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The Investigation on the Application of Digital Technologies for Logistics Business Competitiveness

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Abstract: The logistics sector's performance is integral to nations' economic and industrial progress. The advent of digital technologies marks a monumental historical shift, impacting worldwide transformations in structural organization, business strategies, economic principles, and regulatory frameworks. The landscape of logistics management provides a fertile ground for integrating these digital advancements, as exemplified by the dynamic emergence of logistics 4.0. This study evaluates how implementing digital technology profoundly influences logistics management's competitiveness in the business context. The study investigates applying digital technologies within the logistics sector using multi-stage methodology, which integrated different methods: the formation of hierarchy of quantitative methods and the application of statistical data analysis methods. Statistical data analysis helps to collect knowledge about logistics business, the application of digital technologies and its performance within European Union (EU) countries. The application of hierarchy of quantitative methods allows to compare the applications of various technologies with digital technologies and the competitiveness of various sectors with logistics sector competitiveness. These findings accentuate the intricate interplay between technological advancement and competitiveness within the logistics sector. The study contributes to a deeper comprehension of how digital technologies reshape competitive dynamics and lays the foundation for refined logistics practices in an increasingly digital-driven world.

Keywords: applications; digital technologies; hierarchy of methods; logistics management

1 INTRODUCTION

The study explores how embracing digital technologies opens up added value business prospects for logistics companies, offering opportunities to optimize operations, enhance supply chain visibility, and boost overall efficiency. Propelled by emerging technology trends, a growing worldwide competitive environment, and rapidly evolving customer expectations, businesses are driven to look at how top management could leverage impending digitalization to enhance the management of their supply chain operations.

Contemporary Industrial Revolution, referred to as logistics 4.0, encapsulates the digital metamorphosis within the production and operations domain, driven by an array of ground-breaking digital technologies. The logistics 4.0 concept is described by progressive ideas, innovative assistant systematical solutions, and not a centralized decision-making approach. These inherent digital technologies greatly enhance the ability to respond to fluctuating demand cases and improve flexible needs management [1].

Specifically, digital technologies assume an active and pivotal function in providing vital logistics and transportation services. An example could be geographical information systems (GIS) or big data analytical approaches that have risen to prominence in harmonizing for managing product demand and supply. Among the business benefits of digital technologies are enhanced operational efficiency, cost reduction, fortified decision formulation, and stakeholder interaction management [2].

The technologies enable the separation of information streams from connected physical shipment flows, allowing for smooth digital data exchange among involved parties [3]. This encourages collaboration and forms the foundation for developing extensive logistics networks. Logistics service provider stands to have value from innovative solutions that could broaden the spectrum and the quality of ancillary service extended to trucks, enterprises, and individuals [4].

Indeed, integrating technologies and automated system approaches fosters the productivity increase, enhancement, amelioration of labor conditions, and refinement of strategic approaches among participants.

Prominent scholarly articles [2] concur that the most auspicious digital technologies for Munich Security Conferences (MSC) encompass advanced printing technologies, Human Machine Interface (HMI), augmented reality, Automated System approaches, Big data analytical applications, Blockchain Technologies, Cloud Computing solutions, Internet-of-Things, Location Detection technology, Mobile devices, Multi-level Customer Interactions, Customer Profiling, and Smart Sensor applications.

Tangible devices, like mobile phones, machinery, and intelligent sensors, remain constantly interconnected with humans and their operational surroundings, resulting in the augmentation of operational performance for logistics firms [5]. Enabling digital technologies has brought transformative changes to various operational aspects of logistics activities.

These digital advancements enhance operational efficiency, customer satisfaction, and competitiveness within logistics centers, fostering agile and responsive supply chains.

The paper consists of five chapters. The paper starts with introduction. The second chapter investigates the applications of digital technologies. The third chapter provides the an in-depth exploration of the application of digital technologies in logistics. The fourth chapter presents methodology, which is later on is applied in following sub-chapters. First su-chapter presents materials and methods used for researching the studies on technologies and business competitiveness. The second sub-chapter is dedicated to the statistical analysis of logistics and technology trends and findings. And finally, the fifth concluding remarks chapter is provided and further research directions are provided.

2 THE APPLICATION OF DIGITAL TECHNOLOGIES: LITERATURE REVIEW

Technologies like the Internet, artificial intelligence, and automation can penetrate different industries and sectors, fundamentally altering how businesses operate and people interact. The principal objective of technologies to elevate a company's effectiveness, with a particular emphasis on bolstering or maintaining competitive advantage. It impacts the ability to broaden markets, enhance product quality, and shift the demand curve for a company's product. It has the potential to reshape a company's cost curve. Another aspect pertains to the favorable transformation in a company's capacity to invest, nurturing the development of new knowledge and expertise.

Given the swift progression of digital technologies such as ubiquitous computing, digital convergence, Web 2.0, service-oriented architecture, cloud computing, and the open-source revolution, a crucial facet of enterprise activity lies in the competence and ability to harness digital technologies. The emergence of digital technology marks a significant paradigm shift, reshaping both organizations and markets. Digital technologies can be categorized as "general-purpose technologies" [6]. Digital technology is closely tied to societal transformation driven by technological advancements, digital technologies are reshaping various aspects of our lives. Digital technologies influence how we communicate, access information, conduct trade, and navigate the world. This comprehensive influence recalls the transformative potential of general-purpose technologies. They can potentially restructure economies, redefine jobs, and even affect our daily concerns. This transformative potential aligns them with general-purpose technologies, historically responsible for profound changes in our ways of living and working.

The Swiss International Institute for Management Development characterizes digital transformation as a profound organizational change propelled by contemporary technologies to amplify business efficiency. This transformation entails utilizing various phenomena from modern information technology, including social media, mobile devices, the Internet of Things, cloud computing, and real-time analytical systems [7].

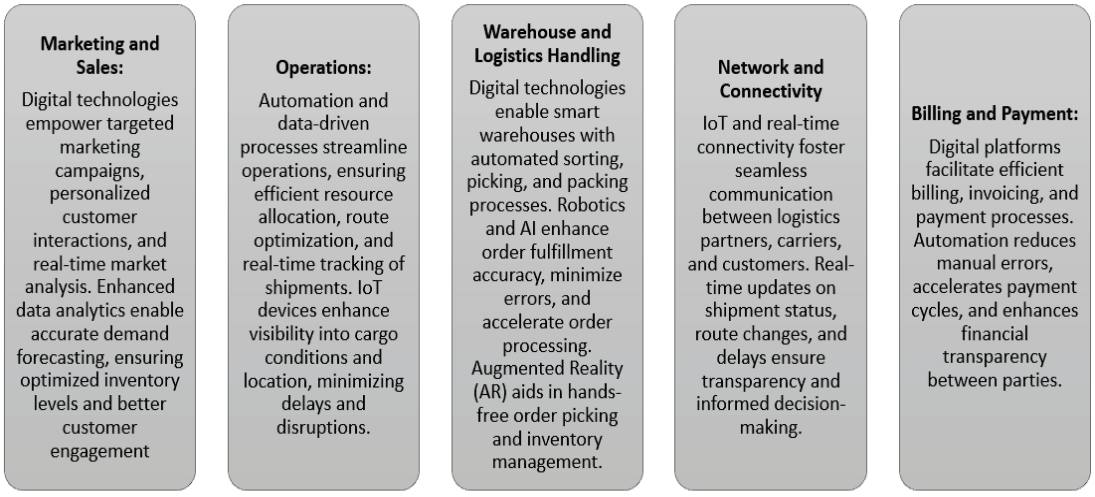

Figure 1 Overview of the primary applications of enabling digital technologies

Digital technologies, enabling the generation of new digitized formats. It goes beyond the simple technical process of converting analog information into a digital format (referred to as "digitization"). Instead, it entails reconfiguring socio-technical systems previously mediated by non-digital artifacts or relationships into systems mediated by digitized artifacts and relationships. This goes beyond mere technical encoding and includes the rearrangement of fresh socio-technical frameworks facilitated by digitized artifacts and alterations to the artifacts themselves. Alternative definitions of digital technology depict it as a technological metamorphosis within a product. We are characterizing digital technology as a result which influence the development of new products and services. With these perspectives in mind, it's evident that digital business is a catalyst for digital technologies, viewed from the perspective of digital technology utilization. Research conducted by the World Economic Forum, involving 14 business sectors, highlights that a higher return on investment in these technologies emerges only when various technologies are thoughtfully integrated [8]. The convergence and synergy of technologies drive the emergence of digital business. A clear causative link suggests that digital technologies are the wellspring within companies, shaping the perception of digital business across diverse sectors. Companies are increasingly reliant on the digitization of the economy. As such, companies must navigate a more dynamically changing external and internal landscape, acknowledging that the company and its entire environment is becoming digitally oriented, ushering in new requirements for business operations [4]. The utilization of contemporary digital technologies, which involves establishing value chains through an innovative management model, shapes the perspective of digital technologies within management methodologies and tools, which foster higher competitive advantage. This aligns with the statement indicating a generational shift in management that requires the integration of digital technologies. To conclude, Fig. 1 provides a concise summary of the key uses of enabling digital technologies across various operational areas related to

logistics. These areas encompass marketing and pre-sales procedures, operations, storage and distribution management, networks and connectivities, invoicing, and paying.

The use of digital technologies in marketing and sales transforms logistics companies to reach a wider audience through online platforms and targeted digital marketing campaigns. Digital technologies make it easy to create easy-to-use websites and mobile apps that provide customers with intuitive and seamless interfaces to track packages, receive offers, and access information, improving the overall customer experience. Digital platforms allow logistics companies to expand their reach and enter new markets, providing a competitive advantage in a globalized and digitally connected business environment. Digital technologies simplify sales processes and help logistics companies manage productivity, track interactions, and analyze data to make informed decisions, increasing sales efficiency. Marketing logistics companies use social media tools to engage audiences, share industry insights, and answer customer questions in real-time, increasing brand visibility and customer satisfaction.

Digital technologies have changed the logistics industry by automating operations and data-driven processes. Digital technologies are changing the way the logistics industry operates by real-time monitoring, automating, optimizing logistics processes, and improving overall operational efficiency. Not only does this automation improve work efficiency, but it also provides real-time data analytics, ensuring informed decision-making and better operations. Digital solutions and data analytics tools enable logistics companies to analyze large amounts of data, gain valuable performance insights that can help you make strategic decisions, and help you continuously improve overall performance. The deployment of Internet of Things (IoT) devices, such as GPS trackers and sensors, will allow logistics companies to track the location, status, and status of shipments, providing greater visibility and control over logistics operations.

Digital technologies have changed the warehouse and logistics handling in the logistics business. Digital warehouse management systems (WMS) simplify inventory management, order fulfillment, and distribution, reduce errors, and improve overall warehouse and processing process efficiency. Inventory management and tracking accuracy have significantly improved the implementation of automated systems, such as barcode scanners and RFID tags. The integration of artificial intelligence and machine learning algorithms makes it possible to actively monitor, predict need, and make advanced decisions, further simplifying warehouse and logistics operations. Real-time tracking systems provide real-time information on inventory levels, shipment status, and shipment updates. Artificial intelligence and machine learning algorithms improve the optimization and planning of transport routes, enabling logistics companies to reduce costs, reduce fuel consumption, and reduce delivery times. Digital technologies will also help with preventative maintenance in the logistics sector, helping companies monitor the status of their vehicles and equipment, prevent breakdowns, and ensure a reliable and efficient fleet of vehicles.

Digital technologies have played an important role in improving the connectivity of manufacturers, suppliers, and customers. The connection of the logistics network has been improved, allowing companies to operate more efficiently. Cloud platforms enable seamless cooperation and data sharing between different stakeholders, including suppliers, manufacturers, and distributors, ensuring better coordination and efficiency. Digital technologies have facilitated connectivity between manufacturers, suppliers and customers, ensuring more efficient and personalized interaction throughout the value chain. They provide real-time information on inventory levels, production schedules, and delivery status, ensuring effective coordination between manufacturers and suppliers.

Digital technologies have fundamentally changed the billing and payment processes in the logistics sector and increased competitiveness. The introduction of online payment gateways and digital wallets allows for faster and more secure transactions, reducing reliance on traditional paper invoices and manual payment processing. Automated clearing systems simplify the clearing process, reduce the number of errors and delays, and improve liquidity management. Digital technologies can track and control payments in real-time, ensuring transparency and reducing the risk of fraud. Digital technologies make it possible to integrate billing and payment data with analytical tools, provide valuable insights, provide personalized payment and payment options, and thus increase customer loyalty through satisfaction, which is essential for the competitiveness of logistics companies.

Digital technologies facilitate enhanced accessibility and analysis of information, thereby promoting mobility. These tools govern logistics activities, which prompts a pertinent exploration of digital technologies in logistics management. This interaction gives rise to digital supply chains and hybrid digital manufacturing systems, both essential and traditional components of the logistics chain.

Research often scrutinizes innovative processes from a technological or a managerial mindset perspective but seldom considers both simultaneously. It is contended that technology and thought processes should be jointly analyzed since they fundamentally share common elements, albeit at distinct interaction levels.

The integration of digital technologies into logistics has led to the emergence of what is known as intelligent logistics or smart logistics. The term "intelligent" is used to describe contemporary technological advancements and further elaborates that anything streamlining human efforts and automating tasks can be characterized as "smart" [5].

In the industry, it is indicated that the transport and logistics (T&L) sector is at the forefront of embracing novel digital technologies, surpassing other industries with a participation rate of 90%, compared to 83% in other sectors. The expansion of the transportation and logistics sector is spurred by improved transport infrastructure and streamlined business processes. Improved infrastructure, in return, has a positive impact on logistics processes that are flexible and scalable. The integration and utilization of digital technologies within companies while concurrently prompting changes in logistics management aimed at securing or gaining a competitive advantage.

3 REVIEW OF THE APPLICATION OF DIGITAL TECHNOLOGIES IN LOGISTICS: AN IN-DEPTH EXPLORATION

The integration of digital technology into the logistics sector, often referred to as "intelligent logistics" or "smart logistics," has brought about a transformative revolution in the transportation, storage, and management of goods throughout the supply chain. This digital integration has significantly enhanced efficiency, transparency, and optimization across various aspects of logistics operations [4].

Here are some key areas presented in Fig. 2 where digital technology is being implemented in the logistics industry.

Regulatory compliance and documentation (i.e. compliance with laws and written documents) plays an important role in improving the competitiveness of logistics companies and ensuring compliance with legal and industry standards. Compliance with regulatory requirements helps build trust and reliability from customers, partners, and institutions, contributing to the logistics company's reputation in the market. Compliance certification can give logistics companies a competitive advantage when it comes to offering contracts, as customers often prefer service providers with proven compliance expertise. Compliance with transportation, customs, or security regulations helps avoid supply chain disruptions and increases reliability and continuity of services. Active compliance management and reliable documentation procedures not only reduce risks, but also contribute to profitability by avoiding fines, penalties, and litigation costs, thereby supporting the overall competitiveness of logistics operations. Accurate and well-maintained records ensure smooth and efficient work, reduce the risk of errors, delays, and any legal issues that may negatively affect the company's competitiveness. Digital documentation replaces paper-based processes with electronic formats and platforms, improving efficiency, reducing waste, enhancing collaboration, and expediting document processing. Electronic documentation and digital signatures streamline regulatory compliance processes. Electronic Data Interchange (EDI) streamlines communication through standardized digital formats, facilitating seamless communication between systems and organizations.

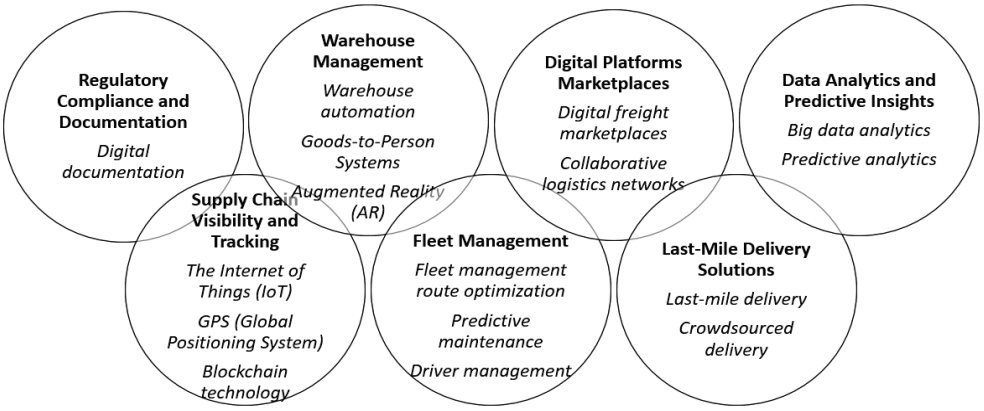

Figure 2 Selected solutions resulting from the implementation of digital technology in the area of logistics

Supply chain visibility and tracking is key to increasing the competitiveness of logistics companies by providing real-time information on the movement and status of goods in the supply chain. Better visibility enables better decision-making, allowing logistics managers to actively address potential issues, allocate resources efficiently, and reduce lead times, helping to increase customer satisfaction. Transparent supply chain transparency allows logistics companies to implement data-driven strategies such as demand forecasting and inventory management, cost reduction, and overall efficiency improvements. The ability to track shipments and inventory levels in real-time allows logistics companies to streamline operations, simplify processes, and respond quickly to any disruptions or changes in demand. Real-time monitoring not only helps avoid delays and roadblocks, but also improves communication and cooperation between stakeholders, fostering closer relationships with suppliers, carriers, and customers. In a competitive market, the ability to provide accurate and up-to-date information on the location and condition of goods builds trust and reliability by positioning the logistics company as the best partner for customers looking for efficiency and visibility in their supply chain. There are several examples. The Internet of Things (IoT) represents a network of interconnected devices capable of autonomously collecting, exchanging, and analyzing data. These devices, equipped with sensors and software, operate without human intervention, collecting and transmitting real-time data about goods' location, temperature, humidity, and other conditions. This technology provides unprecedented visibility into the entire supply chain, impacting industries and everyday life through increased efficiency, automation, and convenience [2]. Global Positioning System (GPS) and telematics technologies are pivotal in real-time vehicle tracking and management. In industries like transportation and logistics, they enhance navigation, monitoring, and operational efficiency. GPS and telematics devices are deployed in vehicles, containers, and assets to facilitate real-time tracking, route optimization, and proactive issue resolution. These technologies empower organizations with immediate insights into asset locations, conditions, and performance, fostering informed decisions, safety improvements, and overall operational efficiency [3]. Blockchain technology introduces a secure, transparent, and tamper-resistant

platform for recording and sharing information, promising to revolutionize supply chain visibility and tracking. Addressing conventional supply chain challenges like transparency, and data consistency, blockchain ensures data integrity and transparency, making records difficult to alter and creating a trustworthy transaction ledger.

Warehouse management deploys technology and machinery to streamline various warehouse operations. Utilizing robotics, sensors, and software enhances efficiency, accuracy, and productivity in storage, picking, packing, and shipping tasks. Warehouse automation encompasses a range of aspects, including goods-to-person systems, picking and packing automation, sorting and conveying, Automated Guided Vehicles (AGVs), robotic palletizing and depalletizing, goods handling, inventory management, Automated Storage and Retrieval Systems (AS/RS), Warehouse Control Systems (WCS), and data analytics. These aspects collectively increase efficiency, accuracy, space optimization, labor savings, 24/7 operations, faster order fulfillment, and scalability.

However, successful implementation requires careful planning, system integration, technology investment, and considerations for maintenance and employee training [9].

Augmented Reality (AR) enriches users' interaction with their physical environment by superimposing digital information and objects onto the real world. AR can enhance worker productivity, accuracy, and efficiency in warehouse management. Benefits include increased productivity, reduced errors, faster onboarding, enhanced accuracy, improved safety, and real-time data access. Fleet management route optimization is crucial in ensuring cost-effective and efficient vehicle movements. It employs technology and data to plan, optimize, and adjust routes, reducing travel time, fuel consumption, and operational costs and improving delivery times. Algorithms utilize real-time data such as traffic conditions, weather, and delivery priorities for route optimization, leading to cost savings, time efficiency, improved customer satisfaction, reduced emissions, and enhanced asset utilization.

Predictive maintenance uses data analysis and technology to forecast equipment or asset failures, enabling timely maintenance and reducing downtime. In logistics, this approach is essential for ensuring smooth operations. Driver management involves coordinating, monitoring, and optimizing driver activities and performance, promoting safe, efficient, and compliant operations through digital tools.

Digital platforms marketplaces facilitate efficient digital connections between shippers and carriers, streamlining freight transactions and offering transparency, collaboration, and cost-effectiveness. Real-time updates in logistics provide stakeholders with timely, accurate information to make informed decisions and respond to changes quickly. Self-service tools empower customers, partners, and stakeholders to manage logistics-related tasks, independently enhancing efficiency and user experience. Optimized routing employs technology and algorithms to determine efficient and eco-friendly transportation routes, minimizing emissions while considering factors like traffic, delivery windows, and vehicle capacity. It contributes to sustainable transportation practices and operational efficiency. Collaborative logistics networks are strategic partnerships among logistics stakeholders, aiming to enhance supply chain efficiency and performance through shared resources, information, and expertise. Both approaches leverage digital platforms to promote cooperation and cost savings, contributing to operational improvements and competitive advantages. Real-time communication and collaboration platforms enable instant information exchange and coordination among supply chain stakeholders, enhancing efficiency and responsiveness.

Last-mile delivery solutions, including delivery drones, robots, and crowdsourced delivery, are transforming the final step in logistics. These innovative approaches offer efficient, fast, and cost-effective last-mile delivery while addressing congestion, distance, and urbanization challenges.

Data analytics and predictive analytics are reshaping the logistics sector by providing valuable insights, optimizing operations, and enhancing decision-making. Big data analytics processes vast supply chain datasets to uncover patterns, trends, and correlations, while predictive analytics utilizes historical and real-time data for informed decisions and operational optimization.

Carbon footprint tracking measures, monitors, and manages greenhouse gas emissions across the supply chain to promote sustainability. Digital tools support sustainability goals by measuring and managing the environmental impact of logistics operations.

This transformation encompasses various facets of logistics operations, from supply chain visibility to last-mile delivery, predictive analytics, and environmental sustainability. Embracing digital transformation is key to achieving greater efficiency, reducing costs, enhancing customer experience, and staying competitive in the ever-evolving logistics landscape. Digital documentation is fundamental in streamlining processes, improving collaboration, and increasing overall supply chain efficiency.

4 METHODOLOGY

The study is based on multi-stage methodology, which aims to reach conceptual understanding about the phenomena. First, the knowledge has to be collected from the publications presented on the topic. Second, the knowledge has to be collected from the data describing logistics business.

Several methods were used to reach the goal. For the first stage, the authors used a hierarchy of quantitative methods and for the second stage -statistical data analysis method.

The authors examined the application of digital technologies within the logistics business. Over time, researchers have shown a keen interest in analyzing technologies. This exploration of technologies has given rise to entirely new concepts and methods, particularly within mathematics and science.

To refine methods beneficial for problem-solving, a hierarchical approach can be adopted to discern the model's type, technique, and specific methods within a category. The authors present the hierarchy of quantitative methods which is used for the investigation studies in the scholarly field.

During statistical analysis the authors identified the concentration of logistics business by countries; the application of various digital technologies (for inventory

management, fleet management, RFID, AI, etc.) in logistics sector across EU countries.

The authors presented the results of the study in two sub-chapters presented below. The first sub-chapter includes the formation of the hierarchy of quantitative methods in several directions, which specify a) the application of technologies compared with digital technologies; b) business competitiveness studies compared with logistics business competitiveness studies. Finally, the summary of various modeling techniques and their corresponding solution methods in the context of the logistics sector is provided. The second sub-chapter presents statitistical analysis provided on the application of digital technologies in logistics business.

4.1 Materials and Methods on Researching the Studies on Technologies and Business Competitiveness

Five primary categories are employed, beginning with the mathematical programming category, progressing to model-based methods, refining heuristic and hybrid models, and concluding with analytical models. Modeling methods vary in their nature and pertain to one or several objectives.

First, in this research, the authors analyzed the methods used for studies researching the application of technologies and digital technologies. To address these issues, various methods were employed and categorized in Tab. 1. Tab. 1 summarizes and provides a hierarchy of quantitative methods and models.

Among the methods, the most popular is the network model in studies dedicated to the differences in researching technologies and digital technologies. In ICT research, the application of such methods is in its early stages but holds significant potential for analyzing various aspects of cloud technology. In principle, the authors investigate the technologies that help to increase efficiency, save energy, and form suitable conditions for achieving optimal resource allocation to maximize output.

Table 1 The hierarchy of quantitative methods and models for investigating the application of technologies and digital technologies

Types	Modeling technique	Solution methods	Authors investigating technologies	Authors investigating digital technologies
Mathematical programming methods	Single-objective	Bi-level linear programming (LP) Multi-objective mixed integer linear programming (MILP) Fuzzy-goal programming Polynomial dynamic programming Queuing model Non-linear programming	[7]	[7-8]
	Multi-objective			
Simulation methods	System dynamics (SD)		[9]	
	Discrete event (DES)			[10]
Heuristic methods	Simple heuristic	Simulated annealing heuristics (SAH)	[11]	
	Artificial intelligence (Al) techniques	Markov chains Object-oriented Petri nets Bayesian network modeling Fuzzy logic Artificial Neural network Grey system and rough sets	[12-13]	[14]
	Meta-heuristic	Genetic Algorithm (GA) Evolutionary Algorithm (EA) Differential evolution algorithm (DEA) Particle swarm optimization (PSO) Ant Colony Optimization Greedy Randomised Adaptive search procedure	[15-16]	[17-18]
Hybrid model	Hybrid simulation	SD-DES		[19]
Analytical model	Multi criteria decision making (MCDM)	Analytical hierarchy process (AHP)	[20]	

Source: Own elaboration

The authors identified that mathematical programming methods are rarely mentioned among above listed quantitative methods. Time series analysis could help to identify factors that support the activation of the application of digital technologies that is required.

Later, the authors presented the application of methods for studies analyzing competitiveness. By delivering investigations on applied techniques, the authors compared which quantitative methods in which studies were the most popular. Many studies on business competitiveness lack the application of mathematical programming methods, such as Bi-level linear programming (LP), Multi-objective mixed integer linear programming (MILP), and simple heuristic simulated annealing heuristics (SAH) method, as specified in Tab. 2.

Many studies on logistics competitiveness focus on applying simple heuristic and meta-heuristic approaches. In addition, different methods have been used in logistics system competitiveness, such as simulated annealing heuristics (SAH), Genetic Algorithm (GA), Evolutionary Algorithm (EA), Differential evolution algorithm (DEA), Particle swarm optimization (PSO), Ant Colony Optimization, Greedy Randomised Adaptive search procedure, etc. However, we could also identify methods that have not yet been explored and applied in studies, i.e., three methods from artificial intelligence (Al) techniques: Object-

oriented Petri nets, Bayesian network modeling, and Fuzzy logic.

Subsequently, the authors devised a framework that could enhance the logistics sector's competitiveness for Descriptive Analysis in the context of investigating the application of technologies in the logistics sector, modeling techniques, and solution methods focused on summarizing and presenting data meaningfully without necessarily predicting outcomes or identifying causal relationships.

Descriptive analysis provides insights into trends, patterns, and distributions within the data [19]. Here's how modeling techniques and solution methods can be applied at this level. Each level of the hierarchy builds upon the previous one, allowing for a more in-depth and comprehensive analysis of the impact of digital technologies on the logistics sector. Descriptive analysis in the logistics sector involves data and statistical techniques to summarize, visualize, and understand various aspects of logistical operations. This type of analysis aims to provide insights into patterns, trends, and characteristics of logistical processes, which can help organizations make informed decisions and improve their overall efficiency.

Table 2 The hierarchy of quantitative methods and models for investigating business and logistics competitiveness

Types	Modeling technique	Solution methods	Authors investigating business competitiveness	Authors investigating logistics business competitiveness
Mathematical programming methods	Single-objective	Bi-level linear programming (LP)	[21]	[22]
	Multi-objective	Multi-objective mixed integer linear programming (MILP) Fuzzy-goal programming Polynomial dynamic programming Queuing model Non-linear programming		
Simulation methods	System dynamics (SD)		[23]	[24]
	Discrete event (DES)		[25]	[26]
Heuristic methods	Simple heuristic	Simulated annealing heuristics (SAH)		[27]
	Artificial intelligence (Al) techniques	Markov chains Object-oriented Petri nets Bayesian network modeling Fuzzy logic Artificial Neural network Grey system and rough sets	[28]	[29]
	Meta-heuristic	Genetic Algorithm (GA) Evolutionary Algorithm (EA) Differential evolution algorithm (DEA) Particle swarm optimization (PSO) Ant Colony Optimization Greedy Randomised Adaptive search procedure	[30]	[31]
Hybrid model	Hybrid simulation	SD-DES	[32]	
Analytical model	Multi criteria decision making (MCDM)	Analytical hierarchy process (AHP)	[33]	

Source: Own elaboration

Comparative analysis in the logistics sector involves comparing different sets of data, metrics, or processes to identify similarities, differences, and trends [34]. This type of analysis helps organizations make informed decisions by evaluating various options, strategies, or scenarios within their logistics operations. Correlation analysis in the logistics sector involves examining the relationships between different variables or factors to determine whether and to what extent they are related. Correlation analysis helps logistics professionals understand how changes in one variable might be associated with changes in another, which can provide valuable insights into the dynamics of logistical operations. Regression analysis in the logistics sector involves using statistical techniques to model and analyze relationships between variables, particularly to predict or explain outcomes. Regression analysis is useful in understanding how changes in one or more independent variables are associated with changes in a dependent variable. Regression analysis can provide insights into various aspects of supply chain and operational performance in the logistics sector. Regression analysis helps organizations make data-driven decisions by quantifying relationships between variables and providing predictive insights. Taking into account factors such as model assumptions, potential multicollinearity (when independent variables are correlated), and the need for validation and refinement of the models. Optimization models are critical in improving efficiency, reducing costs, and making informed decisions within the logistics sector. These models use mathematical techniques to find the best possible solution to complex logistical problems. Optimization models in logistics often require advanced mathematical techniques, algorithms, and specialized software tools to solve complex problems efficiently. However, it's important to consider real-world constraints, data quality, and the dynamic nature of logistical operations when applying optimization models. Simulation models are used in logistics to replicate real-world processes and operations in a virtual environment. These models allow organizations to analyze and understand the behavior of complex logistics systems, test various scenarios, and make informed decisions without directly affecting the actual operations. Predictive analytics in the logistics sector involves using historical and current data to forecast future trends, outcomes, and events. By leveraging

advanced statistical and machine learning techniques, predictive analytics helps logistics professionals make informed decisions, optimize operations, and enhance supply chain efficiency. Supply chain network models are strategic tools used in logistics and operations management to design, optimize, and analyze the structure of a supply chain. These models help organizations make informed decisions about the location of facilities, distribution centers, suppliers, and customers to achieve cost-efficiency, responsiveness, and overall supply chain performance. Supply chain network models are strategic tools used in logistics and operations management to design, optimize, and analyze the structure of a supply chain. These models help organizations make informed decisions about the location of facilities, distribution centers, suppliers, and customers to achieve cost-efficiency, responsiveness, and overall supply chain performance. Supply chain network models often involve mathematical optimization techniques, including linear programming, integer programming, and heuristic algorithms. These models provide insights into how network structure, processes, and resource changes impact key performance indicators such as cost, lead time, and customer service. Agent-based modeling (ABM) is a computational modeling technique used in logistics to simulate and study the behavior and interactions of individual agents within a complex system. In logistics, agents can represent various entities such as customers, suppliers, vehicles, warehouses, and other supply chain components. ABM allows for the exploration of emergent behaviors and the impacts of individual decisions on the overall logistics system. Complex systems modeling in logistics involves studying and understanding the intricate interactions, interdependencies, and emergent behaviors within complex logistics networks. Logistics operations are often characterized by numerous variables, nonlinear relationships, and dynamic changes, making them prime candidates for complex systems modeling. This approach helps capture the logistics ecosystem's complexities and gain insights into how various factors influence overall system behavior. Complex systems modeling in logistics often involves techniques like network theory, agent-based modeling, system dynamics, and computational simulation. However, due to the intricate nature of complex systems, these models may require significant data, expertise, and validation efforts to ensure accuracy and relevance. The hierarchy of quantitative methods and models for investigating the application of digital technologies in the logistics sector is provided in Tab. 3.

Tab. 3 summarizes various modeling techniques and their corresponding solution methods in the context of the logistics sector. In summary, certain modeling techniques like descriptive analysis, comparative analysis, correlation analysis, regression analysis, optimization models, and predictive analytics are more widely employed in logistics due to their practical applicability and effectiveness in addressing operational challenges. Agent-based modeling and complex systems modeling are less commonly used, often requiring more specialized knowledge and resources, possibly requiring abundant data and intricate computer simulation aspects. Consequently, this method might be less studied due to its demand for more comprehensive knowledge and resources. Complexity science and complex systems modeling are rather recent and specialized domains that could be less explored in the logistics sector. This method delves into dynamic processes and nonlinear interactions, which could present challenges when analyzing complex logistics networks. The application of novel or specific machine learning algorithms in the logistics context might be less researched, particularly if these algorithms have emerged recently or aren't traditionally within the focus of logistics research. While mentioned, the comparative analysis method might not be discussed as extensively as other modeling methods. This could indicate that this method might be less explored in the relevant context.

These techniques provide tools for analyzing and optimizing different aspects of logistics operations, considering various data-driven and mathematical approaches.

Table 3 The hierarchy of quantitative methods and models for investigating the application of digital technologies in the logistics sector

Types	Modeling Techniques	Solution Methods
Descriptive Analysis	Charts, graphs, histograms, heatmaps, time series plots	Data aggregation, visualization tools, basic statistical measures, pre-processing, segmentation, narrative, and reporting
Comparative Analysis	Comparative studies between different technologies or processes	Benchmarking, performance metrics, cost analysis, efficiency ratios
Correlation Analysis:	Correlation matrices, scatter plots	Correlation coefficients (Pearson, Spearman), scatter plot interpretation
Regression Analysis	Linear regression, multiple regression, logistic regression	Coefficient interpretation, hypothesis testing, prediction modeling
Optimization Models	Linear programming, integer programming, network optimization	Algorithmic optimization, sensitivity analysis, constraint analysis
Simulation Models	Discrete-event simulation, agent-based simulation	Scenario testing, sensitivity analysis, experimentation
Predictive Analytics	Time series analysis, forecasting models	ARIMA, exponential smoothing, machine learning algorithms
Supply Chain Network Models	Network optimization, supply chain mapping	Network optimization algorithms, strategic decision-making
Agent-Based Modeling	Simulating individual agents' behavior and interactions	Agent behavior rules, interaction dynamics, emergent behaviors
Complex Systems Modeling	Systems dynamics, complexity science	Understanding non-linear interactions, emergent properties, feedback loops

Source: Own elaboration

4.2 Statistical Analysis of Logistics and Technology Trends and Findings

The contribution of the logistics sector to the economy of EU countries is obvious. 10 million people work in the sector. employees (5.2% of all employed in the EU), and its contribution to GDP is 5% [35]. According to the EU

Commissioner for Logistics by 2050 the volumes of this sector will increase by 50%, and the application of digital technologies will be even more relevant for companies in the logistics sector.

Digitization in the logistics sector can help increase efficiency by up to 25%. Such a result is caused by the orientation of users of the logistics business and the services it provides to the use of the advantages provided by digital technologies [35]. 65% of logistics companies recognize the transition to a digital business model to remain competitive in the digital age. As a result of the application of digital technologies in logistics, it is possible to reduce the consumption of material resources and energy and increase the sector's capacity, i.e. increase the competitiveness of the logistics sector [35].

Understanding the intersection of logistics and technology is paramount in today's rapidly evolving business landscape. Eurostat data reveals the significant role played by the logistics sector in the European Union and provides statistics on the utilization of digital technologies within EU businesses. This analysis sheds light on both the opportunities and disparities in technology adoption across EU countries, underscoring the importance of integrating digital tools to enhance competitiveness within the logistics sector.

Eurostat data reveals that the logistics sector comprises 5.4% of the total number of companies in the European Union, contributing significantly to the region's total added value and employment at 7.9%. The labor productivity ratio within the EU's logistics sector stands at 12%.

Fig. 3 provides a snapshot of the concentration of logistics business activity across EU countries, showcasing notable disparities. Germany (DE) takes the lead with a 20% share in both value added and employment, followed by France (FR) at 40% and 38%, respectively. Italy (IT) emerges as the frontrunner with a remarkable 50% share in added value and employment at 43%, showcasing notable disparities that warrant further exploration for enhancing competitiveness in the logistics sector [35].

This data underscores significant disparities in value-added and employment levels across these countries, offering valuable insights for further analysis and enhancing competitiveness in the logistics sector.

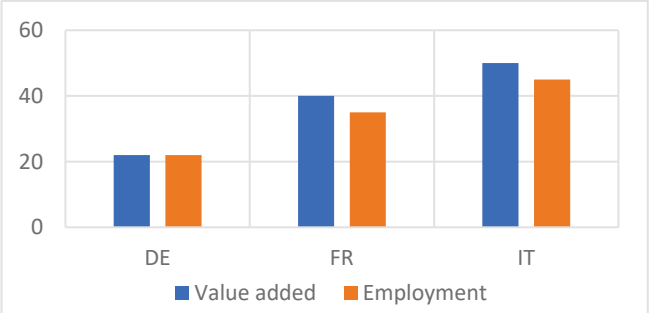

Figure 3 Concentration of logistics business
Source: Eurostat [35]

Tab. 4 provides information about status on logistics activity digitalisation in various European Union countries. The table covers the following categories and numbers:

1) Enterprises that use digital technologies for inventory management;
2) Enterprises that use digital technologies for the management of logistics activities;
3) Enterprises that use radio frequency identification technologies (RFIDs);
4) Enterprises that use digital fleet management technologies.

Table 4 Comparison of application of digital technologies across logistics sectors in European Union countries

Country	Enterprises that use digital technologies for inventory management	Enterprises that use digital technologies for the management of logistics activities	Enterprises that use RFIDs	Enterprises that use digital fleet management technologies
Germany	9 845	7 290	6 790	4 603
Italy	7 493	6 973	5 142	3 534
France	4 230	2 632	2 614	1 972
Portugal	2 051	1 275	1 134	863
Sweden	1 888	:	:	870
Romania	658	359	232	354
Greece	835	741	433	458
Poland	852	1 024	566	457
Hungary	540	616	196	186
Slovakia	275	272	259	144
Lithuania	363	161	119	275
Bulgaria	377	254	364	160
Croatia	342	320	272	166
Slovenia	342	187	248	142
Estonia	228	89	112	82
Latvia	90	57	44	52
Luxembourg	118	78	49	88
Malta	43	20	10	35

Source: Eurostat [35]

Among the European Union countries analyzed in the logistics sector, Germany, Italy, and France emerge as leaders. These nations demonstrate noteworthy efforts and investments in reshaping the logistics landscape.

Germany holds a competitive edge due to its substantial applications of digital technologies for inventory management, extensive efforts to implement and improve digital logistics technologies, a significant use of RFIDs, and a high number of fleet management technologies. This positions Germany as a leader in logistics digitalisation, showcasing a comprehensive approach across various technological aspects of supply chain management. The country demonstrates a comprehensive approach to embracing new delivery models and the automatic identification of products throughout the supply chain.

Italy shows strengths in its commitment to digital technologies in logistics, with considerable usage of inventory management technologies, robust efforts to implement and enhance digital logistics technologies, a notable applications of RFIDs, and a significant number of enterprises applying fleet management technologies. This places Italy as a significant player in embracing technological

advancements across its logistics sector. The country is actively exploring new delivery models and unique product identification across the entire supply chain, emphasizing a multifaceted approach to advancing its logistics sector.

France, while not at the same level as Germany and Italy in terms of numbers, showcases strengths in its focus on digital logistics technologies. It has made noteworthy applications of inventory management systems, efforts to improve digital logistics technologies, a moderate implementations of RFIDs, and a reasonable number of fleet management technologies. This indicates a developing approach towards embracing technological advancements within its logistics landscape.

Each country showcases its strengths in distinct aspects of digital technology application within the logistics sector, contributing to their respective positions in the global logistics landscape. While Germany, Italy, and France demonstrate robust digital technology in the logistics sector, other countries in the table exhibit varying degrees of progress. Some nations may be characterized by fewer or lower applications levels, indicating a relative lag compared to the leaders. It is crucial for these countries to consider strategies for catching up and fostering digital technologies within their logistics industries to stay competitive in the rapidly evolving landscape.

In Fig. 4, we compare enterprises across EU countries that use at least one AI technology. It is evident that the share of such enterprises ranges from 1% to 24%. Denmark has the highest share at 24%, followed by Portugal at 17% and Finland at 16%. In contrast, the lowest shares are found in Romania at 1% and Bulgaria, Estonia, Cyprus, Hungary, and Poland at 3% [35].

These findings shed light on the varying adoption rates of digital technologies across EU member states and highlight the potential for further growth and development in this important sector.

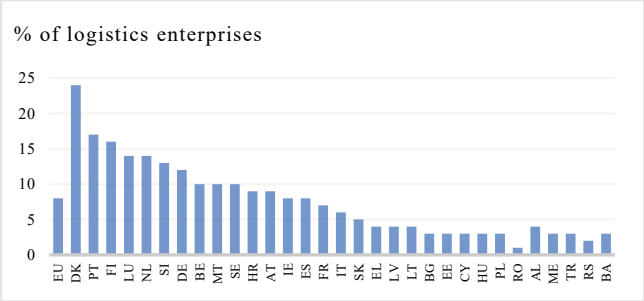

Figure 4 Logistics enterprises using at least one AI technology
Source: Eurostat [35]

The data highlights both the opportunities and disparities in adopting digital technologies across EU countries, emphasizing the importance of promoting the integration of digital technologies to unlock their potential to enhance competitiveness within the logistics sector.

The data clearly indicates that the logistics sector has not fully embraced digital technologies, presenting a significant growth opportunity for this industry. By increasing the adoption of digital technologies in logistics, companies can enhance the efficiency of their supply chains, optimize routes, reduce both time and costs and improve customer service. This boost in competitive advantage has the potential to stimulate growth within the logistics industry and contribute to an overall increase in competitiveness.

Fig. 5 illustrates the variation in the use of digital technology across different economic activities, suggesting significant disparities in its relevance and adoption levels. This analysis allows us to gain insights into the diverse landscape of digital technology utilization in various sectors.

Notably, within this context, we observe that the logistics sector exhibits relatively lower levels of digital technology adoption, as indicated in the figure. This finding highlights potential areas for growth and improvement within the logistics industry [35].

In summary, Fig. 5 provides valuable insights into the varying adoption levels of digital technology across economic activities, particularly emphasizing opportunities for advancement in the logistics sector.

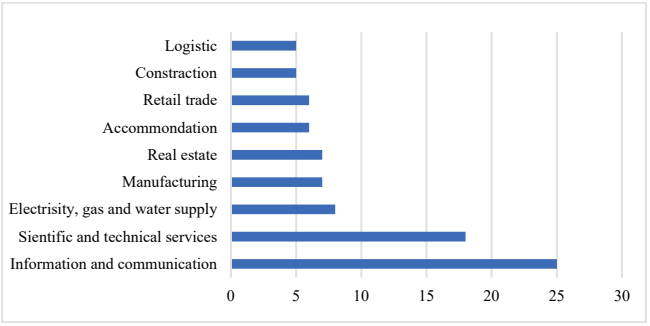

Figure 5 Enterprises using AI technologies by economic activity
Source: Eurostat [35]

This analysis emphasizes that understanding the interaction between logistics and technology is crucial in the rapidly changing context of today's business environment. This is essential to leverage opportunities and address disparities in technology adoption across European Union (EU) countries.

Eurostat data reveals the importance of the logistics sector in the EU, providing statistics on the utilization of digital technologies in businesses. This analysis provides insights into both opportunities and disparities in technology adoption, highlighting the importance of integrating digital tools to enhance competitiveness in the logistics sector. Analyzing the concentration of logistics activity reveals significant differences between countries. Germany, Italy, and France stand out as logistics sector leaders in application of digital technologies, but some countries lag behind, demonstrating fewer or lower interest. The table presents information on the efforts and investments of various EU countries in the logistics sector and the implementation of different technologies.

By increasing the adoption of digital technologies in logistics, companies can enhance the efficiency of their supply chains, optimize routes, reduce costs. This not only increases competitive advantage but also stimulates growth in the logistics industry and contributes to overall

competitiveness. Despite variations between countries, it is clear that the logistics sector still has considerable growth potential through the adoption of digital technologies.

This multifaceted analysis illuminates the intricate interplay between logistics and digital technology, highlighting the need for agile adaptation and innovative strategies in the logistics sector to thrive in the evolving business landscape.

5 CONCLUSION

The theme on digitalisation receives special attention. The statistical analysis shows that countries with the highest logistics sector concentration have the biggest applications numbers in digital technologies.

As a result of literature revision, the authors have identified that covered papers pay a special attention to the topic of digital technologies in logistics.

Digital technology exerts a substantial influence on augmenting the competitiveness of the logistics sector. It enables companies to operate more efficiently, improve operations and sales.

Digital technology is pivotal in managing inventory, warehouse and logistics handling, fleet management, and improving other logistics functions. Real-time tracking and data analysis empower logistics companies to make informed decisions, while electronic traceability systems ensure product quality.

In conclusion, the various analytical techniques employed in the logistics sector serve as invaluable tools for understanding and enhancing operational efficiency.

The authors presented the hierarchy of methods and models used for the researches on the topic. However, it's important to note that the field of logistics is constantly evolving, and researchers are always exploring new methods and approaches to gain deeper insights and improve operations. So, by construction the hierarchy of methods such aspect was taken into account. After, the construction of the hierarchy of methods and models, the authors revised which methods are applied for researching different topics such as technologies and digital technologies, business comptetitiveness and logistics competitiveness.

The author identified that among the methods, the most popular is the network model in studies dedicated to technologies. The authors identified that mathematical programming methods are rarely mentioned among quantitative methods used to research technologies.

Many studies on business competitiveness lack the application of mathematical programming methods, however, artificial intelligence (Al) techniques are also rarely used. And studies researching logistics business competitiveness are still behind with multi criteria decision making (MCDM) method applications.

Although the text extensively discusses various modeling techniques, it does not discuss potential limitations, challenges, or drawbacks.

A research gap could be related to a deeper study that requires future research on the limitations and practical challenges of applying these modeling methods in logistics.

This research can provide valuable insights into the utility and accuracy of these techniques in the real world and help practitioners make more informed decisions based on their strengths and weaknesses. In future the research could be given to practical decision making approach development.

In conclusion, the amalgamation of these diverse analytical approaches not only aids in addressing current challenges but also positions the logistics industry for a future characterized by informed strategies and optimized performance, ultimately enhancing business competitiveness in the digital era.

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