# Supply chain management information system project with the use of digital twins*

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**Abstract**

The article focuses on the project to develop a supply chain management information system using a digital twin for the maritime transport chain. Digital twins reflect real objects and processes in a virtual environment, which enables analysis, modelling and optimisation of supply chain operations. The author describes the main stages of the project, including requirements definition, system architecture development, implementation and testing. Particular attention is paid to the benefits of using digital twins in supply chain management, such as increased efficiency, reduced risk and improved forecasting. The results of the study show the potential of digital twins to optimise supply chain management and increase the competitiveness of companies. The article presents an approach to building a new model of interaction and systematic optimisation of business processes based on digital technologies at all stages of supply chain formation, which ensures the creation of a digital twin for the maritime transport chain. In order to improve supply chains, a digital twin has been proposed, which opens up great prospects for the management of logistics processes and the exchange of information between supply chain participants. This paper presents a framework for an integral Digital Supply Chain Twin (DSCT) capable of covering the entire transport chain. The proposed information system based on the use of the DSCT provides a number of improvements throughout the supply chain, as well as the ability to model and evaluate different scenarios for the supply chain. This creates opportunities to reduce the cost of organising and coordinating transport, improve the quality of transport and logistics services and make them more reliable by identifying potential problems at an early stage. The article analyses the main information technologies that facilitate the use of DSCT as a useful and reliable tool.

**Keywords**

digital twin; supply chain; maritime transport; digital technology; project management

## 1. Introduction

Supply chain management is a critical component of any organisation's success in today's competitive marketplace. The increasing size and complexity of supply chains requires

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organisations to constantly search for effective tools to manage and optimise them. In this context, the use of digital technologies, especially digital twins, is becoming increasingly important, especially in the maritime industry. Supply chain management is an important aspect of modern business, as its efficiency determines a company's competitiveness in the market. However, as data volumes, process complexity and the need for accuracy and responsiveness continue to grow, there is a need for new tools and technologies to optimise supply chain management. The development and implementation of information systems that facilitate the use of digital twins in supply chain management is becoming increasingly important. These information systems can provide companies with access to virtual models of their supply chains, allowing them to analyse, model and optimise various aspects of these chains, taking into account the actual state of resources and processes.

Such information systems can greatly facilitate decision-making, ensure greater accuracy and efficiency in supply chain management, and help to increase the competitiveness of companies in the marketplace. Therefore, the development of such systems is relevant and important for further business development in today's global market.

## 2. State of the problem research

The idea of using digital twins first appeared in the work of E. Glasgren and D. Stargel [1], where scientists explore the actual and predictive fusion of data using digital twins for vehicle certification and fleet management. The main task of the proposed digital twin of a vehicle is to "continuously predict the state of vehicles or systems, which ensures the rate of useful use and the probability of successful completion of tasks". Solving this problem is part of the overall development of the digital transformation of society. In the work of scientists E. Glasgow and D. Stargel, a digital twin is described as follows: "A digital twin is an integrated multi-physical, multi-scale, theoretically plausible model of a vehicle or system that uses the best available physical models, sensor details, and fleet history to simulate the state of the original operating under real field conditions." According to a study by international consultancy McKinsey & Company [2], product developers using digital twins in companies have reduced overall development time by 20-50%, thereby reducing costs - companies have reduced the number of prototypes needed to develop a new product.

In 2021, Google announced Supply Chain Twin, a new Google Cloud solution that allows companies to create a digital twin - a representation of their physical Supply Chain (SC). With Supply Chain Twin, businesses can combine data from multiple sources, enabling them to share information with suppliers and their partners. The solution supports enterprise business systems that contain data about a company's geographic location, products, orders and warehouse operations, as well as data from suppliers and partners, such as inventory levels and product transport status [3].

Supply Chain Pulse provides real-time event management, optimisation and simulation of project management processes using artificial intelligence (AI). It allows project teams to drill down into operational metrics with performance dashboards that make it easy to see the status of the supply chain. They can also set alerts that go off when metrics reach user-defined thresholds and create workflows that allow users to collaborate to resolve issues.

Supply Chain Pulse's AI-driven algorithm provides responses to events, identifies more complex issues and simulates the impact of hypothetical situations.

Gartner, the world's leading research and advisory company, predicts that 13% of organisations are implementing an Internet of Things (IoT) project using digital twins, and 62% are in the process of implementing digital twins[4]. With increasing competition in the industrial and information technology sectors, the digital twin market is expected to continue to grow at a CAGR (Compound Annual Growth Rate) of over 30%, eventually reaching $26 billion by 2025. Although their use is new and requires a high level of planning and integration, digital twins have the potential to transform SC operations at all levels.

The authors in [5] propose modelling capabilities at the level of the maritime supply chain using a digital twin, which are essential for assessing likely future scenarios.

After reviewing the scientific literature on the implementation of the digital supply chain in the field of maritime transport, the issue of building a digital twin in the LP remains unresolved, given the project management methodology in terms of project planning, execution, monitoring, and control.

**The aim of this paper** is to analyse the possibilities of developing maritime supply chain management information systems based on the use of digital twin technology.

In order to achieve this goal, the following tasks were solved:

1. To study the concept of a Digital Supply Chain Twin (DSCT).
2. To consider the vertical integration strategy for the supply chain, which is more appropriate as it can combine different participants: maritime and land activities, port processes, transport, cargo handling and IT services.
3. To present DSCT using the example of the maritime transport chain, which is an important element of international supply chains enabled by the use of new technologies, and to show how the digital twin can help overcome existing shortcomings in transport networks and supply chains.
4. To define the requirements for the maritime supply chain management information system based on the use of digital twin technology.

## 3. The Digital Twin Supply Chain concept

Digital twins, as virtual models of real objects and processes, offer great opportunities to improve supply chain management. They allow you to analyse, model and optimise various aspects of the supply chain, taking into account the actual state of resources, production processes and logistics operations. The concept of digital twins has become widespread in many areas of production and should also be used in project activities. In the formation of a maritime supply chain, the digital twin is studied in the spatial and temporal dynamics and information links between different actors in this chain.

Supply chain management plays a key role in business transformation and market share growth. The development of supply chains (SC) is significantly influenced by the improvement of processes such as the automation and standardisation of warehouse and transport operations, the introduction of electronic document management, the growth of e-commerce and the creation of digital twins of business processes.

The modern interpretation of the digital twin concept was introduced by Michael Greaves (University of Michigan, 2011) [6]. The idea itself was formulated by Greaves in 2002, but at that time it was called the "mirrored spaces model". According to M. Greaves, the concept of a digital twin consists of real and virtual spaces. The virtual space contains both all the information collected from the real space and a detailed (usually numerical) description of a physical device or process from the microscopic level to the geometric macroscopic level. The description provided by a digital twin must be "virtually indistinguishable from its physical counterpart".

Thus, a digital twin is a term used to describe a computerised (or digital) version of a physical asset or process. The concept of a digital twin combines the ideas of modelling and the Internet of Things (IoT). The ability to use a digital twin has arisen due to the massive transition of companies to digital technologies, which simplifies the process of obtaining information and allows you to create a scenario that fits the entire SC [7]. Recent pandemic and military situations have led to an imbalance in the supply and demand of goods, affecting supply chain technology around the world. However, these situations have also increased the need for companies to use technological solutions to manage their supply chain to meet these challenges, as the possibility of supply disruptions or global conflicts cannot be ignored.

Artificial intelligence is becoming essential for innovative supply chain transformation. 46% of supply chain executives expect artificial intelligence, digital twins, cognitive computing and cloud applications to be their biggest areas of investment in digital operations over the next three years [1].

**The digital twin of the supply chain** is a virtual model of the physical supply chain that includes a digital counterpart of each part of the process. But unlike other graphical visualisations, this model is dynamic, as data streams from devices connected to the IoT and then to artificial intelligence for continuous monitoring and updates, effectively reflecting the current state of each moving part.

A digital twin is a semantically related set of models, information and data that fully describes a potential or actual physical system, and as such forms a representation of all aspects of the relevant physical system (e.g. properties, state and behaviour) that may be relevant to the current or subsequent phases of the project lifecycle.

The digital twin of the supply chain is developed together with the relevant logistics system and remains its virtual analogue throughout its life cycle, where it can be used to monitor, analyze, model, and predict the operation of that system, leading to appropriate actions in the physical world.

There are several types of digital twins:

1. A digital twin prototype (DTP) is a prototype used to create an instance of a digital twin. Typically, such a prototype contains a detailed, high-precision model. However, the prototype does not contain measurement results and reports from a specific physical device.
2. Digital Twin Instance (DTI) is a digital twin that contains information about model settings, control parameters, sensor data and chronological information for a specific product, device or process.

3. Digital Twin Aggregate (DTA) - a group of Digital Twins that may not have an independent unique data structure. Instead, the constituent Digital Twin Instances (DTIs) can query and exchange data with each other.
4. Digital Twin Environment (DTE) - an integrated multi-physical and multi-scale environment for working with Digital Twins.

A key requirement of the digital twin concept is dynamism and the ability to be constantly updated in line with the real physical product. Today, the integration of digital technologies into the business processes of any activity, including the supply chain, is a global trend and an evolving innovation.

Research conducted in 2023 showed that DSCT entered the Gartner Hype Cycle [8] as one of the most disruptive technologies in the supply chain.

But in the next two years, none of the digital innovations will be mature enough to significantly change the economy. On average, it takes 5 to 10 years for a technology to come to life, or 'mature'. At the same time, some innovations are studied before they have gone through all the stages of development, and new technologies replace them.

For example, the overall impact of the digitalisation of processes in material handling systems [9] is to:

- Increase production output by 10-15%;
- Speed up the design, production and delivery of products to consumers by 100-150 %;
- Reduce the cost of pre-launch testing of digital twins and visual modelling tools by 50-70 %;
- Reduce delays throughout the supply chain management cycle by 20-30% through increased visibility of operations.

### 3.1. Vertical integration strategy in supply chains

Let's consider the strategy of vertical integration, since it is more appropriate to use such a strategy in the supply chain [10]. Vertical integration usually involves the acquisition of a partner company that supplies the company with raw materials or is a buyer of its products and services. Vertical integration involves the creation of a supply chain that may include the following blocks: shipbuilding, terminal, inland transport, warehousing, distribution, IT services, etc. In the case of vertical integration, a key question is how to organise the vertical chain most effectively. Companies are usually faced with a choice between production and purchasing, which is the solution to the "make or buy" problem [11]. One of the clear examples of vertical integration is the Maersk company, as it includes shore and land activities and everything related to port processes, transport, cargo handling and IT services. It is necessary to note the importance of IT solutions in shipping companies that specialise especially in linear services, because with the help of IT technologies such companies solve the tasks of internal logistics and management of container flows. The consolidation of services with the creation of a supply chain has led to the emergence of so-called 3PL operators, which have integrated logistics services within the company. Their competitive advantage lies in the value-added aspect of the supply chain, which is prioritised by customers.

Despite the significant need for coordination and cooperation, information transparency between supply chain participants is currently low, so that none of the subjects can track the overall progress of the transport in detail (Fig. 1).

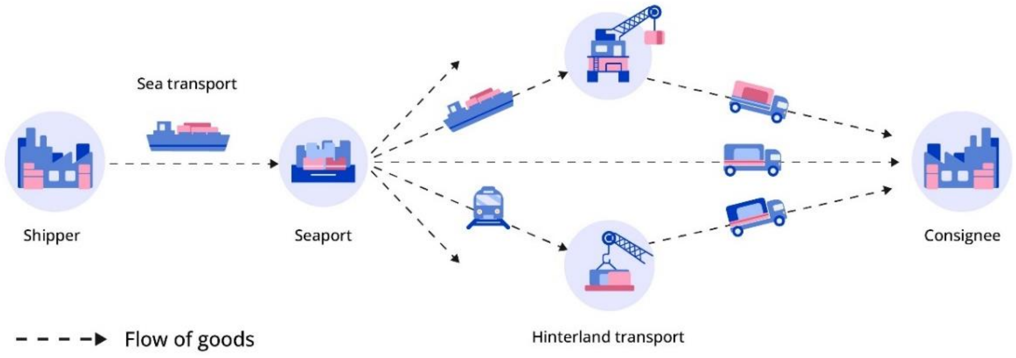


**Figure 1:** A schematic representation of the supply chain.

One reason for this is the lack of comprehensive information on the status of the entire chain and the progress of the transport process. Another reason is that the information available is not systematically shared with other participants due to the low level of digitalisation of communication processes, the lack of interoperability of IT systems and confidentiality requirements. Currently, this drawback can be overcome by using a digital double as a new block integrated into the supply chain, which will accelerate the exchange of information between the participants of the SC and reduce administrative and bureaucratic costs.

Therefore, the planning and control of the transport chain is static and does not reach the general optimum, but each subject carries out local optimisation for its sphere of activity. As a result, the available capacity of transport modes and resources is not used optimally, and preference is given to more stable transport modes - rail and water - due to their flexibility. In addition, uncertainty, low transparency and lack of information lead to the creation of buffers of insurance reserves in the chain and, as a result, to a decrease in performance.

To avoid such problems, planned and synchronised procedures for planning and managing the supply chain are required, which offer the following opportunities:

1. Transparency of the flow of information throughout the SC in real time, including delays en route or in ports, on the progress of the delivery of the material flow to the customer.
2. Forecasting future states (alternative scenarios), which makes it possible to increase the reliability and sustainability of the supply chain.
3. Optimise SC processes by providing decision support both at the transport planning stage and during execution and control.

## 3.2. Building a digital twin of the supply chain

The digital supply chain twin (DSCT) of freight delivery in the space-time dimension is a powerful tool for increasing efficiency and optimising costs in general, reducing risks and improving communication and decision making among the participants in the transport process, ensuring a synergistic effect for each participant. Information flows are bi-directional, generating information about the behaviour of the SC that can be used for further action (Fig. 2).

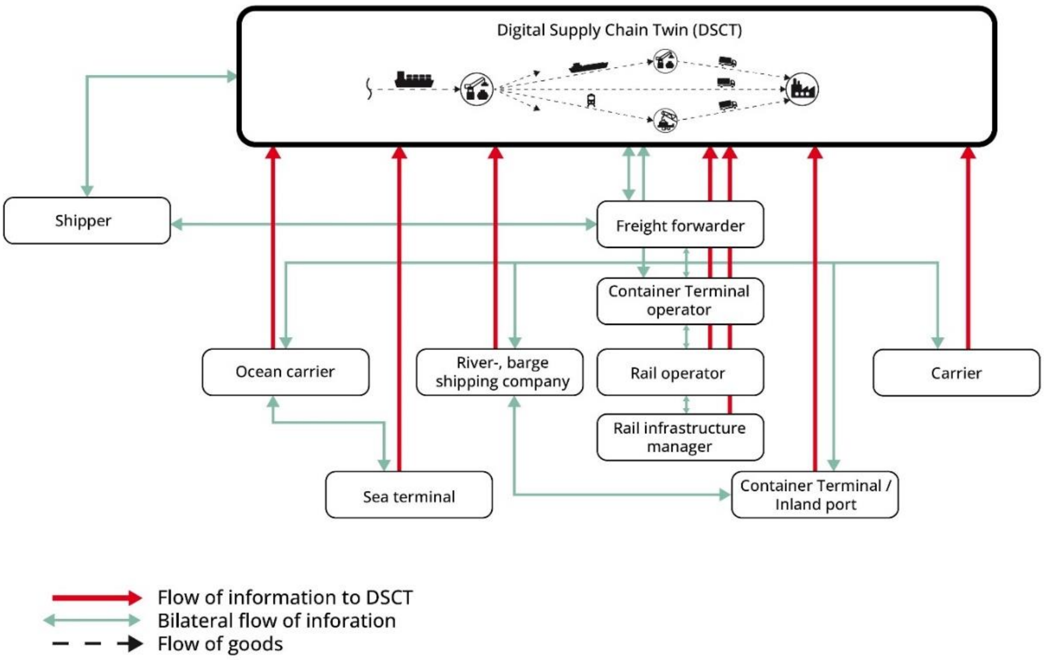


**Figure 2:** Information flows in the maritime transport chain with the use of DSCT.

This is because the maritime supply chain is a dynamic system that includes ships, ports, terminals, cargo, logistics routes, etc. This dynamic model is constantly updated with real-time data from sensors, GPS, meteorological devices, and other sources to reflect the actual state of proper operations. Real-time visibility to update data from multiple sources shows a dynamic picture, allowing you to monitor vessel positions, cargo status, weather conditions and potential cargo delays.

Based on this, the DSCT architecture is proposed, the structure of which consists of five separate blocks for project decision making between stakeholders (Fig. 3).

The central block is the "SC model", which describes the physical SC, its specifics and interdependencies. The model can be implemented using classical algorithms or artificial intelligence technology. The first block of the proposed DSCT structure is the interface block, which provides for the collection of information from different SC participants for its pre-processing, storage thanks to the use of the Internet of Things, 5G, etc., and transmission for the use of the SC Model block. AI technology can be used to process unstructured data into a structure suitable for use in the SC Models block. The Simulation block, powered by the computing power provided by cloud computing, can determine potential future states of the real SC by applying alternative parameters to the DSCT model. This allows the decision making process in the SC to be improved as the results and impact of one or more possible decisions can be determined without actually affecting the real SC.

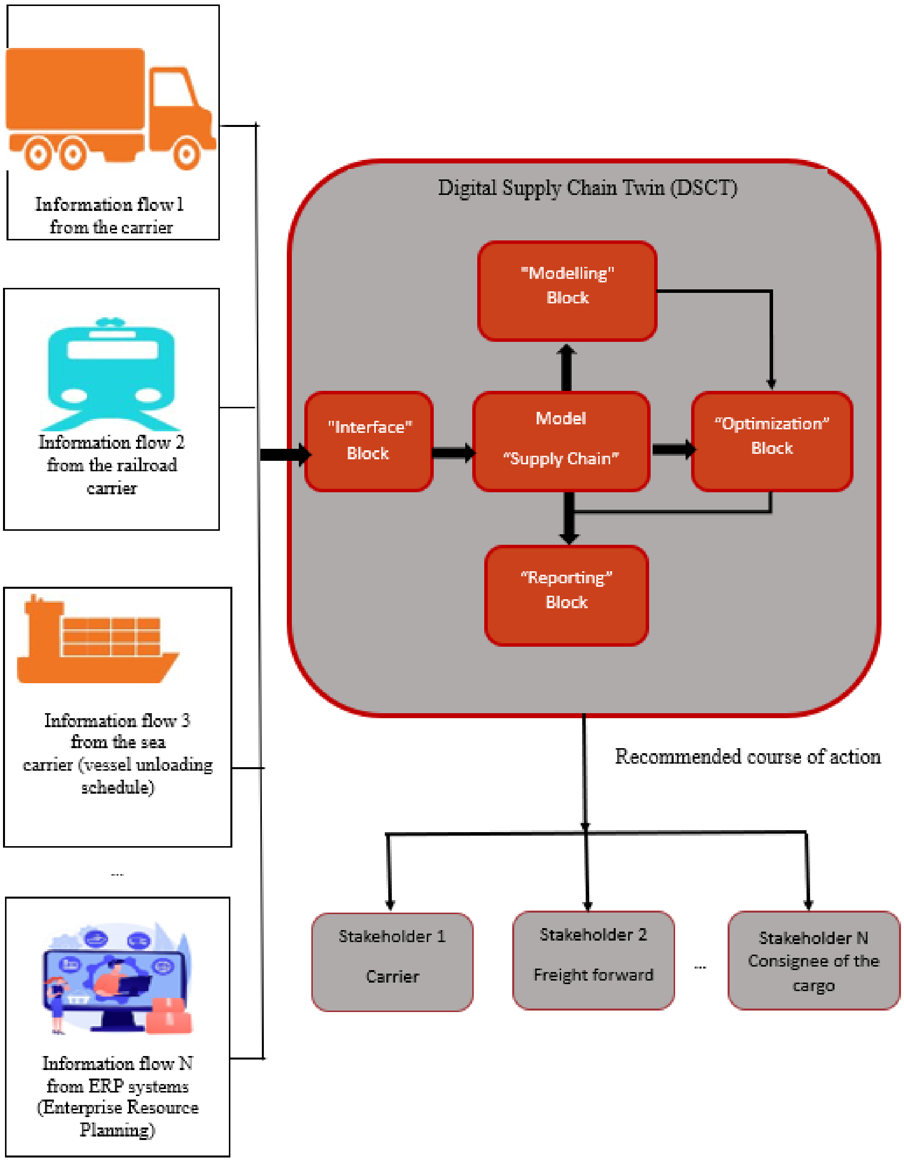


**Figure 3:** The proposed structure of the DTSC.

The modelling of cargo delivery activities in the SC can be represented as a delivery process through different modes of transport, including loading, unloading, transport, customs clearance and delivery. With a digital twin, project activities specific to a particular shipment can be integrated, such as container tracking or special cargo handling requirements. It should be noted that it is necessary to take into account the spatiotemporal direction of the flows in the chain, i.e. the input and output flows at a separate section of the SC for a certain period of time are the input flow in relation to another section of the SC.

The Optimisation block uses both the SC Model block and the Simulation block to optimise the SC represented by the DSCT. AI methods are the most advanced tools for implementing this model. This module potentially allows significant improvements in the SC, such as more efficient route planning, synchronisation and coordination of the work of the carriers, gaining flexibility in order planning, optimising the level of insurance stocks or reducing the order fulfilment time, etc. Finally, the "Reporting" block prepares the results of the "Optimisation" and " SC Model" blocks individually for each interested party and provides them with a structured presentation of all the information and recommendations available through DSCT.

Designing and optimising supply chain operations involves testing different scenarios (route changes, weather conditions, port delays) to determine the most efficient routes, resource allocation and contingency plans.

The benefits to stakeholders of using DSCT should be highlighted:

1. Reducing delays, port disruptions and costs: by optimising routes taking into account fuel consumption, weather conditions, port congestion and regulations; identifying and avoiding 'bottlenecks' in cargo delivery, contributing to smoother operations and cost savings. For example, container carrier Maersk uses DSCT to optimise container placement and reduce fuel consumption.

2. Risk management: Forecasting potential risks in cargo delivery, such as weather conditions, equipment failure or delays, and taking preventive measures to mitigate or eliminate them.

3. Improved collaboration, thanks to DSCT, communication with transport process partners for transparent communication, better decision making and faster response to changes. Communicating with chain participants to track cargo in transit and at the port, and to predict the timing of cargo operations, contributes to faster cargo clearance and eliminates delivery failures. For example, container carrier CMA CGM uses DSCT to optimise port calls, reduce downtime and improve overall supply chain efficiency.

4. Supply chain visibility provides insight into the impact of shipping activities on the entire supply chain, optimising supply chain inventory management and resource allocation. Hapag-Lloyd is also using DSCT to monitor the condition of containers, predict potential losses and improve risk management.

Implementing a DSCT digital twin of the shipping supply chain can be a game changer, delivering significant efficiencies, cost savings and risk reduction. By carefully considering the challenges and adapting the DSCT model to specific needs, a competitive advantage can be gained in modern shipping.

The greatest efficiency is achieved by creating a virtual model of the object in question. Digital doubles solve the following tasks:

1. Carry out a test run of a process or production chain quickly and without significant investment.
2. Identify a problem or weakness before production or commissioning.

3. Increase the efficiency of processes or systems by tracking all failures before the project starts.
4. Reduce risk, including financial risk and risk to the life and health of personnel.
5. Increase the competitiveness and profitability of the company's business.
6. To make long-term forecasts and plan the development of the company or product for years to come.
7. Increase customer loyalty by accurately forecasting demand and product consumption.

Supply chain digitalization tools use different approaches to solve their tasks. In addition to the simplest and most common way of modelling and planning supply chains - spreadsheets - there are more effective methods such as analytical optimisation and dynamic modelling.

The digital double should be used to simulate the supply chain in order to simulate all possible crisis situations along the entire length of the supply chain and, based on the obtained result, prepare certain strategies to counteract such cases. Thanks to the information collected, it is also possible to clearly assess the risks of the introduction of new links in the supply chain, their profitability, and costs at the same time, without wasting time and resources on calculations. The digital replica also makes it possible to track problems in the SC on the basis of up-to-date information and, accordingly, to obtain information on the effectiveness of countermeasures for these problems. Creating a full digital replica of the supply chain allows you to demonstrate the efficiency of the company that owns the supply chain, and also, based on the replica of the full chain, smaller replicas can be created to demonstrate information on a specific part of the chain that consumers are interested in.

## 4. Requirements for the information system of supply chain management using digital duplicates in maritime transport

A supply chain management information system using digital duplicates in maritime transport must meet a number of requirements to ensure efficient and uninterrupted operation. Let's look at the main requirements for the information system:

*Integration with maritime systems*. The system must be able to integrate with various systems used in maritime transport, such as vessel monitoring systems, control systems and security systems.

*Implementation of digital duplication technology*. The system must be able to create real-time digital models of marine objects such as ships, piers, and terminals, allowing an accurate representation of their condition and operating parameters.

*Data monitoring and analysis*. The system should provide continuous monitoring and analysis of data from marine objects to identify possible anomalies, optimise routes and plan cargo operations.

*Data security*. Ensuring a high level of protection of data confidentiality, integrity and availability is critical to the system, especially in the marine environment where there is a significant risk of exposure to external factors.

*Scalability and Reliability*. The system must be scalable to support large volumes of data and operations, and reliable to always ensure uninterrupted operation.

*Intelligent management*. The system should be able to use artificial intelligence and machine learning algorithms to automate decision-making and optimise supply chain management.

Ensuring the fulfilment of these requirements will make it possible to build an information system that will effectively contribute to the management of maritime supply chains with the help of digital duplicates.

The algorithm of the information system using algorithms of artificial intelligence and machine learning to automate decision-making processes and optimise the management of supply chains using the technology of digital duplicates can be presented as follows (Fig. 4).

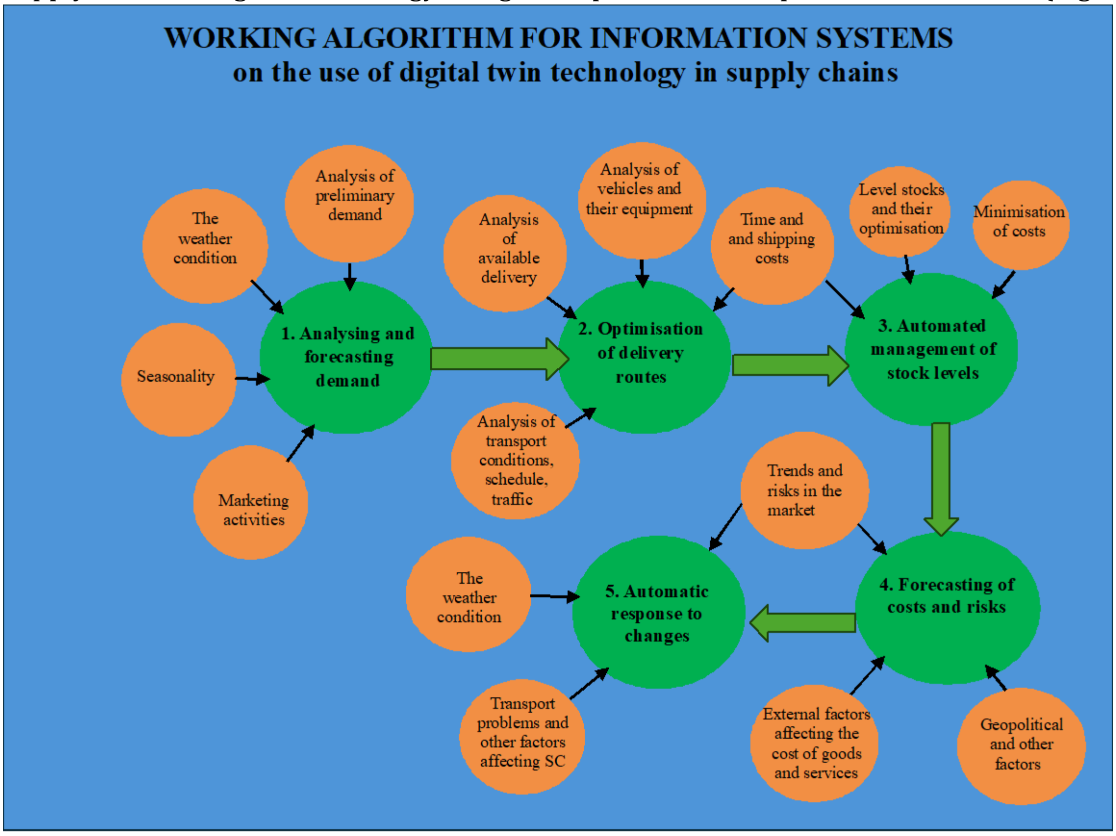


**Figure 4:** Information system operation algorithm to automate decision-making processes and optimise supply chain management using digital twin technology.

*Demand analysis and forecasting*. The system analyses historical data on demand for goods and services and uses it to forecast future demand. Machine learning algorithms such as neural networks or time series analysis algorithms can be used to accurately predict demand based on various factors such as seasonality, weather conditions, marketing promotions, etc.

*Optimize delivery routes*. The system analyses data on available delivery routes, vehicles and their equipment, as well as transport conditions, roads and traffic forecasts. It uses this data to develop optimal delivery routes, taking into account factors such as cost, delivery time and environmental impact.

*Automated inventory management*. The system automatically monitors stock levels in warehouses and forecasts the amount of goods needed based on historical demand and delivery time data. It uses machine learning algorithms to maintain optimal inventory levels, minimising inventory carrying costs and out-of-stock risks.

*Cost and risk forecasting*. The system analyses market trends, geopolitical factors and other external factors that affect the value of goods and services and uses this information to predict future values and risks. Machine learning algorithms help determine optimal pricing and risk management strategies.

*Automatic response to changes*. The system automatically responds to changes in market conditions, weather, transportation issues and other factors that can affect the supply chain. It uses artificial intelligence algorithms to quickly identify changes and make appropriate decisions to resolve them.

The algorithm demonstrates how the use of artificial intelligence and machine learning algorithms can contribute to the automation of supply chain management processes using digital twin technology in maritime transport.

## 5. Conclusions

The concept of a digital supply chain twin (DSCT) has been explored. From a project management methodology perspective, DSCT modelling allows you to create a virtual project model that includes all of its components, such as tasks, resources, schedules and budget. This model can be used to visualise the project, estimate its cost, shorten project schedules, reduce costs and project risks, and determine the critical path.

The DSCT is presented using a maritime transport chain as an example. The proposed DSCT framework can be used to optimise the project, e.g. by reducing task time, reducing costs or improving quality. This can be achieved by modelling different scenarios and selecting the best option. A digital double can be used to predict various aspects of a project, such as its transport duration, its cost, risks during the project, etc. DSCT allows you to make more informed decisions and reduce project risks.

Given the increasing complexity of modern supply chains, the use of an information system based on the use of digital twin technology becomes extremely important. Forecasting accuracy, inventory optimisation through constant monitoring of stock levels in warehouses allow you to avoid overstocking, reduce costs and manage risks. Analysing risks and identifying potential problems in the supply chain in advance can help to avoid delays or disruptions in the production process.

It is important to note the specific benefits and opportunities that can be obtained by implementing an information system:

Time and cost reduction. The use of digital duplicates makes it possible to reduce the time required for planning and production along with the costs of managing supply chains.

Increase in efficiency. The results of the study confirm the increase in productivity and efficiency of supply chain management thanks to the use of digital doubles.

Minimise errors. Digital duplicates allow you to avoid errors and misunderstandings by automating and standardising processes.

Increase competitiveness. The use of digital doubles can make a company more competitive in the marketplace by reducing response time to change and improving the quality of customer service.

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