# DIGITAL TRANSFORMATION IN LOGISTICS: INVESTMENT BARRIERS, COST STRUCTURES, AND STRATEGIC OPPORTUNITIES

**Milena Boskoska Klisaroski**
Ss.Cyril and Methodius University in Skopje, North Macedonia,
milena.boskoska-klisaroski@ek-inst.ukim.edu.mk
**Neda Petroska Angelovska**
Ss.Cyril and Methodius University in Skopje, North Macedonia, neda@ek-inst.ukim.edu.mk
**Zoran Janevski**
Ss.Cyril and Methodius University in Skopje, North Macedonia, zoran.janevski@ek-inst.ukim.edu.mk
**Marija Magdincheva-Shopova**
University Goce Delcev - Stip, North Macedonia, marija.magdinceva@ugd.edu.mk

**Abstract:** The rapid development of digital technologies has significantly influenced the transformation of logistics systems, reshaping operational models, cost structures, and strategic decision-making processes within supply chains. In the context of emerging and transition economies, digital transformation in logistics presents both opportunities and structural challenges. The purpose of this paper is to provide a comprehensive theoretical overview of existing research on digital transformation in logistics in the Republic of North Macedonia and the broader Southeast European region, with a particular focus on investment barriers, cost structures, and strategic opportunities for companies operating in this sector.

The study is based on a qualitative research approach that relies on a systematic review and synthesis of relevant academic literature, institutional reports, and previously published empirical studies addressing logistics digitalization in the regional context. Through comparative and analytical methods, the paper examines the dominant themes and findings in the existing body of research, identifying the main financial, technological, and organizational factors influencing the adoption of digital logistics solutions.

The analysis indicates that companies in North Macedonia and the surrounding region face several structural constraints that hinder the implementation of advanced digital logistics technologies. Among the most frequently identified barriers are high initial investment costs, limited access to financial resources, insufficient digital infrastructure, and a shortage of specialized human capital capable of supporting digital transformation processes. In addition, the literature emphasizes the complexity of the cost structures associated with digital logistics systems, including capital expenditures for technological infrastructure as well as ongoing operational costs related to system maintenance, employee training, and organizational restructuring.

Despite these challenges, previous studies highlight significant strategic opportunities resulting from the adoption of digital logistics solutions. The integration of technologies such as automation, artificial intelligence, Internet of Things (IoT), and advanced data analytics can improve supply chain transparency, enhance operational efficiency, reduce long-term logistics costs, and strengthen the competitive position of firms in regional and international markets.

The contribution of this paper lies in synthesizing and systematizing the existing knowledge on digital transformation in logistics within North Macedonia and the Southeast European region. By identifying key investment barriers, cost implications, and strategic opportunities, the study provides a conceptual foundation for future empirical research and offers insights that may support policymakers, researchers, and business practitioners in designing more effective strategies for the sustainable digital transformation of logistics systems.

**Keywords:** Logistics digitalization, Investment barriers, Logistics cost structures, North Macedonia, Southeast Europe.

## 1. INTRODUCTION

Digital transformation (DT) has become one of the most significant forces shaping modern logistics and supply chain management. The integration of advanced digital technologies such as artificial intelligence (AI), Internet of Things (IoT), big data analytics, cloud computing, and automation is fundamentally transforming traditional logistics operations and enabling the development of more intelligent, data-driven supply chains (Vial, 2019). These technological advancements improve real-time visibility across logistics networks, enhance operational efficiency, and support more effective decision-making processes within organizations. The increasing importance of digital technologies is closely associated with the broader context of the Fourth Industrial Revolution, which is expected to significantly influence logistics and supply chain systems worldwide. The use of interconnected digital devices,

sensors, and automated systems allows companies to collect and analyze large volumes of data, optimize transportation routes, reduce operational inefficiencies, and improve overall supply chain performance (Alicke, Rachor & Seyfert, 2016). As a result, many organizations are investing in digital logistics solutions to enhance competitiveness and respond to rapidly changing market conditions.

Despite these potential benefits, the adoption of digital technologies in logistics is often constrained by several investment barriers. One of the most frequently cited challenges in the literature is the high level of initial investment required to implement digital logistics systems. Companies must allocate significant financial resources for technological infrastructure, automation equipment, information systems, and data management platforms. These financial requirements can represent a substantial obstacle, particularly for small and medium-sized enterprises that may have limited access to capital and external financing (Ivanov, Tsipoulanidis & Schönberger, 2019). In addition to investment barriers, DT also affects the cost structures of logistics operations. The implementation of digital technologies introduces new categories of costs related to system integration, software development, maintenance, cybersecurity protection, and employee training. While these expenditures may increase operational costs in the short term, digital logistics systems often generate long-term economic benefits through improved efficiency, reduced operational errors, and better coordination across supply chains (Hofmann & Rüsch, 2017). At the same time, DT creates important strategic opportunities for companies operating in the logistics sector. By adopting digital technologies, companies can achieve higher levels of operational flexibility, improve customer service, and strengthen their competitive position in global markets. Digital logistics solutions also support more sustainable supply chain practices by optimizing resource utilization, reducing transportation emissions, and improving inventory management (Barreto, Amaral & Pereira, 2017).

Understanding the interaction between investment barriers, evolving cost structures, and strategic opportunities is therefore essential for evaluating the overall impact of DT on logistics systems. Analyzing these dimensions provides valuable insights into the economic and organizational factors that influence the successful adoption of digital technologies in the logistics industry.

## 2. LITERATURE REVIEW

DT represents a comprehensive process of change in business activities, operational processes, and organizational structures through the adoption of digital technologies. It enables companies to improve efficiency, redesign business models, and enhance interactions with customers by digitizing products, services, and communication channels (Vial, 2019; Verhoef et al., 2021). In the logistics sector, DT plays a crucial role in improving supply chain coordination, automating operational processes, and strengthening data-driven decision-making.

Existing studies emphasize that the adoption of digital technologies in logistics often requires significant financial investments and organizational adjustments. Many logistics companies, particularly small and medium-sized enterprises (SMEs), face limitations related to financial capacity, technological readiness, and availability of qualified personnel, which may slow the implementation of digital solutions. Research shows that SMEs dominate the logistics sector in many economies, especially in developing and transition countries, and therefore capital constraints represent one of the main barriers to DT.

Empirical studies indicate that the level of investment in digital technologies in the logistics sector remains relatively modest in many emerging economies. Surveys of logistics companies show that only a limited number of companies allocate substantial financial resources for digitalization, while the majority introduce digital solutions gradually due to budget restrictions and uncertainty regarding return on investment. Such limited investment reduces the ability of companies to fully utilize the potential benefits of DT and may negatively affect their long-term competitiveness.

Recent research also highlights the relationship between DT and operational performance in logistics enterprises. The adoption of digital technologies can improve efficiency, transparency, and coordination across supply chains, but the effects are often visible only after a longer period of organizational adaptation. Studies indicate that successful DT depends not only on technological investment but also on strategic planning, employee training, and the development of appropriate organizational capabilities.

In the context of Southeast European and transition economies, including the Republic of North Macedonia, the implementation of digital logistics solutions is influenced by additional structural constraints. Limited financial resources, insufficient digital infrastructure, and a shortage of specialized human capital represent important factors that slow the digitalization of logistics systems. Nevertheless, the existing literature confirms that DT offers significant opportunities for improving efficiency, strengthening competitiveness, and enabling the integration of regional logistics companies into global supply chains.

## 3. THE ROLE OF DIGITAL TRANSFORMATION IN THE EVOLUTION OF LOGISTICS SYSTEMS

The role of logistics has evolved significantly over time, moving from a primarily operational function to a strategically important component of modern supply chains. Traditionally, logistics focused on activities such as transportation, storage, and handling of goods. However, the development of information and communication technologies (ICT) and the increasing complexity of global markets have transformed logistics into an integrated system that connects production, distribution, and information flows (Pfohl, 2016; Baumgarten, 2008).

With the emergence of DT and the concept of Industry 4.0, logistics systems have become increasingly interconnected both internally and externally. Digital technologies enable the integration of logistics processes with production systems, suppliers, and distribution networks, allowing companies to achieve higher levels of efficiency, flexibility, and transparency. Vertical and horizontal integration of processes makes it possible to coordinate activities across the entire supply chain and to support decision-making through real-time data analysis (Kagermann et al., 2021).

The application of digital technologies has expanded the traditional understanding of logistics from a supporting function to a strategic activity that directly influences business performance and competitiveness. Modern logistics systems rely on digital platforms, automated equipment, and advanced information systems that enable faster information exchange and better coordination between different participants in the supply chain. As globalization increases and customer requirements become more complex, the ability to manage logistics operations efficiently has become a key factor for organizational success (Arnold et al., 2008).

DT also affects the economic dimension of logistics operations. The implementation of advanced technologies requires substantial initial investments in infrastructure, software, and automation, as well as continuous expenditures related to system maintenance, cybersecurity, and workforce training (McLaughlin, 2017). These financial requirements may represent a significant challenge, particularly for companies operating in emerging and transition economies where access to capital and technological resources is limited.

At the same time, digital technologies contribute to the development of more resilient logistics systems. Resilience refers to the ability of organizations to maintain operational stability, adapt to disruptions, and recover quickly from unexpected changes in the business environment. Real-time monitoring, predictive analytics, and automated decision-making tools allow companies to respond more effectively to market volatility and external shocks (Kohl et al., 2021; Warner & Wäger, 2019).

The transformation of logistics into a digitally integrated system therefore highlights the strategic importance of digitalization for modern supply chains. While DT creates opportunities for improving efficiency and competitiveness, it also requires careful planning, significant investment, and organizational adaptation, which remain major challenges for many logistics companies, particularly in developing and transition economies.

## 4. DIGITAL TECHNOLOGIES AND COST IMPLICATIONS IN LOGISTICS

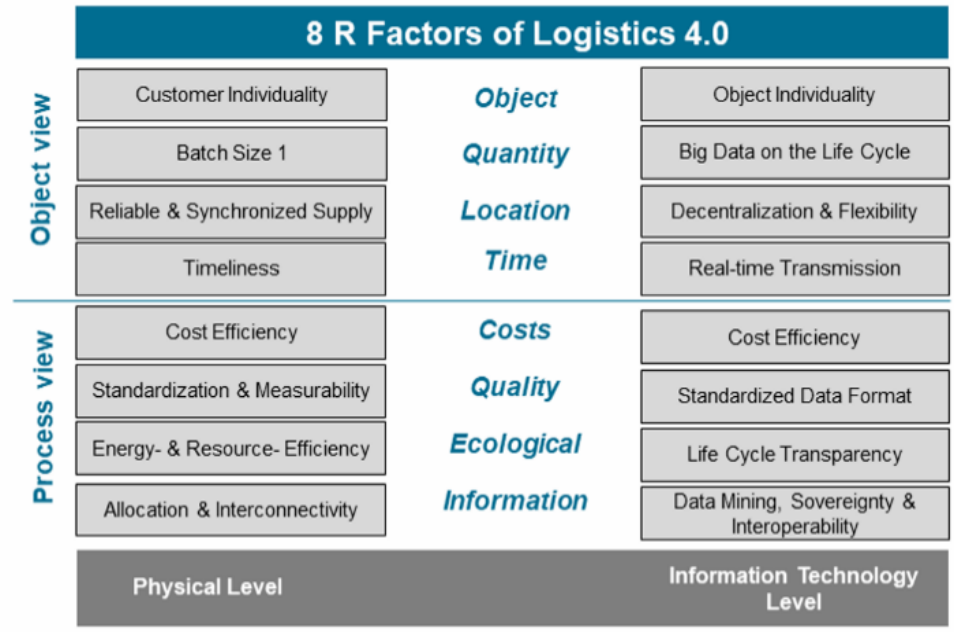
Logistics systems operate in a dynamic environment, but their fundamental objectives remain constant. These objectives include ensuring the efficient movement and distribution of goods, materials, information, and resources throughout the supply chain. The main responsibilities of logistics are commonly described through the "8R" factors (see Picture 1), which emphasize delivering the right product, in the right quantity and quality, at the right place and time, at the right cost, with the right information and in an environmentally responsible manner (Illés et al., 2007). With the emergence of digital technologies and the transition toward Industry 4.0, logistics processes are increasingly influenced by advanced information systems and data-driven decision-making.

DT significantly expands the traditional role of logistics by integrating physical material flows with digital information flows. The growing availability of real-time data enables companies to monitor logistics operations more effectively, respond quickly to disruptions, and optimize resource allocation across the supply chain (Bauernhansl et al., 2014). At the same time, the increasing demand for customized products and flexible production systems has increased the complexity of logistics management, requiring improved coordination of processes throughout the entire product life cycle. Technologies associated with Logistics 4.0, such as IoT, big data analytics, and cyber-physical systems, enable intelligent communication between products, machines, and logistics infrastructure. These technologies allow logistics systems to monitor the status and location of goods in real time, automatically adjust transport routes, and optimize internal logistics operations based on data-driven analysis (Hompel & Henke, 2017; Günthner et al., 2014). As a result, logistics systems can become more adaptive, efficient, and capable of responding to changing market conditions.

Despite these benefits, the implementation of digital logistics solutions often requires significant financial investment and organizational transformation. Companies must invest in technological infrastructure, digital platforms, sensor systems, and data management tools while also addressing the costs associated with system

maintenance, workforce training, and process redesign. Because of these financial constraints, many organizations adopt digital technologies gradually rather than implementing a complete transformation at once (Helmke, 2019).

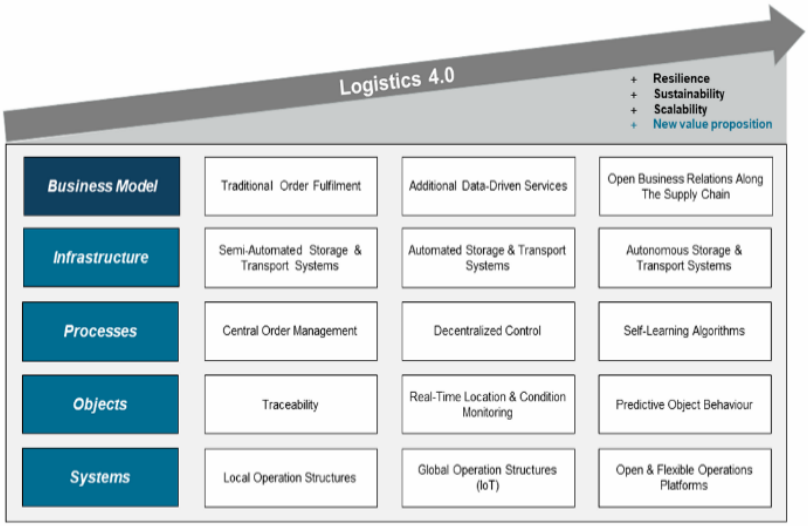
***Picture 1: 8R Factors of Logistics 4.0***




Source: Illés, B., Glistau, E., & Coello Machado, N. (2007). Logistik und Qualitätsmanagement (1st ed.). University of Miskolc.

AI and advanced analytics are increasingly recognized as key technologies for improving logistics performance. AI-based systems can process large volumes of operational data, support complex decision-making processes, and automatically optimize logistics operations such as route planning, warehouse management, and supply chain coordination (Mockenhaupt, 2021). However, successful implementation requires appropriate technological strategies, as well as attention to issues such as data security, regulatory compliance, and employee acceptance of digital technologies.

***Picture 2: Development Stages of Logistics 4.0***




Source: Schenk, M. (2015). Produktion und Logistik mit Zukunft: Digital Engineering and Operation. Springer Berlin Heidelberg; Imprint: Springer Vieweg. https://ebookcentral.proquest.com/lib/kxp/detail. action?docID=4216862

The development of Logistics 4.0 (see Picture 2) creates significant opportunities for improving operational efficiency, increasing transparency within supply chains, and enhancing the competitiveness of companies. At the same time, the transition toward digitally integrated logistics systems requires careful financial planning and strategic investment decisions, particularly for companies operating in emerging and transition economies like North Macedonia where financial and technological resources may be more limited (Schenk, 2015; Gronau & Theuer, 2011).

## 5. TECHNOLOGICAL DRIVERS AND STRATEGIC TRANSFORMATION OF DIGITAL LOGISTICS

DT is increasingly reshaping business environments across industries, including the logistics sector. Rapid technological progress, together with economic, environmental, and social pressures, has increased the complexity of logistics systems and their operational requirements. As a result, logistics has become an important domain for the application of innovative digital technologies and advanced management approaches that support more efficient and resilient supply chains (Hompel & Henke, 2017).

In the context of Industry 4.0, logistics systems are becoming more interconnected through vertical and horizontal integration across the entire value chain. This integration enables improved coordination between production processes, distribution networks, and supply chain partners, increasing transparency and responsiveness in logistics operations. Cloud-based digital platforms provide scalable infrastructure and allow companies to access software solutions and data management tools through service models such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) (Holtschulte, 2022). These technologies facilitate the digitalization of logistics activities and enable more flexible and decentralized operational structures.

Sensors and identification technologies allow logistics operators to track goods, monitor their condition, and manage transportation processes in real time. The data generated through these systems can be analyzed to optimize route planning, improve forecasting accuracy, and support more effective supply chain coordination (Schöllhammer et al., 2020). Despite the significant benefits of digital logistics technologies, their implementation often requires substantial financial investment in technological infrastructure, digital platforms, and workforce training. These investment requirements represent a considerable challenge for many logistics companies, particularly SMEs that may have limited access to financial resources.

In the context of emerging and transition economies such as the Republic of North Macedonia, the adoption of digital logistics technologies remains uneven. The logistics sector in the region is largely dominated by SMEs that often face financial limitations and limited access to advanced digital infrastructure. These structural constraints slow the implementation of technologies such as IoT-based tracking systems, automated warehouse solutions, and advanced analytics tools. Nevertheless, DT presents an important strategic opportunity for logistics companies in North Macedonia and the wider Southeast European region to improve operational efficiency, strengthen supply chain integration, and enhance competitiveness in international markets. Digital technologies play a key role in transforming logistics systems and enabling the development of more efficient and resilient supply chains. However, successful implementation requires not only technological investment but also strategic planning, organizational adaptation, and supportive policy frameworks that encourage the digitalization of logistics operations.

## 6. CONCLUSION

DT represents a fundamental driver of change in modern logistics systems, influencing operational processes, cost structures, and strategic decision-making within supply chains. The integration of technologies such as artificial intelligence, the Internet of Things, cloud computing, and advanced data analytics enables logistics companies to improve efficiency, increase transparency, and enhance coordination across complex logistics networks.

The analysis presented in this paper shows that the adoption of digital technologies in the logistics sector is often limited by significant investment barriers and changes in cost structure. High initial investment requirements, additional operational expenses, insufficient digital infrastructure, and a shortage of qualified human resources represent major challenges, particularly for small and medium-sized enterprises. These constraints are especially evident in emerging and transition economies such as the Republic of North Macedonia, where financial and technological resources are more limited.

At the same time, DT creates important strategic opportunities for companies who works with logistics. The implementation of advanced digital solutions can improve operational performance, strengthen supply chain integration, reduce long-term costs, and increase competitiveness in regional and international markets. The successful realization of these benefits depends on the ability of companies to combine technological investment with organizational change, employee training, and long-term strategic planning.

The findings of this paper contribute to the existing literature by providing a systematized overview of investment barriers, cost implications, and strategic opportunities related to DT in logistics in Southeast Europe. The results

may serve as a basis for future empirical research and may support policymakers and business practitioners in designing strategies that encourage sustainable digital development of logistics systems.
Future research should focus on empirical analysis of DT in logistics companies in North Macedonia in order to better understand the financial, technological, and organizational factors that influence the successful implementation of digital logistics solutions.

**REFERENCES**

Alicke, K., Rachor, J. & Seyfert, A. (2016). Supply Chain 4.0 – the next-generation digital supply chain.
Arnold, D., Isermann, H., Kuhn, A., Tempelmeier, H., & Furmans, K. (2008). Handbuch Logistik. Springer Berlin Heidelberg. doi:10.1007/978-3-540-72929-7
Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. Procedia Manufacturing, 13, 1245–1252.
Bauernhansl, T., ten Hompel, M., & Vogel-Heuser, B. (Eds.). (2014). Industrie 4.0 in Produktion, Au tomatisierung und Logistik. Springer Fachmedien Wiesbaden. doi:10.1007/978-3-658-04682-8
Baumgarten, H. (2008). Das Beste der Logistik. Springer Berlin Heidelberg. doi:10.1007/978-3-540 78405-0
Gronau, N., & Theuer, H. (2011). Potenziale autonomer Technologien in Produktion und Logistik. In C. Siepermann & M. Eley (Eds.), Logistik - gestern, heute, morgen: Festschrift für Richard Vahrenkamp zur Vollendung des 65. Lebensjahres (pp. 269–286). GITO-Verl.
Günthner, W., Klenk, E., & Tenerowicz-Wirth, P. (2014). Adaptive Logistiksysteme als Wegbereiter der Industrie 4.0. In T. Bauernhansl, M. ten Hompel, & B. Vogel-Heuser (Eds.), Industrie 4.0 in Produktion, Automatisierung und Logistik (pp. 297–323). Springer Fachmedien Wiesbaden. doi:10.1007/978-3-658 04682-8_15
Helmke, B. (2019). Digitalisierung in der Logistik. In Projektmanagement in Logistik und Supply Chain Management (pp. 183–207). Springer Fachmedien Wiesbaden. doi:10.1007/978-3-658-23999-2_7
Hofmann, E., & Osterwalder, F. (2017). 'Third-Party Logistics Providers in the Digital Age: Towards a New Competitive Arena?', Logistics, 1(2), p. 9. doi: 10.3390/logistics1020009
Holtschulte, A. (2022). Digital Supply Chain and Logistics with IoT. Springer International Publishing. doi:10.1007/978-3-030-89408-5
Illés, B., Glistau, E., & Coello Machado, N. (2007). Logistik und Qualitätsmanagement (1st ed.). University of Miskolc.
Ivanov, D., Tsipoulanidis, A., & Schönberger, J. (2019). Global Supply Chain and Operations Management. Springer., doi: 10.1007/978-3-319-24217-0
Kagermann, H., Süssenguth, F., Körner, J., Liepold, A., & Behrens, J. H. (2021). Resilienz als wirtschafts- und innovationspolitisches Gestaltungsziel (acatech IMPULS). National Academy of Science and En gineering (ACATECH).
McLaughlin, S. A. (2017). Dynamic capabilities: Taking an emerging technology perspective. International Journal of Manufacturing Technology and Management, 31(1/2/3), 62. doi:10.1504/IJMTM.2017.082014
Mockenhaupt, A. (Ed.). (2021). Digitalisierung und Künstliche Intelligenz in der Produktion. Springer Fachmedien Wiesbaden., doi:10.1007/978-3-658-32773-6
Nguyen, H.K. (2021). Application of mathematical models to assess the impact of the COVID-19 pandemic on logistics businesses and recovery solutions for sustainable development. Mathematics 2021, 9, 1977.
Pfohl, H.-C. (2016). Logistikmanagement. Springer Berlin Heidelberg. doi:10.1007/978-3-662-48784-6
Schenk, M. (2015). Produktion und Logistik mit Zukunft: Digital Engineering and Operation. Springer Berlin Heidelberg; Imprint: Springer Vieweg. https://ebookcentral.proquest.com/lib/kxp/detail. action?docID=4216862
Schöllhammer, O., Schmitt, J. L., Nebauer, S., & Bauernhansl, T. (2020). Everything-as-a-Service Geschäftsmodelle für die Industrie. In M. ten Hompel, B. Vogel-Heuser, & T. Bauernhansl (Eds.), Handbuch Industrie 4.0 (Vol. 109, pp. 1–17). Springer Berlin Heidelberg. doi:10.1007/978-3-662-45537-1_95-2
ten Hompel, M., & Henke, M. (2017). Logistik 4.0 – Ein Ausblick auf die Planung und das Management der zukünftigen Logistik vor dem Hintergrund der vierten industriellen Revolution. In B. Vogel-Heuser (Ed.), Springer Reference Technik. Handbuch Industrie 4.0 (2nd ed., pp. 249–259). Springer Vieweg. doi:10.1007/978-3-662-53254-6_13
Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N., Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. J. Bus. Res. 2021, 122, 889–901
Vial, G. (2019). 'Understanding digital transformation: A review and a research agenda', The Journal of Strategic Information Systems, 28(2), pp. 118–144. doi:10.1016/j.jsis.2019.01.003.

Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongo ing process of strategic renewal. Long Range Planning, 52(3), 326–349. doi:10.1016/j.lrp.2018.12.001

Zhang, P., Fu, Y., & Lu, B. (2025). Analyzing the coupling coordination and forecast trends of digital transformation and operational efficiency in logistics enterprises. J. Theor. Appl. Electron. Commer. Res. 2025, 20, 211.