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Analysis of the Comprehensive Coordination Role of The Smart Command Center in Intelligent Infrastructure

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Abstract. After China entered the stage of high-quality development, the government and relevant departments have made it crucial to use data algorithm-based construction methods to improve the construction efficiency of construction projects. For example, Geographic Information System (GIS) big data maps and Building Information Modeling(BIM) modeling have been successively invested in urban and rural construction projects. Of course, the integration of technology into architectural requirements is becoming increasingly comprehensive. To further explore this phenomenon, this article introduces the concept of a smart command center. Starting from the practical aspects, including the challenges of infrastructure projects, design drawing, and construction requirements during the construction phase, it will elaborate on the corresponding detailed technical integration and simplification solutions. Especially during the construction phase, the two-way integration of BIM5D technology and the command center allows the construction project to form a digital twin. This technology significantly optimizes the supervision and coordination of construction projects. Finally, the article highlights the importance of utilizing smart command centers in data integration, efficient construction coordination, and simulated construction, and looks forward to the deeper application of command centers in future smart infrastructure, leaving room for imagination the sustainable development of the construction industry.

Keywords: Infrastructure construction; intelligent command center; artificial intelligence; big data.

1. Introduction

First of all, infrastructure is important because it determines the skeleton and spatial layout of the city. So far, infrastructure development has been relatively mature, which is specifically reflected in the project volume, the groupization of construction companies, the scale of construction technology, and the scale of financing and capital operation. For the people, the service facilities in the current society and cities are already complete, but the transportation network between cities is still under construction. Therefore, it is not difficult to find that the "regional construction" between cities is the "diamond plot" for future development, such as the Greater Bay Area infrastructure, high-speed rail network, or water conservancy hub construction, and other large-scale projects. However, since infrastructure is closely related to national economic development, these projects are usually only taken over by leading central enterprises or large monopoly enterprises. For example, in the current construction project landscape in mainland China, China Railway, China Construction, and China Communications Construction Company have formed an oligopoly, and other companies have mostly appeared in the form of subcontractors. However, the advantage is that their technology and management methods are more process-oriented and scaled, and they mostly adopt the "Internet + Big Data" management model, which also lays the foundation for the use of smart command centers. Infrastructure projects differ from residential real estate and urban commercial construction projects in that they must comply with higher government standards and requirements, and the level of coordination between construction design and other departments is more complex. Therefore, when it comes to inputting construction standards, the intelligent command center undoubtedly provides a clearer service to workers. In addition, according to Professor Liu Weibo's paper, the command center can use its excellent computing power to restore the real-life architectural environment in the twin drawings with an error accuracy of centimeters, which undoubtedly greatly improves the efficiency and safety of the project.

Secondly, the impact of intelligent construction in infrastructure is also becoming increasingly significant. In the past, huge computing power was consumed in the project design phase to make the drawings fit the actual construction. With Building Information Modeling(BIM) as the foundation, the current support of algorithms and Artificial Intelligence (AI) has undoubtedly greatly improved the comprehensiveness and usability of construction plans. The development of intelligent construction has made the construction process more intelligent. Not only that, in the future, the role of the smart command center will become increasingly important with its ability to combine multiple digital technologies and perceive the construction site in real time. From a rational perspective, intelligent construction is currently in its infancy, but the benefits are already very obvious, so the future of smart construction sites is bright. Human resource allocation will also urgently need to change in the future. How to use existing technology to enable fewer workers to complete qualified and fully guaranteed projects has become the focus of development. In order to comprehensively optimize the quality of construction project management, combine the specific needs of project management, and give full play to the advantages of construction technology application, smart command centers are now frequently appearing in global infrastructure construction, while improving the efficiency of dynamic supervision of construction projects [1]. Compared with the past experience-driven and decentralized infrastructure projects, infrastructure projects with smart command centers undoubtedly have more say in terms of real-time data analysis and information sharing capabilities. However, there are still several obvious difficulties in the involvement of smart command centers in current infrastructure projects. The traditional management model mostly uses paper archives in Excel or telephone communication, while the command center requires real-time public sharing of information; Secondly, in the management and control methods, in the past, quality inspections were mostly carried out after the fact, and by the time they were discovered, cost losses had already occurred. Although digital management and control platforms are complicated to build in the early stage, they will save money in the later stage. These are all objects that need to be overcome.

2. The Theoretical Foundation of the Intelligent Command Center in Infrastructure Projects

This study believes that the smart command center utilizes advanced technologies and intelligent systems in the construction process. It is a central decision-making hub that integrates traditional construction technologies such as BIM and mechanical principles with advanced technologies such as big data and artificial intelligence. First, to better understand the uniqueness of the smart command center, it need to see the difference between the smart command center and smart construction: smart construction is a macro concept that represents more of the trend of the construction industry, while the smart command center is a "tool" or a central decision-making platform for the specific implementation of smart construction [2]. Based on the requirements of past construction projects, it was concluded that the architecture of the smart command center should include four horizontal systems: the first layer is the data collection and input layer, where data sources include machine collection and manual transmission, and interactive preparations are made after the data is collected; the second layer is the network and information exchange layer: it mainly relies on communication platforms and government-specific networks to ensure that construction projects are in line with government policies in real time, and also contributes to communication channels for information transmission, ensures information disclosure, and makes personnel construction more efficient; the third layer is the data processing center, which uses big data centers, Geographic Information System(GIS) platforms, and artificial intelligence middle platforms. This layer must have powerful algorithms, be able to handle complex and diverse data, and have open interfaces. It is the basis for the normal operation of the entire smart construction site on software: the highest layer is the decision-making and application layer, which includes daily monitoring and duty systems, early warning and prediction systems, decision support systems, and comprehensive display systems (command screens) to macro-control the safe progress of construction projects. The difficulty of smart command work lies in the fact that the construction of infrastructure is different from commercial, residential, and

commercial areas. The focus is on the construction of public facilities such as roads, tunnels, and water conservancy hubs. Therefore, it is large-scale, extremely costly, technically complex, and has extremely high safety requirements. Therefore, the smart command center adopts a technology-enabled approach to deal with the above difficulties. The core competitiveness lies in transparent management, real-time perception of risk control, lean management to reduce costs, and the ability to provide scientific decision-making recommendations with big data.

3. Intelligent Management Technology Based on the BIM Model in Infrastructure Construction

3.1. Summary of Infrastructure Construction Information

BIM technology, as an innovative achievement in the digital age, is gradually reshaping the operating model of the construction industry [3]. In the construction of building projects, it is necessary to consider various information to control construction risks, such as the location of the structure, electromechanical and pipelines in the BIM model; in order to comply with construction regulations at all times, the dust and noise indicators collected in real time from the construction site provided by the Internet of Things are required; the command center can be put into use by connecting the Lot Internet of Things, cloud platform Application Programming Interface (API), etc. to the system and uploading them to a unified database. The information summarization of intelligent management and control technology mainly uses a series of technical means to analyze and organize raw data in different formats into the same platform, providing designers with more comprehensive and clear building data, further reducing the dominance of experience in BIM modeling.

3.2. Visualization Strategies for Big Data Technologies

Because big data has been developing for over a decade, numerous platforms have emerged. The Geographic Information System (GIS) we're discussing is a highly specialized computer system whose core functions are the collection, storage, efficient management, convenient retrieval, in-depth analysis, and intuitive display of geospatial data. It introduced this system to leverage its powerful data processing capabilities, enabling precise processing of information with well-defined spatial attributes, thereby revealing the spatial distribution patterns and interrelationships of data. In other words, this means that accurate, on-the-ground information can be collected even on mobile devices. For this reason, GIS maps can effectively provide powerful data support for infrastructure projects and be integrated into BIM models. Secondly, the analysis capabilities of GIS can indeed provide visualization solutions for complex geographic spatial problems such as bridges and highways in infrastructure projects [4]. When deciding on a construction plan, leaders at different levels have different requirements for building information. For example, investors in construction projects require that funds be used more effectively, while contractors prioritize safety and hope to fully utilize building materials in the framework structure. The bidding government prioritizes whether the building meets environmental standards. This is when visualization comes into play, providing a multi-dimensional perspective: central leadership requires information on the overall project architecture, while managers at the local construction level require information on personnel in their jurisdiction and planning for large cranes or other equipment. After the database distributes the diverse data to staff in layers on the platform, managers can easily make optimal plans based on big data intelligence recommendations. GIS maps also demonstrate their full value in cost control program planning: optimizing project cost management, comprehensively considering the site selection of material yards and the distance of material transportation to reduce material procurement costs, identifying macro-risk areas such as geological disasters, and evaluating potential governance costs in some aspects that are difficult for the client to consider and incorporating them into investment estimates [5]. In the final plan finalization stage, in order to ensure the comprehensiveness and feasibility of the plan, an interactive online map is generated to display it to the public and collect feedback. It is undeniable that the system has the advantage of a comprehensive thinking model.

3.3. Artificial Intelligence Solution Selection

There is no doubt that artificial intelligence has enabled various industries in recent years. In the construction of a smart command center, the embedded system of artificial intelligence models is equivalent to adding an "administrator" to the entire information database. It has the ability to automatically identify information that exceeds the risk threshold and provide feedback to managers. For the screening of infrastructure plans, on the one hand, it must ensure the quality and scientific nature of the project. Secondly, it must also take into account the factors that infrastructure projects involve a wide range of geological conditions, complex design parameters, stringent climate requirements, diverse material properties, and long construction periods. It use AI to help screen options because AI algorithms can identify features in historical construction project databases and real-time data, and calculate the potential advantages and risks of different options in terms of safety, economy, and sustainability. By training models and analyzing the success and failure cases of similar projects in the past, artificial intelligence can predict the performance of a specific design scheme under different environmental conditions and provide a quantitative basis for scheme selection. This data-based analysis method undoubtedly improves the scientificity and accuracy of solution screening. On the other hand, it is difficult for traditional methods to complete data collection and analysis in a short period of time. In the past infrastructure projects, the scope of traditional scheme screening was limited to a small number of construction schemes discussed by the engineering team. Artificial intelligence has transformed this situation into using algorithms to find the optimal solution set among many schemes, providing a scientific basis for decision makers [6].

4. The Application of the Intelligent Command Center during the Construction Phase

4.1. Application in Quality Management

According to multiple research reports, in today's infrastructure quality management, infrastructure projects often use a wide variety of building materials, use large quantities, and involve a wide construction area. Therefore, many processes in actual construction require 24-hour uninterrupted inspection. For example, in the construction of elevated bridges, key procedures such as concrete pouring and steel bar binding are required. Construction sensors connected to the command center can collect real-time data on temperature, humidity, stress, vibration, and more. Before transmitting this data to management personnel, the big data platform will conduct a comprehensive comparison and present potential safety hazards and guidance suggestions to ensure the safe implementation of the project. The core role of the smart command center in the construction phase is to change the traditional quality management model that relies on manual labor, post-inspection, and passive response. This undoubtedly changes and creates a new approach to construction projects. The Smart Center not only provides management with intuitive and quantitative decision-making basis, but also enables the shift from experience-driven decision-making to data-driven decision-making. Our vision is that the core of the platform's operation lies in integrating real-time data on construction personnel, production materials, construction tools, etc., which will be uniformly processed and presented in the construction control hall through digital technology. Finally, the overall quality status of the project will be centrally displayed on the large screen of the smart command center, including indicators such as the acceptance rate, the total number of quality issues, and the progress of each project. Project columns will then be further added according to specific needs. This shows that this intelligent detection system significantly improves the timeliness and accuracy of problem discovery during construction. Of course, it also reduces the blind spots and lags of manual inspections, reducing the probability of accidents from the source.

4.2. The Application of Artificial Intelligence in Security Management

First of all, the most prominent and significant role of artificial intelligence in safety management is intelligent identification and risk warning. Compared with traditional safety management, construction sites are highly dependent on manual inspections. The obvious shortcoming is that it is

not only inefficient but also prone to omissions. The strategy it designed is to use artificial intelligence to enter the construction site. On the one hand, it provides construction workers with convenient services such as admission, physical examination, training, and attendance, thereby enhancing their sense of ownership and ensuring construction safety. On the other hand, the supervisor strengthens safety supervision through remote video real-time monitoring, face recognition, and other means, and closely provides convenient and effective monitoring means for on-site safety management [7]. In addition, it plan to connect AI with sensors. Artificial intelligence will detect data on the construction site, such as gas concentration, temperature, vibration amplitude, etc., in order to determine in real time whether construction workers are poisoned or there are sudden situations such as equipment damage during work. Next, to ensure that construction status is reflected in real time on terminal devices, it plan to integrate GIS and BIM into a single map: the entire construction site will be digitally restored at a 1:1 ratio, allowing project managers and the client to intuitively see the distribution of construction personnel and equipment status. Secondly, the system will intelligently capture and warn staff members of any irregular behaviors, such as not wearing reflective clothing, smoking, and illegal gatherings. Since artificial intelligence technology itself has the ability to continuously iterate and update itself, it hope that artificial intelligence can fully play the role of learning and analysis in safety management. The AI system will then analyze and learn from large amounts of construction data to conduct risk analysis on safety conditions at different stages. For example, after equipment imaging, by analyzing multiple sources of data such as the operating habits of construction personnel, the status of equipment operation, and changes in the working environment, AI will generate exclusive risk heat maps for managers based on these data to provide risk warnings. It is particularly noteworthy that AI will also establish risk assessment models based on past accident type data and propose optimization strategies for construction plans in advance.

4.3. Application in Project Cost and Progress

It created the Smart Command Center because it is capable and can be relied upon in multi-party collaboration and costly infrastructure projects. Digital twin technology provides a powerful tool for intelligent construction, enabling realistic presentation of the physical construction environment and virtual models, and effective and efficient data interaction and feedback [8]. After processing, this information data is converted into visual progress curves and trend charts and presented to staff. There is no reason not to use such an epoch-making construction tool. Let us return to the underlying logic of the command center. It can find that all this is due to the smart command center integrating multiple information into a unified digital twin through "BIM 5D" technology (3D model + time + cost). That is, the corresponding cost expenditure and project progress can be known at any time in the infrastructure project, truly enabling project management to achieve a closed-loop model from data acquisition to decision implementation [9].

5. Conclusion

In general, the smart command center is the "smart brain" of modern infrastructure projects. Its core role is reflected in its powerful data integration capabilities, intelligent early warning functions, efficient collaborative command capabilities, and construction simulation capabilities. Incorporating smart technology into the BIM design phase of infrastructure projects allows us to generate a three-dimensional model of the plan to display the overall structure of the project during the design process. Our goal is to enable managers and builders to predict conflicts between the design and actual conditions, pipeline intersections, and other problems in advance. This digital verification will undoubtedly make adjustments in the design phase more precise. During the construction plan screening stage, it used large artificial intelligence models to avoid problems such as plan limitations and a lack of plan diversity, greatly saving labor and time costs consumed in collecting data. Overall, there are many favorable factors in the BIM design stage, including technology-driven factors, management factors, and model innovation factors. After the project enters the construction phase, which is the most critical stage, the smart command center serves as the highest information carrier

and the highest construction commander. It use the Internet of Things, big data platforms, and AI to empower it, so that the smart command center can control the comprehensive and detailed information on building materials use, construction specifications, and personnel scheduling from the beginning of construction. Ultimately, this information is intuitively projected on the central large screen for management personnel in the form of a digital twin, ensuring the precise implementation and control of building quality, construction safety, project progress, and cost control during the construction phase. The command center has become an indispensable management tool in contemporary infrastructure projects. However, all these ideas and implementations will certainly be impacted by realistic factors. As intelligent construction matures, potential problems in the future will naturally become the focus of attention for the government and central construction companies. This includes data security. For example, will uploading all the data in the project digitally to the cloud be stolen by hackers, leading to the leakage of some core data? Where do it need to strengthen the reinforcement? In addition, the cost pressure brought by technological iteration cannot be ignored, because the construction tools developed based on the Internet are inevitably updated and iterated, and now it are in an era of rapid development of the Internet. Some hardware facilities are expensive, and how to solve the incompatibility problems caused by software development still needs to be optimized. The research results show that breaking through the traditional construction methods of the construction industry and taking intelligent construction digitization and intelligence as the core links to achieve high efficiency, high quality, and low consumption in engineering construction are indispensable in future modern infrastructure. Therefore, the increasing proportion of intelligent platforms in the construction industry has become a trend of the times.

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