2nd International Conference on Problems of Logistics, Management and Operation in The East-West Transport Corridor (PLMO 2023) Baku, Azerbaijan
DOI:10.54381/plmo2023.44

Application of Digital Twin technology in customs processes for logistics: A conceptual framework

Babak ABBASOV*, Asif GANBAYEV
Academy of the State Customs Committee, Baku, Azerbaijan
**Corresponding author*. E-mail: babek.abbasov@ascca.edu.az

Abstract. This research explores the application of digital twin (DT) technology to customs processes in logistics. DT technology involves creating a virtual model of a physical system and integrating it with real-time data from sensors and other sources. By applying this technology to customs processes, it is possible to improve the efficiency and accuracy of these processes and enable more efficient use of resources. The paper examines the current state of DT technology in customs processes, the key considerations and challenges associated with developing a digital twin, and the potential benefits and limitations of using DT technology compared to existing approaches. The paper also discusses the implications of the adoption of DT technology for stakeholders involved in customs processes and identifies future areas of research, including the integration of DT with blockchain technology, optimization of logistics operations, development of advanced algorithms, application of DT to different areas of logistics, and collaboration among stakeholders in the logistics industry. Overall, the application of DT technology to customs processes in logistics has the potential to revolutionize the way goods are imported and exported across borders, leading to a more efficient and secure global supply chain.

Keywords: *Digital Twin; customs; logistics; virtual space; IoT*

1. INTRODUCTION

The rapid growth of global trade and e-commerce has brought about significant challenges for logistics providers. Today's supply chains are highly complex and dynamic, with multiple stakeholders and processes involved [1]. Logistics companies are under pressure to improve their operational efficiency and responsiveness while meeting increasingly demanding customer expectations [2]. At the same time, logistics operations are subject to a range of external factors, such as regulatory changes, weather disruptions, and unexpected events, that can impact supply chain performance [3].

To address these challenges, the logistics industry has been exploring the use of digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain. One of the most promising digital technologies for logistics is Digital Twin (DT) technology, which involves the creation of a virtual replica of a physical object or system [4]. The DT technology has been widely used in manufacturing, aerospace, and construction sectors, and is now gaining traction in the logistics industry.

DT technology can be applied to various aspects of logistics operations, such as warehousing, transportation, and last-mile delivery. The creation of a DT allows logistics companies to monitor and optimize the performance of physical assets, predict maintenance needs, and simulate scenarios to optimize operations [5]. DTs also enable logistics providers to improve customer service by providing real-time information on the status of goods, delivery times, and estimated arrival times [6].

Recent studies have shown that DT technology can provide significant benefits for logistics operations. For instance, a study conducted by DHL found that the use of DT technology in warehousing operations led to a 15% increase in productivity and a 25% reduction in order picking time [7]. Another study conducted by McKinsey & Company estimated that the use of DT technology in logistics could lead to a 30% reduction in logistics costs [8].

However, despite the potential benefits, the adoption of DT technology in logistics is not without challenges. One of the main challenges is the lack of standardization in the industry, which can limit interoperability and hinder the scalability of DT solutions [9]. Other challenges include the high costs of implementing DT technology, the need for specialized skills and expertise, and concerns around data privacy and security [5].

In the following sections, we will explore the potential of digital twin technology for improving customs processes within logistics. We will describe the development and application of a digital twin to model and simulate customs processes, and we will discuss the opportunities and challenges associated with this technology. By doing so, we hope to contribute to the growing body of research on the application of digital twins to logistics and supply chain management, and to highlight the potential benefits of this technology for improving customs processes in particular.

1.1. Objectives of the Paper

The main objective of this paper is to explore the potential of digital twin technology for improving customs processes within logistics. Specifically, we aim to achieve the following objectives:

- To provide an overview of digital twin technology and its application in logistics and supply chain management.
- To describe the development and application of a digital twin to model and simulate customs processes within logistics.
- To evaluate the potential benefits and challenges associated with the use of digital twin technology in customs processes, including its impact on efficiency, compliance, and stakeholder collaboration.
- To provide insights into the future development and application of digital twin technology in logistics and supply chain management, with a focus on customs processes.

By achieving these objectives, we hope to contribute to the growing body of research on the application of digital twin technology in logistics and supply chain management, and to provide practical guidance for businesses looking to optimize their customs processes using this technology.

To guide our exploration of the potential of digital twin technology for improving customs processes within logistics, we will address the following research questions:

1. What is the current state of digital twin technology in logistics and supply chain management, and how has it been applied to date?

2. How can a digital twin be developed and applied to model and simulate customs processes within logistics, and what are the key considerations and challenges associated with this process?

3. What are the potential benefits and limitations of using a digital twin to optimize customs processes within logistics, and how do these compare to existing approaches?

4. What are the implications of the adoption of digital twin technology for customs processes in terms of stakeholder collaboration, compliance, and efficiency, and how can these be managed?

By addressing these research questions, we aim to provide a comprehensive overview of the potential of digital twin technology for improving customs processes within logistics, as well as practical guidance for businesses looking to implement this technology.

2. DIGITAL TWIN

2.1. A Brief History of Digital Twin

The concept of digital twins is relatively new but has already made significant contributions to various industrial domains, such as manufacturing, aerospace, and smart cities. A digital twin is essentially a virtual model of a physical system or asset that can be used for simulation, analysis, and optimization. It is created by integrating data from various sources, such as sensors, historical records, and physical models, and applying advanced analytics and machine learning techniques to generate insights and predictions.

2.1.1. Early Developments

The history of digital twins can be traced back to the early developments of computer-aided design (CAD), computer-aided engineering (CAE), and computer-aided manufacturing (CAM) in the 1970s and 1980s [9]. These technologies enabled engineers to create virtual models of physical objects and systems, which could be used for simulation and analysis. Initially, these tools were primarily used in electronics chip circuit design and printed board circuit design. However, they soon expanded to other domains, such as mechanical engineering.

2.1.2. Conceptualization of the Digital Twin

The conceptualization of the digital twin can be attributed to Grieves, who in 2002 proposed the idea of a "Mirrored Spaces Model" (MSM) [10]. This model consisted of a physical product in real space, a virtual product in a virtual space, and a connection of data and information that tied the two spaces together. In 2011, NASA introduced the specific concept of a digital twin as "an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin" [11].

2.1.3. Evolution of the Digital Twin

Since its initial conceptualization, the digital twin has undergone significant evolution and expansion. Initially, it was primarily used in the aerospace domain for health maintenance and protection of spacecraft. However, with the proliferation of the industrial internet of things (IoT), the digital twin has gained widespread importance in various other domains, such as manufacturing, production process optimization, and smart cities [12]. As a result, the definition and scope of the digital twin have expanded to include virtual counterparts of production resources, DT shop floors, Industrial Internet reference frameworks, and prognosis & health management [13].

The history of digital twins can be traced back to the early developments of computer-aided design (CAD), computer-aided engineering (CAE), and computer-aided manufacturing (CAM) in the 1970s and 1980s. The concept of the digital twin was first proposed by Grieves in 2002 and subsequently refined by Vickers [14] and NASA in the early 2010s. Since its initial conceptualization, the digital twin has undergone significant evolution and expansion, with its scope and definition expanding to encompass a wider range of applications and domains. Today, the digital twin is a powerful tool that can be used for simulation, analysis, and optimization in various industrial domains, and it is poised to play an even more significant role in the future.

2.2. Definition of Digital Twin

Digital twin (DT) technology has emerged as a promising solution for businesses to enhance their performance, efficiency, and profitability. DT is defined as a virtual replica of physical objects, processes, and systems that enables the analysis, simulation, control, and optimization of their real-world counterparts [15]. It is based on the concept of connecting the physical and virtual worlds, allowing businesses to gain a better understanding of their operations, make data-driven decisions, and improve their overall productivity [16].

DT technology has evolved over time, and its architecture consists of three main components: the information model, the communication mechanism, and data processing [17]. The information model gathers and abstracts data related to the physical object, and the communication mechanism enables bidirectional communication between the physical and virtual models. Data processing feeds the DT with data from various sources, synchronizing it with the information model to mirror the physical object's behaviour, characteristics, and performance.

DT can be classified into four types: component twins, asset twins, system twins, and process twins, each focusing on different areas of the production stage [18]. Component twins resemble single parts of a manufacturing system and are the smallest units of a DT. Asset twins are comprised of several component twins and allow for the study of multiple assets that work together to achieve the system's goals. System twins integrate asset twins, providing more detailed information on the system's characteristics, functions, and structures. Process twins encompass all the system's parts in the supply chain of manufacturing and provide a managerial perspective to increase process efficiency.

DT technology is widely used across various industries, including manufacturing, electricity, automobiles, aerospace, healthcare, drilling platforms, vessels, construction, and urban applications [19]. Major technology companies such as Microsoft, Siemens, ANSYS, and Dassault have developed DT software packages, enabling businesses to create dynamic business logic, enhance their supply chain management, and improve their overall performance [20].

In summary, DT technology provides businesses with a powerful tool for understanding, controlling, and improving their operations in a virtual environment. With its various types and wide range of applications, DT has become an essential tool for businesses to stay competitive in an increasingly complex and data-driven world. However, it also presents various challenges and limitations that need to be addressed for the technology's wider adoption and implementation.

2.3. The Characteristics of Digital Twin Technology

The characteristics of Digital Twin (DT) technology play a crucial role in changing the traditional project execution process and enabling its wide-ranging applications in various real-world scenarios. DT constructs a high-fidelity model in the virtual space that mimics the behaviour of objects in the physical world through continuous closed-loop information interaction and data fusion [21]. This allows for centralized and unified management of data throughout the life cycle of a physical system, making data transfer more efficient.

DT integrates all subsystems of a complex system, enabling high-precision modeling and real-time monitoring of data for model updates [21]. This dynamic interaction between physical systems and digital models allows for the models to contain all the knowledge of the system and evolve throughout their life cycle. Sensor data describing the physical system environment or state can be used for real-time updates of the DT model, which can then guide actual operations and improve system performance.

The unified management of data in DT allows for different departments to work in parallel and access and add data to the DT at any time, enabling efficient collaboration [21]. Traditional project design processes often face challenges in information interaction between departments, leading to inefficient design. DT overcomes these challenges by providing a unified data platform for seamless communication and collaboration among different stakeholders.

One of the key advantages of DT is the ability to perform virtual testing and simulation before physical devices are manufactured, changing the traditional approach of verifying systems after physical equipment is produced [21]. This allows for early detection of errors and optimization of system performance, reducing production costs and time. DT also enables real-time monitoring and dynamic updating of the model based on actual system performance and changing environmental conditions, making it more adaptable to complex and dynamic operational environments.

Due to these characteristics, DT has found applications in various industries such as industrial production, health care, smart cities, aerospace, and business [21]. DT has shown immense potential in improving operational efficiency, decision-making, and performance optimization in these industries. However, there are still challenges and limitations that need to be addressed for wider adoption and implementation of DT. Nevertheless, the current development status of DT is promising, and future trends point towards further advancements and integration of DT in diverse fields.

In conclusion, the characteristics of DT, including centralized data management, high-precision modelling, real-time monitoring and updates, and virtual simulation, enable its wide-ranging applications in various real-world scenarios. DT has the potential to revolutionize traditional project execution processes and improve operational efficiency in different industries. This paper will further explore the applications of DT in industrial production, health care, smart cities, aerospace, and business, and provide insights into the current development status and future trends of DT technology.

3. LITERATURE REVIEW

3.1. Digital twins in logistics and supply chain management

Digital twin technology has become increasingly popular in logistics and supply chain management as a means of modelling and simulating complex systems and processes. A digital twin is a virtual representation of a physical object or system, which can be used to monitor, analyse, and optimize its performance in real-time. In the context of logistics and supply chain management, digital twins can be used to model and simulate various aspects of the supply chain, including production, transportation, and inventory management.

Research has shown that digital twin technology can provide a number of benefits in logistics and supply chain management. For example, digital twins can be used to identify inefficiencies and bottlenecks in the supply chain, and to optimize processes to improve efficiency and reduce costs. They can also be used to model and simulate different scenarios to test the impact of changes to the supply chain, and to develop predictive models to forecast future demand.

Several studies have examined the application of digital twin technology in logistics and supply chain management. For example, a study by [22] explored the role of digital twins in logistics and supply chain management, and identified several potential applications for this technology, including improving supply chain visibility, enhancing supply chain collaboration, and optimizing logistics processes.

Another study by [23] focused specifically on the application of digital twins in warehouse management. The authors developed a digital twin of a warehouse and used it to model and simulate different scenarios to optimize inventory management and improve warehouse efficiency.

Despite the potential benefits of digital twin technology, there are also challenges associated with its implementation in logistics and supply chain management. For example, developing and maintaining a digital twin requires significant investment in data infrastructure and analytics capabilities. Additionally, digital twins must be integrated with other systems and processes in the supply chain to be effective, which can be a complex and time-consuming process.

Overall, the literature suggests that digital twin technology has significant potential for improving logistics and supply chain management. However, further research is needed to explore its practical applications and to develop best practices for implementation in real-world settings.

3.2. Customs Processes and Challenges

Customs processes play a critical role in international trade and logistics, serving as a gatekeeper to regulate the flow of goods and services across borders. However, customs processes can also be complex and time-consuming, and can present significant challenges for businesses engaged in international trade.

Several studies have identified common challenges associated with customs processes. For example, a study by [24] identified a lack of transparency and predictability in customs processes as a major challenge for businesses. The authors found that inconsistent and opaque customs procedures can create delays and uncertainties for businesses, which can impact supply chain performance and increase costs.

Another study by [25] identified a lack of harmonization and standardization in customs processes as a challenge for businesses engaged in global trade. The authors found that different customs procedures and requirements in different countries can create complexity and increase the risk of non-compliance, which can lead to penalties and other legal consequences.

Digital twin technology has the potential to address some of these challenges by providing greater visibility and predictability in customs processes. For example, a digital twin of a customs process could be used to model and simulate different scenarios to identify potential delays or bottlenecks, and to optimize processes to reduce wait times and increase efficiency. Additionally, a digital twin could be used to provide real-time tracking of shipments and customs clearance status, which could help businesses to better plan and manage their supply chains.

However, there are also challenges associated with applying digital twin technology to customs processes. For example, customs processes involve multiple stakeholders, including customs agencies, freight forwarders, and importers/exporters, which can make it difficult to develop a comprehensive digital twin that takes all of these stakeholders into account. Additionally, customs processes involve sensitive information, such as trade secrets and personal data, which must be protected to ensure compliance with data protection regulations.

Overall, the literature suggests that customs processes present significant challenges for businesses engaged in international trade. Digital twin technology has the potential to address some of these challenges, but further research is needed to explore its practical applications and to develop best practices for implementation in real-world settings.

3.3. Benefits and limitations of digital twins in customs processes

Benefits:

- Improved accuracy and efficiency: Digital twins can provide real-time and accurate information on the movement and location of goods, reducing the need for manual tracking and increasing efficiency. This can help customs agencies to quickly identify and address potential issues in the supply chain, reducing the time and cost of inspections [26].
- Enhanced transparency and visibility: By providing a detailed and transparent view of the supply chain, digital twins can help reduce the risk of errors, delays, and fraud in customs processes. This can lead to more efficient and effective customs procedures, as well as improved security and compliance [27].
- Improved decision-making: Digital twins can provide customs agencies with real-time data and analytics on supply chain operations, enabling more informed decision-making. This can help to optimize customs procedures, reduce costs, and improve overall performance [28].

Limitations:

- Complexity and cost: Developing and implementing a digital twin system for customs processes can be complex and expensive, requiring significant investment in technology and infrastructure [28].
- Data privacy and security: The use of digital twins in customs processes may raise concerns over data privacy and security, particularly if sensitive information is shared between different organizations and systems [26].
- Resistance to change: Resistance to change from stakeholders, such as customs officers and traders, may limit the adoption and effectiveness of digital twin technology in customs processes [27].

4. DIGITAL TWIN DEVELOPMENT PROCESS

This framework for digital twins, consisting of physical space, information processing layer, and virtual space, was introduced in the literature [29]. The physical space includes various components such as equipment, machines, materials, and workers, which are equipped with sensors and other technologies for data collection. The data collected is stored in the information processing layer, which includes various layers such as data, system, and technology. Finally, the virtual space is the digital representation of the physical space and is used for simulation and analysis of the processes. This framework provides a structured approach for the development of digital twins in various industries, including logistics and supply chain management.

To apply DT to customs processes in logistics, we can adapt the physical space, virtual space, and information processing layer.

4.1. Physical Space

The physical space in this case would include the physical infrastructure involved in customs processes such as ports, customs offices, warehouses, and transportation vehicles. This physical space would need to be equipped with sensors and other IoT devices to collect data on the movement of goods, as well as the status of equipment, vehicles, and personnel involved in the customs processes.

For example, in case of the customs warehouse the physical space would be equipped with sensors, cameras, and other monitoring devices that capture real-time data on the movement of goods, as well as environmental factors such as temperature, humidity, and light.

4.2. Virtual Space

The virtual space would be built on top of the physical space and would include a 3D virtual model of the customs processes, which would be used for simulation and optimization purposes. The virtual space would also include a virtual environment platform (VMP) that would provide an operating environment for algorithms library, and a DT application subsystem (DTs) for product lifecycle management. The VMP would provide various virtual models for DTs, including polyphysical model, workflow model, simulation model, etc. The DTs would accumulate various models, methods, and historical data that are created during the operation into VMP.

For example, in case of the customs warehouse the virtual space would consist of a 3D model of the customs warehouse, which is used to create a digital twin of the physical space. The virtual space would also include a simulation model that simulates the movement of goods through the customs process, as well as the behavior of customs officials and other stakeholders. This simulation model would be used to test different scenarios and identify potential bottlenecks or areas for improvement.

4.3. Information Processing Layer

The information processing layer would be responsible for processing and analyzing the data collected from the physical space and the virtual space. This layer would use machine learning algorithms and other analytical tools to identify patterns and optimize customs processes. The DT application subsystems for product lifecycle management would also be built on this layer and would be responsible for functions such as product function analysis, product performance prediction, product testing, ergonomics analysis, production layout planning, equipment status prediction, process implementation analysis, plant operation optimization, and product maintenance prediction, etc.

For example, in case of the customs warehouse the information processing layer would consist of a data management system that collects, processes, and analyzes data from the physical and virtual spaces. This system would use machine learning algorithms to detect patterns and anomalies in the data, and provide insights into the customs process. The information processing layer would also include a dashboard that displays real-time information on the status of goods in the customs warehouse, as well as alerts for potential issues.

The DT application subsystems for customs processes in logistics would include knowledge fusion, data management, algorithm optimization, status evaluation and prediction, plan and instruction release, and other functions. These subsystems would be used to analyze the customs process, predict potential issues, optimize workflow, and improve the efficiency of customs clearance.

For example, the DT application subsystems could be used to analyze the customs clearance time for different types of goods, and identify ways to streamline the process and reduce delays. The subsystems could also be used to predict potential issues with goods, such as damage or contamination, and recommend actions to mitigate these risks. Overall, the application of DT to customs processes in logistics has the potential to significantly improve the efficiency, accuracy, and safety of the customs clearance process.

5. CONCLUSION

In conclusion, the application of digital twin technology to customs processes in logistics can significantly improve the efficiency and accuracy of these processes. By creating a virtual model of the physical customs space and integrating it with data from sensors and other sources, customs officials can gain real-time insights into the status of shipments and potential risks. This allows them to identify issues and take corrective action before they become major problems.

Furthermore, the use of digital twin technology can enable more efficient use of resources and optimization of customs procedures. By simulating different scenarios and testing various process changes in the virtual space, customs officials can identify the most effective and efficient solutions to complex logistics challenges. This can lead to faster processing times, reduced costs, and increased customer satisfaction.

Overall, the application of digital twin technology to customs processes in logistics has the potential to revolutionize the way customs officials operate. By providing real-time insights and enabling more efficient processes, digital twins can help ensure that goods move through the customs process quickly and securely, benefiting both businesses and consumers.

Following are summary of answers to research questions stated in the introduction and answered thought research paper:

RQ1: What is the current state of digital twin technology in customs processes within logistics, and how has it been applied to date?

Answer: Digital twin technology is still in its early stages of adoption in customs processes within logistics. However, some initial research has been conducted on developing digital twins to simulate and optimize customs procedures such as cargo inspections and clearance processes.

RQ2: How can a digital twin be developed and applied to model and simulate customs procedures within logistics, and what are the key considerations and challenges associated with this process?

Answer: Developing a digital twin to simulate customs procedures within logistics involves creating a virtual representation of the physical environment and integrating real-time data from various sources such as sensors and IoT devices. Key considerations and challenges include ensuring data accuracy and security, designing a realistic model, and integrating the model with existing IT systems.

RQ3: What are the potential benefits and limitations of using a digital twin to optimize customs processes within logistics, and how do these compare to existing approaches?

Answer: Potential benefits of using a digital twin to optimize customs processes include improved efficiency, increased transparency, and reduced costs. Limitations include the need for significant upfront investment and the potential for technical difficulties or errors. Compared to existing approaches, a digital twin offers more comprehensive and real-time monitoring and analysis capabilities.

RQ4: What are the implications of the adoption of digital twin technology for stakeholders involved in customs processes, including regulatory bodies, logistics companies, and importers/exporters, in terms of collaboration, compliance, and efficiency, and how can these be managed?

Answer: The adoption of digital twin technology can have significant implications for stakeholders involved in customs processes. Regulatory bodies can benefit from increased transparency and data analysis capabilities, while logistics companies and importers/exporters can improve efficiency and compliance. However, managing collaboration between stakeholders and ensuring compliance with regulations can be challenging and requires careful planning and communication.

6. FUTURE WORK

In the future, there are several areas that could be explored to further enhance the application of DT technology to customs processes in logistics:

1. Integration with blockchain technology: Blockchain technology can provide secure and transparent data sharing among different parties involved in the logistics supply chain. The integration of DT with blockchain can help to improve the transparency and traceability of customs processes, reduce the risk of fraud and errors, and enhance the overall efficiency of logistics operations.
2. Optimization of logistics operations: DT technology can be used to optimize logistics operations, including routing, scheduling, and resource allocation. Future work could focus on developing algorithms that can analyze data from the DT system and provide recommendations for improving logistics operations.
3. Development of advanced algorithms: The development of advanced algorithms can help to optimize customs processes by predicting potential bottlenecks and providing real-time recommendations for process improvement. Machine learning algorithms, for example, can help to identify patterns and anomalies in customs data, and provide insights for process optimization.
4. Application of DT technology to different areas of logistics: DT technology can be applied to different areas of logistics, such as inventory management, transportation planning, and warehouse optimization. By integrating DT technology with other logistics processes, it is possible to achieve greater efficiency, productivity, and cost savings.
5. Collaboration with other stakeholders: Collaboration among different stakeholders in the logistics supply chain, such as customs authorities, freight forwarders, shippers, and carriers, can help to improve the overall efficiency and effectiveness of customs processes. By sharing data and insights, stakeholders can work together to identify opportunities for process optimization and improve the flow of goods across borders.

In terms of future work, further research and development are needed to fully realize the potential of DT technology in customs processes. This includes developing more sophisticated algorithms for prediction and optimization, as well as improving the accuracy and reliability of sensors and data collection. Furthermore, there is a need for greater collaboration between stakeholders in the logistics industry, including shippers, customs brokers, and government agencies, to ensure that the technology is being used effectively and efficiently.

Overall, the future of DT in customs processes in logistics looks promising, and as the technology continues to evolve, it has the potential to revolutionize the way goods are imported and exported across borders, leading to a more efficient and secure global supply chain.

References

1. Richey, R. G., Chen, H., Yeniyurt, S., & Nix, N. W. The role of supply chain agility, adaptability and alignment in achieving flexibility and firm performance. *Journal of Business Logistics*. 2015. Vol. 36. I. 1 P. 21-38.
2. Giunipero, L. C., Hooker, R. E., & Denslow, D. Purchasing and supply management sustainability: Drivers and barriers. *Journal of purchasing and supply management*. 2008. Vol. 14. I. 3. P. 163-178.
3. Christopher, M., & Peck, H. Building the resilient supply chain. *The international journal of logistics management*. 2004. Vol. 15 I. 2 P. 1-14.
4. Chen, J., Liu, X., Huang, G. Q., & Wang, X. Digital twin-driven supply chain management in industry 4.0. *International Journal of Production Research*. 2020, Vol. 58. I. 1. P. 185-199.
5. Cavalcante, C. A. V., Leal, F., & Ribeiro, J. L. D. (2021). Digital Twins in Logistics: A Systematic Literature Review. *Sustainability*. 2021. Vol. 13. I. 4. P. 2064.
6. Sicilia, J., López, R., García-Sánchez, A., & Sánchez, L. (2020). Simulation and Optimization of a Customs Control Process. *Advances in Intelligent Systems and Computing*. Springer. 2021. P. 711-721.
7. DHL. *Logistics trend radar*. 2023. Available at: https://www.dhl.com/global-en/home/insights-and-innovation/insights/logistics-trend-radar.html
8. McKinsey & Company. *Digital manufacturing: The revolution will be virtualized*. 2018. Available at: https://www.mckinsey.com/business-functions/operations/our-insights/digital-

manufacturing-the-revolution-will-be-virtualized.
9. Su, Y., & Yang, Y. Digital twin: a survey from data perspective. *Journal of Cleaner Production*. 2019. Vol. 233. P. 1308-1322.
10. Grieves, M., & Vickers, J. Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. *IEEE Access*. 2016. Vol. 4. P. 7167-7185.
11. Glaessgen, E. H., & Stargel, D. S. The digital twin paradigm for future NASA and US Air Force vehicles. 2012. In: *53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*.
12. Zhang, X., Xu, X., & Qiao, L. A review on digital twin: From concept to applications. *Journal of Cleaner Production*. 2021. Vol. 289.
13. Wang, X., Liu, C., Yin, Y., & Liao, X. The digital twin: from concept to future directions. *IEEE Transactions on Industrial Informatics*. 2020. Vol. 16. I. 10. P. 6318-6326.
14. Vickers, J., & Vogl, G. W. Realizing the digital twin: How manufacturing firms can reduce risk and improve performance. *Deloitte Review*. 2017. Vol. 20. P. 140-151.
15. Tao, F., Cheng, Y., Qi, Q., Zhang, M., Zhang, H., & Kusiak, A. (2018). Digital twin-driven product design, manufacturing and service with big data. *The International Journal of Advanced Manufacturing Technology*. 2018. Vol 94. I. 9. P. 3563-3576.
16. Tao, F., Zhang, M., Cheng, Y., & Zhao, D. Digital twin-driven product innovation and service transformation. *Annual Reviews in Control*. 2018. Vol. 45. P. 204-217.
17. Wang, X., & Wang, L. (2020). Research on the architecture of digital twin technology. In: *IEEE International Conference on Power*. *Intelligent Computing and Systems* (PICSY). 2020. P. 1-5.
18. Tao, F., Qi, Q., Liu, A., Kusiak, A., & Fan, J. Digital twin-driven smart manufacturing: Connotation, reference framework, applications and challenges. *Robotics and Computer-Integrated Manufacturing*. 2021. Vol. 68.
19. Zhang, L., Yao, X., Wang, C., Zhang, L., & Tao, F. Digital twin and big data analytics for smart manufacturing. *International Journal of Production Research*. 2021. 59. Vol. 5. P. 1321-1336.
20. Zhang, M., Liu, Y., Tao, F., Zhang, L., & Nee, A. Y. C. Digital twin: A survey from data acquisition to decision-making. *IEEE Transactions on Industrial Informatics*. 2021. Vol. 17. I. 4. P. 2663-2673.
21. Yan, X., Peng, X., & Cheng, G. Digital Twin: Characteristics, Applications, and Research Trends. *IEEE Access*. 2021. Vol. 9. P. 15020-15039.
22. Rose, J. Digital twins: Changing the face of logistics and supply chain management. *Supply Chain Management Review*. 2019. 23. Vol. 5. P. 14-19.
23. Li, L., Hu, J., & Cao, J. Digital twin and its application in warehouse management: a literature review. *Enterprise Information Systems*. 2021. P. 1-27.
24. Caccetta, L., D'Elia, A., & Gastaldi, M. Customs process optimization in international trade. *Transportation Research Procedia*. 2018. Vol. 32. P. 593-602.
25. Kim, Y. H., Kim, H. J., & Lee, H. S. Harmonizing customs procedures in Northeast Asia: Implications for logistics performance and regional integration. *Sustainability*. 2019. Vol. 11. I. 14. P. 3894.
26. Chen, C.-Y., Lin, T.-C., & Chang, Y.-S. The Application of Digital Twin Technology in Customs Clearance Process for Trade Facilitation. *Journal of Marine Science and Technology*. 2021. Vol. 29. I. 1. P. 57-66.
27. Lee, J., Choi, M., & Kim, M. A Study on the Digital Twin Technology for the Intelligent Customs Process. *International Journal of Advanced Science and Technology*. 2020. Vol. 29 I. 8. P. 2451-2459.
28. Ma, Y., Sun, X., Zhang, H., & Zhu, J. Research on the Application of Digital Twin Technology in Customs Clearance. *Advances in Mechanical Engineering*. 2021. Vol. 13. I. 2. P. 1-11.
29. Zheng, X., Tang, O., & Xu, X. A Framework of Digital Twin in Supply Chain. In: *IEEE International Conference on Industrial Engineering and Engineering Management* (IEEM). Bangkok, Thailand. 2018. P. 937-941.