzed period. Meanwhile, Lithuania and Latvia exhibit varying patterns in their logistics-related labor productivity levels. Among these nations, Estonia consistently maintains higher productivity levels within the logistics sector. They've invested in advanced digital technologies for logistics, including automation, robotics, smart solutions, and data analytics, which effectively streamline processes and boost efficiency in the logistics sector.

3.3 Application of Digital Technologies

Descriptive analysis results show that using advanced digital technology has completely changed how things work in various industries. It has greatly increased productivity, accuracy, and overall efficiency. Companies in different sectors like healthcare and publishing have adopted this technology to make their logistics processes more efficient, and the results have been impressive. This technological shift has improved how employees work and significantly reduced the time it takes for training and the number of errors made.

It highlights how powerful and transformative high-productivity digital technology can be in different business settings.

Tab. 3 overviews how specific advanced digital technologies are used in different logistics operations industries.

Table 3 Results of high-productivity digital technology application for logistics operations [6]

Firms	Application results
Elsevier	Achieving 99.72% accuracy, boosting employee productivity, and quickly realizing a return on investment were notable outcomes. In just 9 months, a significant return on investments was observed. The average training time to familiarize workers with the new system was reduced to 4 hours, an improvement of 2 days compared to RF Scanning. This resulted in a 75% reduction in training time.
Belron	Achieved a 20% increase in productivity, notable enhancements from hands-free work, a higher accuracy rate of 99.95%, improved efficiency resulting in savings of 1.5 million euros, and reduced operating costs.
Simon & Schuster	Achieved a 100% increase in efficiency, quickly realized a return on investment, and eliminated 50 temporary positions. Return on investment was achieved in less than one year. Consolidated the warehouse into one, doubling productivity and efficiency, with 600,000 units shipped daily (150 million units annually).
Pierre's Ice Cream	Improved accuracy by 20%, achieving an accuracy level of 99.96%. This led to higher productivity and accelerated employee training, typically reduced from 7-15 days to 4 hours or less with voice picking, resulting in reduced seasonal hires.
FDL	Improved efficiency in operations, shortened training time, optimized workforce allocation, and analytics solutions aid in order and worker management. These adjustments during peak periods are facilitated, establishing a performance-based intensive pay program.
Anacapri Foods	Boosted productivity without hiring additional staff, minimized errors, expedited employee training, achieved a 20% increase in volume without expanding the workforce, and successfully served over 1800 pizzerias and restaurants.
Frontier Distributing	Attained an outstanding accuracy of 99.9%, boosted productivity, and accelerated employee engagement within the company.
PRSG	Reduced workforce by 25%, improved staff management, minimized travel time, increased on-time orders, and decreased overtime. Enhanced priority management and eliminated manual hand label printing.
Mission Health	Significantly increased accuracy by 30%, improved productivity, enhanced warehouse management, fulfilled more orders, achieved more precise matches on cycle counts, optimized inventory management, and gained the ability to assign priority to work orders.

The outcomes reported by the companies outlined in Tab. 2 reveal a notable 20% surge in workforce productivity. This outcome substantiates its classification as a high-productivity technology. The incorporation of high-productivity digital technology into logistics operations has demonstrably elevated precision, productivity, and operational efficiency within these companies. By integrating this technology, these companies streamlined logistics processes, reduced errors, and optimized workforce management. These findings underscore the versatility and influential impact of high-productivity digital technology in instigating favorable transformations in logistics operations and operational excellence across various sectors.

3.4 The Application of Digital Technologies Estonian Logistic Sector

To thoroughly investigate how digital technologies impact labor productivity in Estonia's logistics sector, this section conducts a detailed analysis from 2005 to 2020. The focus is specifically on investments in computers and software.

The statistical analysis compared labor productivity across various EU logistics sectors, revealing gaps between them. The productivity index was sourced from Estonia, which is known for its significant investments in digital technologies in the Baltic region. The regression analysis formulated regression equations for seven logistics sub-sectors, highlighting the varied effects of digital technology adoption. Empirical data from 2005 to 2020 underscored the increasing focus on digitalization within the logistics domain, particularly concerning labor productivity.

The authors collected data from Estonia Statistics [37] on investments in software and computers by companies in the logistics sector. This covered various sub-sectors, including Postal and courier activities, Warehousing and support activities for transportation, Transportation, and storage, and Transportation by different modes. The intensity of investments varied significantly over the years.

Separate data on labor productivity, calculated by dividing Gross Value Added by the number of persons employed in thousand euros, was gathered for each logistics sub-sector from Estonia Statistics [37].

The analysis centers on labor productivity per person employed, measured by turnover per thousand euros.

The regression analysis reveals changes in labor productivity, notably visible concerning different types of investments (i.e., computer and software) within each logistics sub-sector.

The regression analysis results indicate that understanding the impact of investments in software and computers on labor productivity involves utilizing a regression equation (Eq. (1)).

$$y = \beta_0 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \varepsilon, \tag{1}$$

x_1 – investments in software; x_2 – investments into computers; y – labor productivity; β_0, β_1, β_2 – coefficients of the regression equation; ε – residuals.

The research used the HAC (heteroskedasticity and autocorrelation consistent) test to model and analyze time-series data. This test provides a robust framework for understanding intricate temporal relationships within the dataset and addresses issues of autocorrelation and heteroscedasticity. The method incorporates autoregressive and moving average components of a time series, integrating additional exogenous variables for a more comprehensive and accurate analysis. By using the HAC test, the study aimed to reveal patterns, trends, and dependencies, allowing for a nuanced exploration of the influence of values on the dependent variable. The results underwent validation using test statistics.

Table 4 Formed regression equations (Authors' compilation)

Logistic sub-sector	Regression equation
Investments in software	
Postal and courier activities	$y = 26.3128 + 0.0037 \cdot x_1$
Support activities for transportation	$y = 216.2125 + 0.0077 \cdot x_1$
Warehousing and support activities for transportation	$y = 198.112 + 0.007 \cdot x_1$
Investments in software and computers	
Freight transport by road and removal services	$y = 78.02 + 0.072 \cdot x_1 - 0.0275 \cdot x_2$
Land transport and transport via pipelines	$y = 64.1775 + 0.0336 \cdot x_1 - 0.0064 \cdot x_2$
Transportation and storage	$y = 141.489 + 0.002 \cdot x_1 - 0.009 \cdot x_2$

To understand the impact of investments, regression equations were created for seven sub-sectors in the logistics industry, focusing on two investment categories: software and computers. The coefficients in these equations indicate the change in the dependent variable when the independent variable increases by one unit (see Tab. 4). The authors developed six regression equations.

The regression equation clarifies the relationship between labor productivity and material capital per person employed, quantified in turnover per thousand euros. It's essential to highlight that indicators of investments in computers and software significantly influence logistics sector labor productivity through digital technology. The findings of this analysis are outlined in Tab. 5.

Tab. 5 illustrates that within logistics sub-sectors, investments in software have a discernible impact on labor productivity in Postal and courier activities, Support activities for transportation, and Warehousing and support activities for transportation sub-sectors.

Table 5 Results validation (Authors' compilation)

Variables	FTRRS	LTTP	PCA	SAT	TST	WSAT
β_0	78.0285*** 6.1129	64.1775*** 3.9007	26.3128*** 2.6007	216.2125*** 11.6211	141.489*** 15.5570	198.112*** 10.6550
β_1	0.0720*** 0.0059	0.0336*** 0.0114	0.0037*** 0.0002	0.0077*** 0.0028	0.0020*** 0.0005	0.0070*** 0.0025
β_2	–0.0275*** 0.0110	–0.0064*** 0.0026			–0.0090*** 0.0034	
R-squared	0.3492	0.5999	0.2114	0.1514	0.4926	0.1615
DW		1.5231				
HAC test						
PwlAIC	2		2	2	0	2
BkNW	3		3	3	3	3

Note: *** means that the probability is lower than 0.1. Explanation of abbreviations: FTRRS - Freight transport by road and removal services; LTTP - Land transport and transport via pipelines; PCA - Postal and courier activities; SAT - Support activities for transportation; TST - Transportation and storage; WSAT - Warehousing and support activities for transportation; DW - Durbin-Watson statistics; BkNW - Bartlet kernel, Newey-West fixed bandwidth; PwlAIC - Prewhitening with lags AIC.

We can draw several conclusions based on the findings presented in Tab. 5. Firstly, different sub-sectors show varied responses to investments in software and computers. For instance, all six sub-sectors strongly respond to investments in the corresponding investment year. Each sub-sector demonstrates a distinct correlation between software investments and productivity. However, computer investments positively impact labor productivity in specific sub-sectors, such as Freight transport by road and removal services, Land transport and transport via pipelines, and Transportation and storage.

These findings highlight the diverse influence of software investments on labor productivity across various sub-sectors and types of investments. This emphasizes the importance of tailoring strategies for investments to specific sub-sectors. The formulated regression equations (Tab. 5) reveal that the most significant impacts on labor productivity are associated with investments in software, as all six equations include variables related to such investments. The analysis underscores the varied outcomes of technology investments in different logistics sub-sectors. Additionally, in certain sub-sectors, investments in computers did not show a significant impact on labor productivity. Recognizing these sub-sector-specific characteristics is crucial when planning investments and anticipating their outcomes. Each logistics sub-sector has unique attributes and responds differently to technology investments. Therefore, while technology investments can enhance labor productivity in the logistics sub-sector, it's essential to consider each sub-sector's specific requirements and characteristics when evaluating them. This study provides insights into how digital technologies impact labor productivity in the logistics sector. It highlights a research gap as other authors have not focused on this type of analysis within the logistics sector.

4 DISCUSSION

Recognizing the potential of digitalization in logistics, this paper highlights key areas that require further exploration.

Prajogo et al. (2012) analyzed data from 232 Australian firms and found that logistics integration significantly influences operations performance. Information technology capabilities and sharing are significant in logistics integration [38]. Author Gizetdinov (2024) examined key innovations in transport services, which provide Western companies with a significant advantage in improving logistics efficiency [39]. Al-Ababneh et al. (2023) aimed to define the peculiarities of trends in the evolution of digitalization, innovation in marketing, and logistics among modern companies [40]. Frohlich and Westbrook (2001) modeled supply chain integration in terms of information and material using eight items concerning IT, information sharing, and logistics integration [41]. They found that a wider scope of integration

had a positive association with performance improvement. Lee et al. (2000) show that information sharing can lower costs through reductions in inventories and shortages [25]. However, to realize this value, changes in the logistics system are required, such as Vendor-Managed Inventory (VMI) programs, lead time reductions, order quantity reductions, and more frequent deliveries.

Although many researchers have examined the impact of digital technologies on the competitiveness of the logistics sector, there is a clear research gap in exploring future logistics trends. There is a significant opportunity for further scholarly inquiry in this area. Advancements in digital technologies could profoundly influence the competitiveness of the logistics sector. For instance, many studies indicate that information sharing and information technology capabilities are crucial in logistics integration and operational efficiency. However, additional research is needed to further explore how digital technologies may continue to transform and enhance productivity in the logistics sector, thus sustaining business competitiveness.

Bridging the gap between theory and practical applications poses a significant challenge, especially when integrating digital technologies like AI, automation, and data analytics into day-to-day logistics operations. Investigating the obstacles hindering a smooth transition from theory to practice is crucial for successful implementation. The article points out several research gaps:

a) Sectoral Disparities: The analysis reveals diverse responses among different logistics sub-sectors to various technological investments, emphasizing the need to assess these investments while considering the specifics of each sub-sector. This illustrates how identical investments can impact labor productivity differently in various sub-sectors of the logistics industry.

b) Effectiveness of Digital Technology Investments: The effectiveness of digital technology investments can significantly vary depending on the sub-sector. These gaps underscore the importance of considering sub-sector-specific characteristics when planning and implementing technological investments within the logistics sector.

While acknowledging the role of digital technologies in enhancing operational efficiency, understanding the application of specific mechanisms that influence productivity metrics could provide actionable insights for businesses aiming to optimize their logistics operations.

These suggested areas for further investigation aim to address existing research gaps and contribute to a more comprehensive understanding of how digital technologies shape productivity within the logistics sector. Exploring these aspects can provide valuable guidance for businesses navigating the evolving landscape of digital transformations in logistics.

5 CONCLUSION

In summary, our comprehensive analysis underscores the pivotal role of digitalization in transforming the logistics industry and enhancing competitiveness. The focus on applying digital technologies, optimizing efficiency, and understanding emerging trends reveals the transformative potential that lies within the adoption of these technologies. The logistics sector, faced with challenges and opportunities, undergoes a significant reshaping of processes, leading to improved operational efficiency and refined supply chain activities.

Based on papers from the Web of Science, the literature analysis focused on 2020-2024 and delved into various digital technologies, particularly examining their impact on logistics competitiveness. The identified clusters, especially those centered on the Internet of Things (IoT) technology, highlight the interconnectedness of digital technologies and their profound influence on the logistics economy.

Michael Porter's Competitive Advantage Theory, Porter's Diamond Model, Competitive Strategy Theory, Resource-Based View (RBV) theory, Dynamic Capabilities Theory, and Digital Transformation Theory provide valuable frameworks for understanding and improving logistics operations.

Empirical findings illustrate tangible outcomes, indicating a substantial increase in productivity across diverse logistics sectors following technology implementation. The results showcase a 20% boost in productivity, affirming that digital technologies significantly advance company operations, optimize employee activities, and reduce error rates.

However, it's crucial to acknowledge the limitations of our research, particularly the exclusive focus on the Estonian sector due to data constraints. Despite this, Estonia's exceptional labor productivity among Baltic countries is a compelling example of the positive impact of high-productivity digital technologies.

As logistics firms navigate this era of digital adaptation, the presented insights suggest that embracing technology is not merely an option but a necessity for sustained success. The seamless integration of digital solutions positions logistics helps companies meet the evolving demands of tomorrow, fostering a dynamic and efficient industry landscape.

In conclusion, our research illuminates the transformative journey of the logistics sector in the digital age. It reinforces the importance of strategic decision-making based on technology investments, optimizing resource allocation, and cultivating best practices. As logistics companies continue this journey, they address current challenges and position themselves for long-term competitiveness in the ever-changing global marketplace.

In the future, the authors aim to study productivity in other EU countries, focusing on the impact of technology on competitiveness.

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Authors' contacts:

Aurelija Burinskiene, Associated Professor
Vilnius Gediminas Technical University,
Sauletekio Avenue, 11 10223 Vilnius, Lithuania
E-mail: aurelija.burinskiene@vilniustech.lt

Diana Daškevič, PhD student
Vilnius Gediminas Technical University,
Sauletekio Avenue, 11 10223 Vilnius, Lithuania
E-mail: diana.daskevic@vilniustech.lt