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DIGITAL TRANSFORMATION IN LOGISTICS USING DIGITAL TWIN TECHNOLOGY

Ekaterina Kalinina ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ katya.kalinina.01@list.ru

Abstract. This article explores the possibilities of digital transformation, including definitions of relevant notions and current trends in logistics. The authors focus on key technological trend: digital twins. This research is highly relevant due to the growing significance of digital transformation in logistics and its influence on competitive advantage. Automation of information and physical processes is a major achievement, with the potential for long-term impact on strategic, tactical, and operational planning and control in logistics systems. Therefore, exploring digital transformation in logistics is a crucial area for research and further practical application. The authors aim to explore the potential of using a digital twin in logistics, as well as to model the architecture of information systems using this approach.

Keywords: logistics, digital transformation, digital twin, architecture of information systems, modelling

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ЦИФРОВАЯ ТРАНСФОРМАЦИЯ В ЛОГИСТИКЕ: ТЕХНОЛОГИЯ ЦИФРОВОГО ДВОЙНИКА

Екатерина Калинина ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ katya.kalinina.01@list.ru

Аннотация. В данной статье рассматриваются возможности цифровой трансформации в логистике, включая определение терминологии, существующие тренды и применение технологий. Особое внимание в данном исследовании уделяется одному из ключевых технологических трендов — цифровым двойникам. Актуальность данной технологии обусловлена важностью цифровой трансформации в отрасли логистики и ее влиянием на конкурентные преимущества перед другими предприятиями. Развитие компаний в данном направлении представляет огромные возможности для достижения конкурентных преимуществ на различных уровнях. Автоматизация информационных и физических процессов представляет собой одно из наиболее значительных достижений, поскольку оно потенциально может оказать долгосрочное влияние на планирование и контроль логистических систем на стратегическом, тактическом и оперативном уровнях. В этой связи, изучение возможностей цифровой трансформации в логистике является важным направлением исследования и последующего практического применения. В рамках данной статьи авторами были определены возможности использования цифрового двойника в логистике и моделировании архитектуры информационных систем.

Ключевые слова: логистика, цифровая трансформация, цифровой двойник, архитектура информационных систем, моделирование

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Introduction

The origin of logistics as a scientific subject began in the United States during wartime. Its creation was encouraged by the need to ensure military transportation and delivery. Precisely in the late 1970s, the concept of logistics spilled over from industry and the military sphere into the civilian application. Currently, logistics proves to be one of the most defining facets of a company's sustainability.

Logistics is an integral management tool that hits both operational and strategic goals and satisfies the end user more by improving the quality of products and services. What is more, the organization shows higher performance in managing all material and information flows (Levkin, 2019; Sergeev, 2023; Jesus, 2024). Thus, the effectiveness of logistics lies in ensuring accurate and timely delivery of products in the required volume and appropriate quality while minimizing costs.

"Digital transformation in logistics" is a compound structure that requires scrutinized observation due to the fact that the term combines definitions of such notions as digitalization, digital transformation, and logistics. Consequently, it is important to figure out the specifics of several approaches to the concept of "digital logistics" in order to see the bigger picture.

The notion primarily rests on the term "digitalization". A collection of the most comprehensive and versatile interpretations of this definition is given in Table 1.

Table 1. Definitions of the term "digitalization"

Author	Definition	Promotion tools
J. Scott Brennen and Daniel Kreiss	"Digitalization is the restructuring power for many areas of social life in terms of the digital infrastructure of communica-tions and media" (Brennen, Kreiss, 2014).	This definition is based on connecting people via innovative digital communication channels.
Gartner IT Glossary, 2022	"Digitalization implies the use of technology to change the business model and create additional ways to generate revenue and create value" (Glossary Gartner).	Gartner focuses on changing business models that bring value through the use of digital technologies.
Khalin V. G., Cher-nova G. V.	"Digitalization in a narrow sense refers to the transformation of information into digital form, leading to lower costs, and the emergence of new opportunities, etc. Meanwhile, in a broader sense digitalization can be considered as a trend of effective global development only if it meets the following require-ments: it affects production, business, science, the social life; the result of digitalization bring in new development prospects; its results are available to users, and not only specialists, but also ordinary citizens" (Khalin, Chernova, 2018).	This definition observes the concept as digitization of data within a specific framework.
Vartanova E. L.	"The translation of information into numbers and at the same time the infrastructural, managerial, behavioral, cultural com-ponents of the content of education – this is what makes digi-talization" (Vartanova, 2017).	The transformation of information into a digital format that affects various aspects of public life is considered digitalization.
Shestak Ksenia	"Digitalization is the use and implementation of technologies in the company's processes to improve their quality and effi-ciency" (Digital business transformation and digitalization).	

Having examined the essence of digitalization from various perspectives, it is evident that the concept does not boil down to technological transformation only, but also to a multifaceted cultural and societal phenomenon. According to the definitions provided in Table 1, digitalization extends beyond the realm of business operations and internal company processes, permeating into the fabric of society as a means of enhancing its overall standard. Most scholars concur that digitalization entails the integration and application of digital technologies with the aim of enhancing various sectors and aspects of human existence (Botнn-Sanabria et. al., 2022).

If we consider digital transformation and digitalization, it is possible to see that digital transformation has a broader purpose, representing a strategic transformation of business (Digitization and digital transformation). In fact, digital transformation has more to do with changing the organization comprehensively. At a time when the company is becoming customer-oriented from top to bottom and its activities are becoming increasingly important, making changes becomes its core competence. Such adaptability contributes to those initiatives that are aimed at digitalization but does not replace them completely (Zhang, Guo, Sun, 2022; Lyamin, Voronova, 2023.).

In their research, Afanasenko I.D. and Borisova V.V. coin two definitions of digital logistics. "In a broad sense, digital logistics is a supporting subsystem. The object of its study is digital flows that accompany or replace the economic flow. The main goal is to ensure the required environment for the logistics system (sustainability, efficiency, etc.).

In a narrow sense, digital logistics itself is a system that ensures the digitalization of the

projected object. Digital logistics studies the patterns of digital flows in economic systems" (Alekseev, 2019).

Digital technological trends in logistics are associated with the following factors:

– development of robotics;
– development and use of AI (artificial intelligence);
– automation of logistics processes.

All these factors are aimed at reducing the workforce. One of the most efficient technologies that reduce the number of operations performed by humans is digital twin technology. This trend encompasses virtual models that accurately reflect the conditions and behaviour of the physical objects or processes they represent in real time. For enterprises, the digital twin is valuable because, it ensures diagnostics and analysis of equipment, forecasting and modelling new scenarios, and process optimization without interacting with a physical real twin (Jeong, Baek, Kim, 2022).

Over the past few years, the application and diversification of various sensor technologies, the growth of cloud computing, and the development of artificial intelligence have allowed expanding the functionality. Thus, AI-based digital twin technology creates more accurate digital models for both the asset and component, as well as the entire process, depending on the application level. Between 2021 and 2027, the market, which was estimated at more than $5 billion in 2020, is projected to grow by more than 35% due to the introduction of new digital counterparts (Afanasenko, 2019).

The introduction of a digital twin into an enterprise is not enough to ensure maximum efficiency and safety of the process. In addition to the introduction of this technology, the company should also consider such technological trends (Afanasenko, 2019) as blockchain, cloud computing, artificial intelligence, as well as big data. The combination and adaptation of all these technologies will allow companies to have competitive advantages, transparent logistics processes, information about all failures, inconsistencies, problems, as well as forecasting and modelling possible process optimization scenarios at all their control points. Each of these technological trends should be considered in detail.

The blockchain. Blockchain technology is used to create secure, reliable and transparent systems that store and process data without centralized control. In this case, it is assumed that security is achieved through the use of blocks containing information, as well as hash sums. This structure creates a complex chain of blocks that ensure data security (Gillespie, Tarleton, 2014).

Interactive artificial intelligence. Interactive artificial intelligence is an extension of AI algorithms capable of processing text, speech, voice, handwriting for analysis and giving reasonable response. Advanced versions of this technology are able to conduct complex conversations, simulate a sense of empathy for users, etc.

Cloud technologies. Cloud technologies and APIs are models that can be used to provide users with remote access to hardware resources via Internet. Cloud technologies allow running applications on remote servers, working with data online, as well as storing and processing information.

Big data. "Big Data is structured or unstructured arrays of large amounts of data. They are processed using special automated tools for statistics, analysis, forecasts and decision-making" (Afanasenko, 2019).

The digital twin in supply chain management, known as DSCT (Digital Supply Chain Twins), is a virtual replica of a physical system that encompasses all the components, assets, and processes within a logistics network. This digital twin serves as a comprehensive representation, displaying the data, statuses, interactions, and behaviours of the logistics system. It stores and analyzes data through specialized repositories, providing a detailed overview of the system's

operations (Bimber, Flanagin, Stohl, 2012).

Moreover, the digital twin enables simulation experiments, modelling novel scenarios and system behaviors. This capability empowers companies to meticulously test new strategies and concepts prior to their implementation, ensuring a smoother and more efficient operational process.

Scientific community studies the digital twin in the supply chain in terms of its diverse functions. It can be a tool for better visibility, traceability, and product authentication (The Logistics Trend Reader 6.0), a decision support system for managing failure risks, or a means to effectively manage long-term supply chains (Park, Son, Noh, 2020).

Materials and Methods

Various research methods were employed in this article, such as literary analysis, synthesis, induction, generalization, a systems and process approach, and graphical interpretations of the research data. ArchiMate was used in data processing.

Results and Discussion

As previously defined, a digital twin in logistics is the same version of a physical process in a virtual state; one can imagine that this is the same process, but performed by a computer. This model is able to change by processing information received from various sources; for example, data from a real object obtained from a repository or through the use of various IoT technologies such as sensors, or data provided by specialists for forecasting and modelling a new, improved process. Thanks to this abilities management can draw conclusions and make decisions on the feasibility of suggested innovations.

Based on the information analyzed earlier, an automation model for the logistics process should be assessed in the context of digital twin technology. Figure 1 depicts the relevant model.

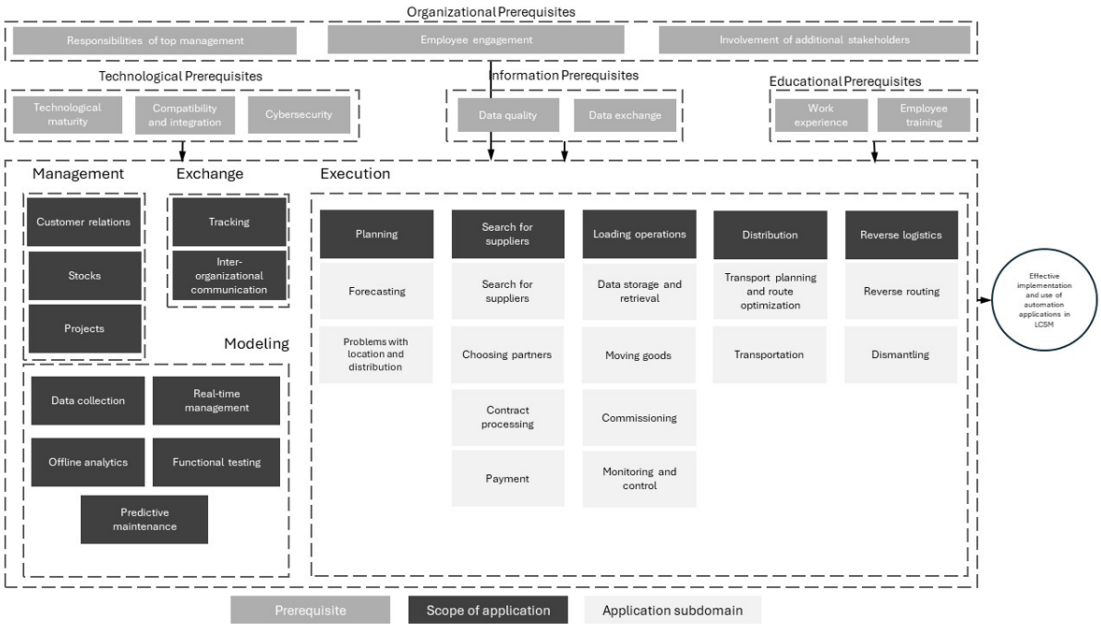


Fig. 1. Conceptual bases of automation in logistics and supply chain management using digital twin technology

The classical model of the logistics process consists of three main blocks: management, exchange, and execution. When using a digital twin, another aspect is added — modelling. It is aimed at supporting the execution of the main customer order using a digital twin (Jensen,

2013). This includes data collection, real-time management, offline analytics, health checks, and forecasting.

Considering the conceptual foundations of automation in logistics and supply chain management using digital twin technology (Bhandal, Meriton, Kavanagh, Brown, 2022), a model of information systems architecture within a single enterprise is proposed. The model presented in Figure too takes into account all the previously described trends in logistics.

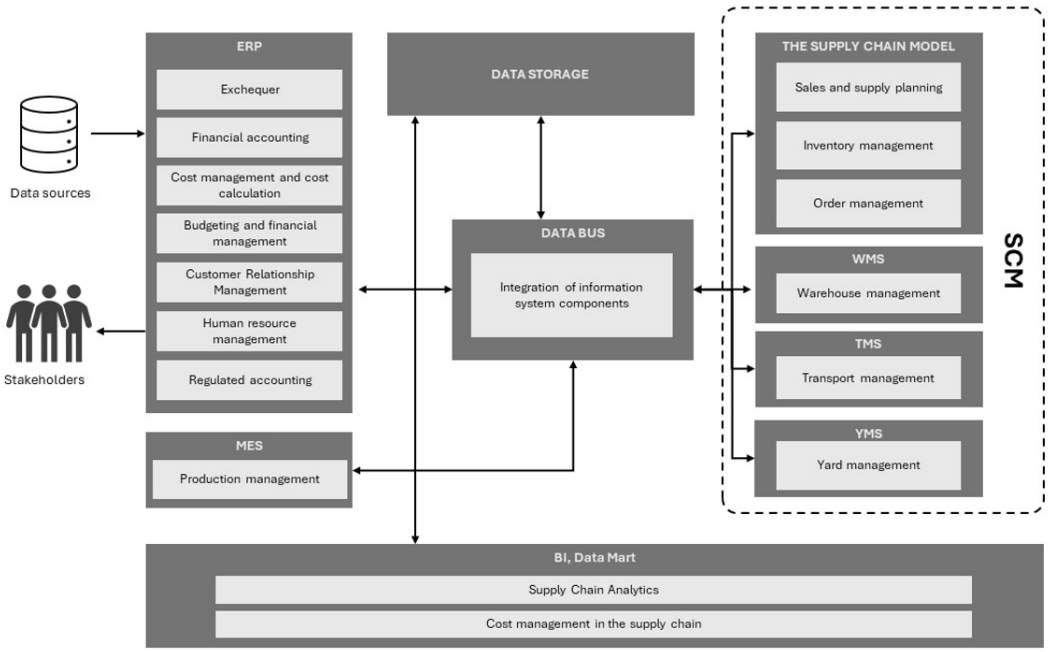


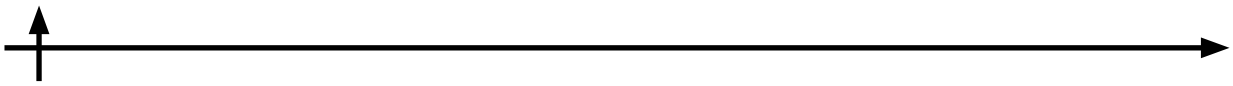
Fig. 2. Architecture of information systems within a single enterprise

The main system in this scenario is a supply chain management model that collects and analyzes data between other logistics systems, such as WMS, TMS, and YMS, while also supporting the planning of the entire enterprise's supply chain (Kabanov, Fedorov, 2022). Digital twin technology shapes the ground for this model. By inputting data collected from actual objects or parameterized by experts, it's possible to simulate processes, improve them, and identify bottlenecks. This also helps describe the accurate and current state of the process within the company. Each component of the SCM can interact with other parts of the system.

Thus, the virtual model is supposed to have the ability to adapt to changes, which implies changing parameters in accordance with technological progress, new trends, and improvements in the industry. It is also necessary to convert and transform information from various sources related to a physical object into a usable format. Cloud computing and APIs can be used to collect and store data. Artificial intelligence (AI) can be used to work with simulation models and arrays of unstructured data. Cloud technologies can be employed to ensure data confidentiality and security, while blockchain can verify and preserve the integrity and authenticity of data. Strategic planning, including scenario modelling, can be carried out via artificial intelligence (AI) capable of analyzing various scenarios and potential consequences in the long run.

Conclusion

Digital twin in logistics allows enterprises to improve processes, adapt to new approaches, improve the quality of services provided to customers, and also gain an advantage in the market. In order to boost the reliability and accuracy, as well as increase the technological advantage,



blockchain, cloud computing, AI, and big data should also be implemented.

Overall, the model of the enterprise information system architecture presented in this research is based on the concept of digital logistics, which defines the purpose and objectives of the logistics system. This model is aimed at the successful implementation and application of digital twin technologies in logistics.

Further research on the topic is required in order to comprehensively assess the interaction of digital twins of several enterprises with each other, measure the economic efficiency of this innovation, and define what equipment is necessary for the whole-scale implementation of digital twins.

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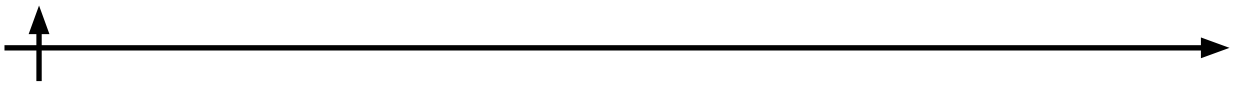

INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

KALININA Ekaterina A. – student.
E-mail: katya.kalinina.01@list.ru
КАЛИНИНА Екатерина Алексеевна – студент.
E-mail: katya.kalinina.01@list.ru

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