Proceedings of CONF-FMCE 2026 Symposium: Smart City and Infrastructure Engineering
DOI: 10.54254/2755-2721/2026.CH35095

Research on Innovation and Development of Logistics Management under Intelligent Logistics: Taking Yangshan Deep Water Port as an Example

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Abstract. With the rapid development of information technology, smart port and shipping has become an inevitable trend in the development of port and shipping field. This paper focuses on the innovation and development of logistics management under the background of smart port and shipping, and expounds its important position in economic development through an overview of port and shipping. In-depth analysis of the application and development of intelligent port and shipping information technology, including automated terminal technology, blockchain technology and big data technology in the port and shipping field, taking Yangshan Port as an example to discuss how these technologies can improve the efficiency of logistics management, reduce costs, enhance safety and transparency, and provide theoretical support and practical guidance for the reform of port and shipping logistics management.

Keywords: Smart port and navigation, Logistics management, Automated terminal, Blockchain, Big data, Yangshan Port

1. Introduction

As a key backbone of global trade, the port and shipping industry plays an important role in economic globalization. Traditional port and shipping logistics face challenges such as inefficiency, lack of transparency, and poor coordination, making it difficult to meet the growing demands of trade. The rise of smart ports and shipping, which makes use of advanced information technology, has brought new opportunities and changes to port and shipping logistics management. Researching the innovation and development of logistics management under the framework of smart ports and shipping helps enhance the overall competitiveness of port and shipping logistics, facilitates trade, and drives the development of regional and global economies. Smart transformation is the key pathway for ports to break through traditional development bottlenecks, and its impact on reshaping logistics management models is far-reaching. This paper will combine literature reviews with real-world case studies of smart transformation practices at Yangshan Port to examine the development of smart port and shipping technologies and automated terminal technologies, and analyze the synergistic application of different technologies in port and shipping logistics management [1].

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DOI: 10.54254/2755-2721/2026.CH35095

2. Overview of ports, shipping, and logistics

2.1. Functions and classification of ports

Ports serve as gathering points and hubs for water and land transportation, performing functions such as loading, unloading, and handling; cargo storage; transportation coordination; and information services. They are key nodes that connect inland economic hinterlands to maritime transport and play an important role in the distribution and circulation of goods. According to the theory of "Port Management," the various functions of a port are interrelated and work together to ensure that port logistics activities are carried out in an orderly manner.

Ports can be classified according to their purpose into commercial ports, fishing ports, industrial ports, and military ports [2]; according to geographical location, they can be classified into seaports, river ports, and lake ports. Different types of ports vary in their functional positioning and operational models, but all play unique roles within the logistics system.

2.2. The development history and current status of shipping

The development of shipping has spanned the eras of sailing ships, steam ships, internal combustion engine ships, and modern container shipping. With technological advancements, the carrying capacity, speed, and safety of vessels have continuously improved, and shipping has gradually become the primary mode of transport for global trade. Yan Xinping et al., have documented the evolution of shipping technology in detail in academic journals, providing a technical and professional perspective for understanding the development of shipping [3].

Currently, the global shipping market is large, with routes across the world. Container shipping dominates, while liner and tramp shipping complement one another. Meanwhile, the shipping market is highly competitive and faces challenges such as stricter environmental requirements and trade protectionism.

2.3. The status and role of ports and shipping in the logistics system

As logistics hubs, ports serve as transfer nodes for various modes of transport, enabling the efficient transfer of goods from one mode to another. Shipping, meanwhile, is the primary means of long-distance, large-scale cargo transport and acts as a vital link in the global logistics supply chain. Zhang et al. have emphasized the central position of ports as integrated hubs within modern logistics systems, highlighting their role as a key link in the integration and efficient allocation of logistics resources [4].

The development of ports and shipping has driven the clustering and growth of related industries, such as port logistics, shipbuilding, and shipping finance, making significant contributions to regional economic growth and job creation. At the same time, they provide fundamental support for international trade and promote the optimal allocation of global resources. The construction and development of Yangshan Port have greatly boosted the economic of Shanghai and its surrounding areas, serving as a key driver of regional economic growth.

DOI: 10.54254/2755-2721/2026.CH35095

3. Overview of smart port and shipping information technology

3.1. The essence and characteristics of smart port and shipping information technology

Smart port and shipping information technology refers to the application of advanced information technologies—such as the Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI), and blockchain—to the port and shipping sectors [5], with the aim of achieving intelligent, automated, informatized, and digitized port and shipping operations. In terms of its main features, smart port and shipping information technology is well integrated, combining multiple information technologies; it has strong real-time capabilities, collecting and processing large amounts of data in real time; it features a high degree of intelligence, enabling autonomous decision-making and optimization through data analysis and intelligent algorithms; and it is broadly open, facilitating information sharing and collaboration with other systems.

3.2. Main components and applications of smart port and shipping information technology

Smart port and shipping information technology can be grouped into three categories. The first is the use of Internet of Things (IoT) technology, which involves installing sensors, radio-frequency identification (RFID), and other devices on objects such as cargo, equipment, and vessels to achieve comprehensive sensing and interconnectivity of port and shipping logistics elements, and provides the foundation for data collection and intelligent management. Numerous case studies demonstrate the successful application of IoT technology in port cargo management and equipment monitoring, effectively enhancing the precision of port operations. The second is cloud computing technology. It provides robust computing power and storage resources, enabling port and shipping enterprises to store, process, and analyze massive amounts of data, which reduces IT infrastructure costs and improving system operational efficiency. The third is artificial intelligence (AI), which primarily utilizes machine learning, deep learning, and natural language processing. These technologies are applied to automated control of port equipment, intelligent scheduling, and risk prediction, thereby enhancing the intelligence of port and shipping operations and the scientific rigor of decision-making [6].

The Internet of Things (IoT) enables end-to-end cargo tracking and real-time monitoring of equipment status; cloud computing builds a port computing platform to support daily terminal operations and data sharing. Artificial intelligence is used in areas such as intelligent vessel stowage, automatic berth planning, and equipment failure prediction, helping terminals move toward unmanned operations and optimize vessel turnaround efficiency. The integrated application of these three technologies significantly reduces labor costs and shortens operation times, driving the transformation of the port and shipping industry toward greater efficiency, smarter operations, and improved safety.

4. Development of automated terminal technology: a case study of the Yangshan deep-water port automated terminal

4.1. Key technologies for automated terminals

The efficient and intelligent operation of automated terminals relies on the support of several core technologies, which fall into three modules: automated cargo handling equipment, intelligent control systems, and automated guided vehicle (AGV) technology [7]. These technologies work together to

DOI: 10.54254/2755-2721/2026.CH35095

establish a fully automated terminal operation system. Regarding automated cargo handling equipment, the Yangshan Port automated terminal is equipped with automated ship-to-shore cranes and automated rail-mounted gantry cranes (ARMG). Using advanced intelligent control technology, these systems enable precise container handling and placement, significantly improving operational accuracy and efficiency. This enables 24-hour uninterrupted terminal operations, reduces container handling time, and strengthens the foundation for automated terminal operations. As the terminal's dispatch hub, the intelligent control system manages all equipment and optimizes operations. Relying on intelligent algorithms and data models, the system integrates real-time operational information—such as vessel arrival times, cargo types, and total cargo volume—to dynamically optimize the overall workflow and achieve efficient coordination among various types of equipment. Before a vessel berths, the system can complete preparatory tasks such as planning the loading and unloading sequence and allocating equipment in advance, significantly improving the terminal's overall operational scheduling efficiency. Its scheduling optimization philosophy is consistent with the core principles of "Optimization of Port Production Scheduling Processes." Automated Guided Vehicles (AGVs) are key equipment in the terminal's horizontal transport operations. Equipped with functions such as autonomous navigation, intelligent route planning, and automatic obstacle avoidance, they perform container transshipment tasks according to operational requirements. Additionally, they can automatically adjust their routes based on real-time terminal traffic conditions and changes in operational tasks, Avoiding congestion and keeping the terminal's horizontal transport processes running smoothly.

4.2. Impact of automated terminal technology on logistics management

This impact shows up in three main ways. First, operational efficiency has improved a lot. The high-speed operation and precise control of automated equipment at Yangshan Port's automated terminal have drastically reduced cargo loading, unloading, and transshipment times. According to statistics, the operational efficiency of Yangshan Port's Phase IV automated terminal is about 30–50% higher than that of traditional terminals, which gives the port a much greater throughput capacity. Second, automated terminals rely less on manual labor, which lowers labor costs. The number of staff at Yangshan Port's Phase IV automated terminal is approximately 70% lower than that of a traditional terminal of comparable scale. This cuts labor costs and work intensity, and also leads to fewer errors and accidents caused by human factors. Finally, Yangshan Port has achieved real-time tracking and precise management of cargo. Through IoT technology and intelligent control systems, customers can check the location and status of their cargo in real time. This makes logistics services more reliable and transparent, and meets customer demands for efficiency and accuracy.

5. Applications and development of blockchain technology in the port and shipping sector

5.1. Principles and characteristics of blockchain technology

Blockchain is a distributed ledger technology that links data in chronological order into an unchangeable chain of blocks. Each block contains the hash value of the previous block, a timestamp, transaction data, and cryptographic algorithms ensure the security and integrity of the data.

Blockchain technology is characterized by decentralization, immutability, traceability, and smart contracts. Decentralization eliminates the need for a central authority, which makes the system more reliable and autonomous; immutability and traceability ensure data authenticity and security, making

DOI: 10.54254/2755-2721/2026.CH35095

it easier to monitor and audit logistics processes; and smart contracts automatically execute predefined rules and conditions, allowing for automated transactions and management [8].

5.2. Application scenarios of blockchain technology in port and shipping logistics

Because blockchain is decentralized, tamper-proof, and traceable, it has been used in a variety of practical applications in the port and shipping logistics sector, primarily in three areas: logistics information sharing, supply chain finance, and cargo tracking and traceability [9].

For logistics information sharing, Yangshan Port used blockchain to build a dedicated information-sharing platform that records real-time data across the entire logistics process—including cargo transportation, warehousing, and loading/unloading—and grants query access to multiple stakeholders, including the port, shipping companies, freight forwarders, and customs authorities. This model removes information barriers, ensures data transparency and consistency, and reduces efficiency issues and business disputes caused by information asymmetry. Particularly during the customs clearance process, it enables all parties to quickly verify documents, significantly improving clearance efficiency.

In the field of supply chain finance, blockchain provides a trusted foundation for port and shipping supply chain finance operations, enabling the automated processing of procedures such as accounts receivable assignment and financing. With smart contracts doing settlement and repayment automatically, business risks drop sharply. Shipping companies can use the platform to get accounts receivable financing quickly, which eases cash flow pressures and improves the overall efficiency and security of supply chain finance.

For cargo tracking and traceability, the entire flow of goods—from the point of origin, through Yangshan Port, to the final destination—is recorded on the blockchain. Because the data cannot be changed, regulatory authorities and relevant personnel can verify the origin and transport history of goods at any time, which ensures product quality and thesupply chain safety. This application is especially important for the management of high-value goods and food products.

6. Applications and development of big data technology in the port and shipping sector

6.1. Data sources and characteristics of big data in port and shipping logistics

Big data in port and shipping logistics comes mainly from vessel navigation, port operation, cargo transportation, market transaction, and other sources. Yangshan Port collects massive amounts of data through various sensors, equipment monitoring systems, and information management systems. During navigation, sensors collect data on vessel status, position and fuel consumption; during port operations, equipment monitoring systems recordcargo handling and equipment performance; and during cargo transportation, tracking devices and logistics information platforms generate large amounts of transport trajectory and status data. Publications such as Shipping Information Platforms in the Big Data Era and Research on the Application of AIS Big Data in Port and Shipping Operations Management analyze big data sources in detail, providing a theoretical foundation for data collection and integration at Yangshan Port.

Big data is often described as havingmassive volume, diverse types, high velocity, and low value density. Yangshan Port generates a huge amount of data daily.The data types include structured data (such as tables in databases), semi-structured data (such as XML or JSON files), and unstructured data (such as text, images, and videos). The data is generated quickly and requires real-time

DOI: 10.54254/2755-2721/2026.CH35095

processing and analysis. Although the total volume is large, valuable information is often buried in it, so the value density is low.

6.2. Application of big data technology in port and shipping logistics management

With its massive data processing and analysis capabilities, big data technology is important in port and shipping logistics management, mainly in three areas: demand forecasting, logistics route optimization, and equipment maintenance and failure prediction.

Regarding demand forecasting, Yangshan Port integrates various types of data—such as historical transport records, market demand, and economic indicators—to build predictive models and analyze trends in cargo transport demand. The port combines historical import and export data with market dynamics to forecasts seasonal transport demand for different cargo categories which helps enterprises allocate transport capacity more effectively, optimize resources, and improve operational efficiency.

Regarding logistics route optimization, the platform utilizes real-time traffic and port congestion data, along with optimization algorithms, to plan transportation solutions. It takes into account factors such as voyage duration, fuel consumption, and port fees, to find optimal routes for vessels, which reduces transit times, cuts operational costs, and improves overall logistics service levels.

Regarding equipment maintenance and failure prediction, the port collects and analyzes real-time operational data from various types of equipment to build predictive models that forecast the probability and timing of failures. On this basis, maintenance is done proactively to prevent sudden failures from disrupting normal operations, and at the same time it reduces equipment maintenance and operational expenses.

7. Innovative strategies for logistics management in smart port and shipping

7.1. Building a smart logistics ecosystem

To build a smart port and shipping logistics ecosystem, work needs to be done on two fronts at the same time: resource integration and industrial convergence. This will connect all links in the industrial chain and achieve coordinated development across the entire system [10].

taking the Port of Shanghai and Yangshan Port as the core, we need to deepen collaboration and coordination among key entities—including ports, shipping companies, freight forwarders, and logistics parks—should be deepened. Using a unified information platform, various logistics resourcescan be shared and better allocated, connecting all operational links such as warehousing, transportation, and forming an integrated logistics service system. This ensures that cargo information flows in real time and is processed in a coordinated way among all involved parties.

On promoting integrated industrial development, the region should drive cross-sector integration between port and shipping logistics and finance, trade, and information technology. The region should actively develop shipping finance businesses such as ship financial leasing and shipping insurance, and use digital tools to optimize trade processes and expand new business models such as cross-border e-commerce logistics. By utilizing blockchain technology for cross-border logistics payments and settlements, Practitioners in related industries can effectively enhance transaction efficiency and fund security.

DOI: 10.54254/2755-2721/2026.CH35095

7.2. Strengthening the development of logistics information platforms

Logistics information platforms are the core infrastructure for a smart port and shipping logistics system, and they are the key to making industry data flow and achieving digital operations. Based on the current operational realities of Yangshan Port and Shanghai Port, the logistics information platform system needs improvement in two areas: industry standards and specifications, and platform functionality upgrades. This will drive the intelligent and integrated development of port and shipping logistics. To solve the problems of disorganized data and incompatible systems in the port and shipping logistics sector, the first step is to establish a unified logistics information standard system. This involves defining uniform data formats, system interfaces, and information transmission standards. Using the mature operational systems of Shanghai Port and Yangshan Port, industry standards can be put into practice. This will open data channels between enterprises and operational platforms, eliminate long-standing information silos, and improve the efficiency of logistics information sharing, transmission, and circulation. In doing so, it lays a solid data foundation for the coordinated development of port and shipping logistics.

On this basis, the platform's functional modules also need to be continuously improved. This should be done by combining Yangshan Port's actual operations with the business needs of logistics enterprises. While retaining basic functions such as information dissemination and end-to-end cargo tracking, new intelligent services—including big data analysis, smart decision-making, and online transaction settlement—should be added. This will create a one-stop port and shipping logistics information service platform, helping logistics enterprises optimize management models, reduce operational costs, and enhance the overall operational quality and market competitiveness of the regional port and shipping logistics industry.

7.3. Cultivating professional talent for smart logistics

Talent is the key to building and sustaining smart port and shipping logistics. A pool of professional, multidisciplinary talent provides solid human and technical support for the intelligent transformation of ports. To keep up with the rapid development needs of smart port and shipping logistics, it is necessary to improve the talent cultivation system through both institutional education and corporate on-the-job training, so as to build a professional workforce that fits industry needs. Major universities and vocational colleges can optimize their logistic management curricula by aligning them with industry trends and job requirements. This includes adding courses related to intelligent technologies, such as information technology and big data analysis, to break through the limitations of traditional logistics education. At the same time, using institutions in the Shanghai region, they should deepen industry-academia partnerships with leading port enterprises like Yangshan Port to establish a talent development model that integrates industry, academia, and research. This approach will cultivate versatile logistics professionals who possess both a solid logistics foundation and practical IT skills.

Furthermore, Port and shipping enterprises must also pay attention to the professional development of their current workforce. Through diverse training models—including internal training, industry study tours, and online self-directed learning—they should regularly train employees on topics like intelligent equipment operation, data analysis, and smart logistics concepts. Yangshan Port has long been committed to smart technology training for its employees, encouraging them to actively learn new technologies and concepts in the industry. This approach continuously enhances the professional competence and practical skills of its staff, helping the entire team adapt to the modern requirements of the smart port and shipping sector [11].

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8. Conclusions and outlook

Based on this study of logistics management innovation and development under smart ports and shipping, and using Yangshan Port as a practical case, we reach the following conclusions: Ports and shipping play a vital role in the global logistics system; traditional port and shipping logistics face numerous challenges, while smart ports and shipping offer new opportunities for logistics management. The application of smart port and shipping information technologies—such as automated terminal technology, blockchain technology, and big data technology—at Yangshan Port has significantly improved logistics management efficiency, reduced costs, and enhanced safety and transparency. Logistics management under the framework of smart ports and shipping requires innovative strategies, including the construction of a smart logistics ecosystem, the strengthening of logistics information platforms, and the cultivation of professional talent, to meet future development needs.

As information technology continues to develop and innovate, smart ports and shipping will move toward smarter, greener, and more globalized operations. Technologies such as artificial intelligence, the Internet of Things, and blockchain will be applied more extensively in port and shipping logistics management, enabling intelligent control and management throughout the entire logistics process. Meanwhile, green and environmentally friendly concepts will be built into the development of the port and shipping sectors, driving the transformation of port and shipping logistics toward low-carbon and sustainable practices. On international cooperation, large ports like Yangshan Port will play a bigger role in the global interconnection and coordinated development of port and shipping logistics, benefiting global trade and the economy.

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