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# Application of Intelligent Technology in the Construction Phase of Port Engineering

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**Abstract.** Port engineering serves as a core hub and strategic infrastructure in the development of the national coastal economy. Although modern port engineering exhibits trends of larger scale, deeper draft, and higher specialization, the construction phase is confronted multiple challenges, including large project scale, tight construction schedules, poor information transmission and significant interference from natural factors such as offshore wind, waves, and geological conditions, as well as frequent cross-operation of various types of personnel and mechanical equipment. The traditional construction management modes suffer from information silos, resulting in superficial application of construction data analysis, and inability to proactively identify and early warn risks; thus, an effective solution is urgently needed. This article focuses on the application of intelligent technology in the construction phase of port engineering. Based on a systematic review of recent related research literature, this paper summarizes the specific applications of intelligent technology and finds that it has significant advantages in improving the efficiency of emergency response, optimizing resource allocation, and reducing energy consumption in construction progress and resource optimization, safety management, and ecological environmental protection. At the end of the paper, the author reflects on the potential application challenges of intelligent technology in the port environment and prospects its future development path.

**Keywords:** Port engineering; construction phase; intelligent technology; application.

## 1. Introduction

As a core hub of the national coastal economy, port engineering is not only a key gateway that connects domestic and international economic and trade exchanges, but also a strategic infrastructure that supports the coordinated development of the industrial chain and ensures the stability of the supply chain. In addition, the impact of natural factors such as sea waves and geological conditions has led to multiple high-risk operations and cross-construction, significantly increasing the difficulty of construction organization.

The construction participants involve many subjects, such as construction and supervision. The personnel composition covers many types, such as professional and technical personnel and industrial workers. The mechanical equipment includes dozens of categories such as large cranes, pile driving boats and shield machines, and the cross-operation of multiple subjects and elements is frequent, which also brings many problems to the construction, safety management and training work [1]. The traditional construction management mode has the phenomenon that different systems are independent and lack correlation with each other, and the analysis and application of construction data is shallow, so it is unable to actively identify and warn risks [2].

In this context, the application of intelligent technology provides an effective way to solve these problems. The use of intelligent technology can integrate data from multiple systems, build a centralized data platform and analyze the correlation law behind the data, to provide data support for management decisions. The intelligent technology can accurately detect the potential risk signals, such as structural displacement, abnormal operation of equipment, illegal operation of personnel, and automatically trigger the warning mechanism to help the construction participants identify the potential risks in advance, whichgreatly enhance the risk control ability [3]. Intelligent technology can also improve the communication and training of construction personnel in construction

management, and reduce the operational difficulty and workload of construction personnel to a certain extent. In conclusion, the application of intelligent technology can improve many challenges faced in the construction phase of port engineering.

Based on a systematic review of relevant research literature in recent years, this paper first summarizes the specific applications of intelligent technology in the construction phase of port engineering. Then this paper focuses on core application fields and summarizes the advantages and values of intelligent technology in construction progress. At the same time, considering the practical conditions of port engineering construction, such as complex natural environments and special operation scenarios, the paper reflects on the challenges in the application of intelligent technology. In the end, based on industry development trends and technological innovation directions, the paper further prospects the future application paths, development potential, and upgrading directions of intelligent technology in the construction phase of port engineering, providing references for promoting the intelligent transformation of port engineering construction management.

## 2. Progress and Material Management

### 2.1. Construction Schedule Management with Building Information Modeling (BIM) Technology

Building Information Modeling (BIM) technology improves the accuracy and efficiency of construction management with features such as visualization and real-time performance, which are mainly used for the visualization of construction schedules, real-time monitoring, and optimized adjustments [4].

On the visualization of construction schedules, BIM technology can construct a 3D model that is highly consistent with the actual building, and add a timeline to form a 4D model, to transform the construction plan into a dynamic process simulation. BIM technology allows construction personnel to directly grasp the sequence of various processes.

On real-time monitoring, the BIM system can collect construction progress data by connecting Internet of Things sensors and intelligent construction equipment. When there is a schedule deviation, a timely early warning can be issued. When a schedule deviation occurs, BIM technology can analyze the impact of the deviation on subsequent processes based on real-time monitoring data and propose an adjustment plan.

### 2.2. Resource Optimization and Material Management

The construction site has limited space, making it difficult to store large-scale materials centrally. Due to the large scale of ports, material transportation distances are long. The supply chain is complex, and some construction processes have high requirements for the timeliness of material supply. Through the intelligent scheduling system, the material demand plan is automatically generated according to the construction progress, and the inventory is reasonably arranged in combination with the site limits. Through the establishment of a component coding system, the one-to-one correspondence between materials and processes is realized, to solve the management problems of site, transportation, and timeliness [5].

In summary, technologies such as BIM and the Internet of Things greatly facilitate the construction management of port engineering, provide solutions for the real-time adjustment of construction plans and material management, enhance the responsiveness and efficiency of construction, and reduce costs and energy to some extent. However, the use of intelligent technology increases the demand for interdisciplinary talents proficient in both engineering and computer science, proposing higher requirements for personnel training.

## 3. Application in Safety Management

### 3.1. Hydrological and Meteorological Monitoring

Port engineering is greatly affected by hydrological and meteorological conditions in the construction process, and real-time monitoring of relevant data is very important for construction safety. The intelligent monitoring technology can monitor the hydrological and meteorological parameters, such as water level, velocity, wave, wind speed, and wind direction in real time and comprehensively.

By arranging multiple hydrological and meteorological monitoring points around the port and equipping them with relevant equipment such as water level sensors, current meters, and anemometers, real-time monitoring of hydrological and meteorological parameters can be monitored in real time. Through the data analysis model, the received data is deeply analyzed and predicted [6]. If abnormal conditions are detected in the relevant data, the early warning mechanism can be quickly started, thus the construction unit can be quickly notified, and relevant operations can be stopped in advance. The temporary facilities shall be reinforced to protect the lives of construction personnel and ensure equipment safety and minimize the impact of adverse weather conditions [7].

### 3.2. Personnel Safety Management

**Table 1.** Intelligent Personnel Safety Management

| Technology Category | Description of Core Functions | Application Advantages |
|---|---|---|
| Intelligent Camera Technology | Real-time monitoring of the wearing of protective equipment (such as safety helmets and reflective clothing) by construction personnel. With Artificial Intelligence (AI) recognition technology, it monitors unsafe behaviors as well as object deformation and displacement. It issues alarms immediately when dangerous situations occur. | Solves the management problems of scattered port construction areas and complex personnel allocation. Improves the efficiency of supervision and rescue, and reduces losses caused by dangerous accidents. |
| Virtual Reality (VR) Safety Experience | In the Phase III Project of the Automated Terminal in Qianwan Port Area of Qingdao Port, a VR safety experience room was set up to construct a virtual construction environment. Combined with wearable devices, it creates an immersive learning scenario involving vision, hearing, and touch [8]. It simulates safety accidents and their hazards to assist in safety knowledge teaching and examinations. | Enhances construction personnel's safety awareness and stimulates their initiative in learning. Enriches training forms, evokes emotional resonance, and significantly improves training effectiveness. |
| Intelligent Bracelet for Personnel Health Monitoring | Real-time monitoring of the physical status of construction personnel; automatic early warning when the status exceeds safe values [3]. When personnel are lost or injured, it automatically alarms and locates to assist in rescue. | Prevents health risks in advance and ensures the physical safety of personnel. Shortens the rescue response time and improves the efficiency of emergency disposal. |

Intelligent technology has a variety of applications in personnel safety management, as shown in Table 1. The table introduces the application of three intelligent technologies in personnel safety management and summarizes the core functions and application advantages.

Intelligent technology provides great convenience for construction safety management and enhances the diversity and effectiveness of personnel training methods. In the open and scattered port construction areas, intelligent technology can issue alarms immediately when emergencies occur through real-time monitoring, providing time for the evacuation of construction personnel and rescue work.

At the current stage, limited by technological maturity and adaptability to complex scenarios, intelligent monitoring still needs to operate in a human-machine collaboration mode. The intelligent system is responsible for data collection and preliminary risk identification, while the staff conducts in-depth analysis and decision-making based on on-site experience. The two complement each other to form an efficient safety management closed loop. With the continuous development of technology, the safety management of port construction will become more intelligent and automated in the future.

### 3.3. Structural and Equipment Safety Monitoring

The surrounding environment of the port is complex, and problems such as landslides and settlement may occur in the construction area, which can easily affect the construction. The construction of ports and wharves relies on shield machines, shore bridges, and other large-scale special equipment, and its operational status directly affects the construction efficiency and safety. Through installing vibration sensors, temperature sensors, pressure sensors, inclination sensors, etc., the operation status and load weight of relevant facilities in relevant areas are monitored in real time [3]. By analyzing past cases through intelligent algorithms, the construction participants can identify precursors and issue early warnings, facilitating the design of response plans in advance or carrying out maintenance to extend the service life of related facilities.

## 4. Application in Environmental Monitoring

Intelligent monitoring systems can help construction personnel understand the pollution situation at the construction site in real time, take preventive measures promptly, and protect the health of construction personnel and the surrounding environment and climate. However, changes in air flow and water flow at the ports may affect the accuracy of data from monitoring equipment, reducing the effectiveness of actual monitoring. In the future, with the continuous development of technology, these problems are expected to be alleviated.

### 4.1. Air Quality Monitoring

There will be a large number of solid particles and other pollutants in the construction of port engineering. These pollutants may harm the health of construction personnel, and affect the climate of nearby areas or sink into nearby waters, causing pollution. Therefore, it is very important to spray water to reduce dust promptly in the construction area. By monitoring relevant indicators such as the PM2.5 index at the construction site, the intelligent management platform links the monitoring equipment with the spray device. When the pollution index is close to a specific value, the spray device is automatically activated to achieve real-time dust suppression [9]. The application of intelligent spray equipment can improve construction efficiency, reduce the impact of dust on construction personnel and the surrounding environment.

### 4.2. Intelligent Water Quality Monitoring

Construction operations may cause solid particles and mud to enter nearby waters, affecting water turbidity and destroying the living environment of aquatic organisms in the vicinity. Intelligent water quality sensors can be installed around the construction area to monitor water parameters such as suspended solids and pH value. When the environmental protection standard is exceeded, an

automatic warning will be given to remind the construction personnel to use the antifouling curtain to prevent the suspended particles from spreading to the surrounding. At the same time, the construction company suspended the operation and adjusted the operation scheme to avoid further impact on the nearby sea area [10]. This measure can not only effectively avoid the further impact of construction water pollution on nearby sea areas, rivers and other waters, but also help the construction unit to ensure environmental protection and efficiency at the same time[10].

## 5. Conclusion

This paper discusses the application of intelligent technology in port engineering and its practical effects. By analyzing the application effects and existing challenges of intelligent progress management, safety management, and monitoring systems, the following conclusions are drawn:

Intelligent management technologies such as BIM and Internet of Things show significant advantages in the process of port engineering construction. Their characteristics of visualization and automation not only greatly reduce the work difficulty of relevant personnel, improve the response speed and disposal efficiency for emergencies, but also effectively optimize resource allocation, reduce unnecessary energy consumption and lower the overall construction cost of port engineering, which provides strong support for the efficient advancement of the project.

The application of intelligent technology in the field of safety management provides an effective solution to the pain points of port engineering, such as large-scale, scattered operation areas, and difficulty in timely capturing environmental changes. Intelligent sensors can monitor on-site environmental abnormalities in real time, intelligent cameras can standardize the operational behaviors of construction personnel, and VR technology can enhance the safety awareness of construction personnel. In the event of sudden special situations, the intelligent system can automatically issue an alarm immediately, gaining valuable time for subsequent rescue operations and personnel evacuation, and significantly improving the safety guarantee level of port engineering construction.

The application of intelligent monitoring systems is of great significance in environmental protection and personnel health protection. The system can capture pollution data at the construction site in real time and accurately, helping the construction team fully grasp the distribution and diffusion of pollution. This not only builds a solid defense line for protecting the health of construction personnel, but also provides data support for controlling climate and environmental pollution. Based on the monitoring results, relevant personnel can adjust construction processes and procedures promptly, effectively alleviating pollution problems and realizing the coordinated advancement of project construction and ecological protection.

The application of intelligent technology in port construction still faces practical challenges. On the one hand, the initial investment cost of intelligent facilities is relatively high, increasing the financial pressure of some projects. On the other hand, intelligent technology has an urgent demand for interdisciplinary talents proficient in both engineering and computer science, and the talent gap has become an important factor restricting the implementation of the technology. These problems need to be solved gradually through collaborative cooperation inside and outside the industry, combined with technological innovation, policy support, and the improvement of talent training systems.

In conclusion, intelligent technology provides an efficient new path for port engineering construction management, and its application effects in progress management, safety management, and environmental monitoring have been fully demonstrated. Although its current application in port engineering still faces challenges such as facility costs and talent demand, with the further development and maturity of technology, intelligent technology is expected to achieve wider popularization and in-depth application in the field of port construction in the future. This will promote the transformation of port construction management towards a more integrated, automated, and efficient direction, injecting new impetus into the development of the port engineering industry.

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