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The Application of Digital Technology in Improving the Progress Management of Assembly Buildings

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

In recent years, guided by the new development concepts and against the backdrop of national economic transformation and upgrading policies, the construction industry has also embarked on modernization and transformation and upgrading. Digital technology plays a significant role in this process. Schedule management, as one of the three major objectives of project management, directly affects construction costs and quality if not properly managed. Starting with the schedule management theory of prefabricated buildings, this paper focuses on analyzing the problems existing in the process of schedule management of prefabricated building projects. Through the application of digital technology, corresponding measures are proposed to solve the problems in the design, production, transportation, construction and maintenance of components, so as to improve the schedule management of components and build a sound project schedule management strategy.

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Keywords: Digital Technology; prefabricated construction; schedule management.

1. INTRODUCTION

In the era of rapidly advancing information technology, digital technology has become a significant driving force for transformation and upgrading in various industries. Particularly in the field of project management, the application of digital technology has provided new possibilities for enhancing the efficiency and accuracy of project schedule control [1,2]. Traditional methods of project schedule control often rely on manual record-keeping and human analysis, which are prone to human factors leading to information lag and decision errors. With the rapid development of digital technologies such as big data, artificial intelligence, and cloud computing, project managers can now access real-time project progress information and make more scientific and timely decisions through data analysis and predictive tools [3,4].

The purpose of this paper is to discuss the application of digital technology in project schedule control and the changes it brings. By analyzing the factors that affect the project schedule management in each stage of assembly building through digital technology, some practical countermeasures are put forward, which can effectively shorten the construction speed of the project. complex and ever-changing environments.

2. EXISTING PROBLEMS IN CURRENT PROJECT SCHEDULE MANAGEMENT

Construction Information Integration Issues: With the expanding scale of construction projects and increasing requirements for engineering quality and construction technology, a vast amount of construction information data is generated, and the frequency of information exchange between departments has increased. In traditional information management models, relevant data must be sought from personnel in various departments, and then the required data must be screened and organized manually, which makes information inaccessible anytime and anywhere. This results in tedious work procedures and hinders the integration and sharing of information, making it difficult for construction enterprises to exert substantial control over costs .

Schedule Management Process Issues: Currently, issues such as poor coordination between different disciplines, rework due to technical difficulties, and design changes due to discrepancies between drawings and actual construction commonly occur throughout the project construction cycle. Traditional schedule management methods often fail to clearly identify the logical key points between different processes, make strict control of critical areas, and compare actual and planned schedules in a complex manner. They cannot make corresponding adjustments based on comparison results, nor can they conduct precise analyses of material consumption or dynamically manage and make precise decisions on construction progress.

Personnel and Machinery Operation Issues: Prefabricated construction, compared to traditional cast-in-place construction, requires higher technical skills from workers. There are few experienced technical personnel available to construction parties, and the proficiency of workers is insufficient, directly impacting the efficiency of component production and stacking. The lack of project managers familiar with the management model of prefabricated construction also leads to unsatisfactory progress. Additionally, prefabricated construction is an industrialized process that requires specialized machinery and equipment for the production, transportation, and handling of prefabricated components. For instance, to ensure components are not damaged during transportation, devices must be installed on the transport vehicles that match the components. When machinery malfunctions, it can also cause deviations in construction progress.

Management Issues of Participating Parties: Prefabricated construction differs significantly from traditional construction in terms of management, requiring close cooperation among multiple parties. Traditional construction enterprise management models are difficult to change, and poor information flow and the agency construction management model severely constrain the integrated development of the industry. The current management system is still in the stage of cast-in-place management, with unclear management functions, systems, and processes for all participating parties. Due to a lack of experience in managing prefabricated construction, construction parties cannot resolve issues raised by the construction side in a timely manner, leading to delayed decisions and potential design changes. At the same time, there are instances of inadequate supervision and oversight by supervisory parties . The construction side plays a key role in the management of project construction schedules, and the rationality of their construction organization plan constrains schedule objectives. The production, transportation, and assembly of prefabricated building components are critical links, and China's prefabricated construction is still in its early stages. The production cycle for components is long, and if the quality of component processing does not meet standards, rework is required, issues that are currently difficult to control and urgently need to be resolved.

3. APPLICATION OF DIGITAL TECHNOLOGY IN THE SCHEDULE MANAGEMENT OF PREFABRICATED CONSTRUCTION

The case selected in this paper is a prefabricated building project in Fujian Province, with a building area of 1.39×104 m², a total building height of 91.7m, one underground floor, and thirty floors above ground, with prefabricated components used from the 4th to 9th floors, including prefabricated shear walls, prefabricated floor slabs, prefabricated stairs, and a single prefabrication rate of approximately 50%.

3.1 Factors Influencing the Schedule Management of Prefabricated Construction

In the entire construction process, the progress factors during the construction phase are the most numerous and have the greatest impact on the construction duration. The following aspects are analyzed to determine the factors influencing progress.

3.1.1 Design Stage

In prefabricated building construction, its design is significantly different from traditional construction, and the design scheme requires a longer period of optimization. It also requires the full participation of construction contractors, project owners, and other parties. All parties should work together to discuss and explore the design scheme, solve various problems, and ensure that the scheme is reasonable and feasible. Therefore, it is crucial for information sharing and communication among the parties during this process. However, there are currently problems with the lack of fluidity in information exchange and insufficient communication and exchange among the parties. There is no clear definition of each party's respective responsibilities, which has negatively impacted the preliminary work and led to an extended design period, affecting the project schedule [5].

3.1.2 Production Stage

In prefabricated building construction, the production of various components is a critical link, and all components required for the project must be produced by factories. Therefore, the production, storage, and lifting of components will all become key factors affecting the project schedule. The production of prefabricated components includes steps such as mold making, steel bar binding, concrete pouring, and demolding. During this production process, the workers at prefabricated building factories need to have higher qualifications and skills in terms of technical control, machine operation, process control, information and intelligentization than traditional construction workers [6]. Currently, there is not a complete professional talent team, and the workers' operation levels are low, which can lead to quality problems in production, causing return work to directly affect production speed and the entire construction progress. The production process of prefabricated components may face time constraints, heavy workloads, lax supervision, and unstandardized operations, which can affect the overall quality and lead to quality problems that will also affect subsequent progress.

3.1.3 Transport and Storage of Components Stage

In this phase, it is necessary to develop a transportation strategy, design and manufacture transportation racks, calculate the strength of structural elements, and check the inventory of components. Choosing transportation routes rationally according to the actual situation of transportation is crucial. The transportation of components significantly influences both the quality and efficiency of the entire construction process, a well-known difficulty in the management of construction [7]. Moreover, there is a high risk of collisions during the storage of components and while unloading them. If problems occur in these stages, it can impact the execution of the entire project.

3.1.4 Installation Phase

In this type of building, construction involves the on-site assembly of prefabricated components, which differs significantly from traditional construction methods. The installation process requires the coordinated operation of multiple large-scale lifting machines, increasing the complexity of management. The assembly of prefabricated components is more precise than cast-in-place work, further complicating on-site installation management. The tasks for installation workers mainly include scheduling of on-site large transportation machinery, stacking and protection of prefabricated components on-site, precision control of lifting machinery, positioning, setting in place, installation, support of components, and handling of other details related to prefabricated building construction. This demands that the operators possess qualities suited to intelligent building practices and that the machinery is highly specialized. Any improper operation, inadequate supervision, or failure to follow proper lifting procedures during the installation process can affect the overall installation efficiency [8].

3.2 Strategies for Accelerating Prefabricated Construction Progress through Digital Technology

3.2.1 Construction of the Three-dimensional modeling phase

In the model construction period, the BIM technology is utilized for the three-dimensional modeling of projects. In the BIM modeling procedure, corresponding software is used to build three types of models: 3D models, progress schedules, and associated models. The three-dimensional modeling of buildings can be completed using the Revit software, where after starting a new project, specific parameters such as design levels and grid networks are detailed, and finally, the view design is completed, leading to the establishment of a BIM three-dimensional information model for the building. The preparation of a schedule necessitates a detailed division of the engineering structure based on the differing types of prefabricated building components. The structure is divided into multiple WBS (Work Breakdown Structure) work reports, and then a schedule is created[9] . The division in the set of constructs within the model and the WBS work packages must be in alignment, ensuring that PC components are solidified and automatically linked to the schedule. The simulation feature of Navisworks can be applied to dynamically simulate the building construction process. After the initial few stages of work are complete, predictions are made about the requirements for various resources on the project site, and whether there are any issues with each work surface is understood. Upon identifying problems, swift solutions are required.

3.2.2 Project schedule analysis

Schedule planning is a cyclical task that requires multiple checks and problem-solving based on construction simulation to continuously improve the schedule plan. Using the visualization function of BIM technology and the real-time observation function of VR technology, progress managers can understand the virtual construction process during the construction period, check the rationality and orderliness of the construction process, and judge whether the final results of each work link can meet the expected design[10]. The progress data and model are dynamically synchronized, so that the progress control personnel can make synchronized modifications to the progress plan and the three-dimensional building model. When modifying the parameters of the three-dimensional building model, the progress plan will also be dynamically modified and dynamically adjusted.

3.2.3 Construction production stage

By analyzing the progress impact factors in the prefabricated residential building construction, it can be found that the quality and accuracy of the components directly determine the efficiency of the prefabricated assembly process. By using BIM technology to transmit project information from the design phase to the component production phase, it is possible to ensure the standardization and efficiency of component production [11]. Cloud computing technology can also be used to provide powerful data processing and storage capabilities to support the large-scale data management and analysis of prefabricated building projects. Through cloud computing technology, building information can be centrally stored, shared, and collaboratively worked on, improving the management efficiency and decision-making level of prefabricated building projects. By leveraging the advantages of standardized component production, a component library can be established for the construction project, such as prefabricated exterior walls, prefabricated beams, prefabricated stairs, and prefabricated air conditioning panels, etc. Then, the design unit can upload the BIM model to the BIM management cloud platform, and during the production of components, the manufacturer can design or adjust the mold based on the aggregated three-dimensional building model provided by the platform, guiding workers to manufacture the components [12]. For example, in Revit, wall types and thicknesses can be selected from the component library and placed in the model based on the wall type information. The manufacturer can realize precise production and processing based on the size and reserved holes of the wall in the model.

In the factory production preparation stage, the manufacturer can prepare the corresponding materials In the production stage, RFID technology can be used to track and manage the components throughout their lifecycle using wireless radio frequency signals for identification and information retrieval [13]. This can enable the tracking and management of components from production to construction, enabling precise material flow, improving production efficiency and accuracy, reducing production losses, and installing RFID tags on components to record related information. RFID readers can also be installed in production workshops and construction sites to read and retrieve information from components. A component tracking management system can be established to track and manage components throughout their lifecycle. In the quality inspection process, if defects such as cracks are found in components, they can be recorded in the cloud BIM management platform for managers to view and analyze, and solutions can be proposed. This process can also be carried out for incoming component inventory, and all information about components can be shared through the cloud BIM platform.

3.2.4 Construction transportation stage

At the end of the component production, it should be ensured that the component is transported smoothly and stored properly. When building the factory, the manufacturer can scan the components in batches through the reader, and enter their information directly into the BIM database, so that the specifications, quantities and batches of the components can be timely and comprehensively mastered. In the link of transporting components, it is necessary to refer to the order of simulated lifting to arrange the transportation of components reasonably. BIM technology can be used to simulate the loading and unloading of large components, so as to avoid damaging components in loading and unloading activities, so that the difficulty of component inspection on the construction site can be reduced, and the project progress can be shortened. When loading components, labels should be installed on each transport vehicle, input the number, name and type of components and other information, to ensure that the information has integrity and accuracy, and accurate positioning of each vehicle. Before transportation work, it is necessary to optimize the vehicle route to ensure the best route, and use logistics information tracking to ensure timely warning when delays occur, so that transportation activities can effectively reduce time and cost [14]. When the components have arrived at the site, they should be placed and stored in a reasonable position, because there are corresponding labels for the components. To this end, you can refer to the specific information of the labels to arrange the components according to the classification, to provide convenience for their use, to facilitate the rapid grasp of the location of the components, not only to facilitate the lifting activities, but also to effectively reduce the construction time and improve the efficiency of progress management.

3.2.5 Site construction phase

In the assembly building, the on-site construction is generally the on-site assembly activities for the components. During our on-site construction of the building case, in the construction stage, the intelligent management of the construction process is realized by using smart site technology, the Internet of Things, cloud computing, big data and other technologies, the comprehensive information management of the site, the intelligent and digital production process of the site, and the timely detection and elimination of security risks by optimizing the construction process and improving the utilization rate of construction equipment. In the process of project progress management, BIM technology can be used to share information and data in real time, and the specific process of assembly can be visually and dynamically managed by constructing a 4D space-time model combined with GIS technology [15]. With the accurate collection of component information, the line chart can be made, and based on the construction schedule, the delays that will occur in assembly activities can be analyzed, and the specific measures to solve them can be formulated through active communication [16]. In this process, the construction progress can be reflected in real time, and the assembly materials and specific processes can be visually reflected. Before the assembly work, you can try to simulate the specific operation of large equipment, such as tower crane, etc., to determine its position and avoid interference between equipment. The location of components and the specific route of mechanical activities on the site should also be reasonably planned to ensure that the construction site will not be chaotic and avoid schedule problems and safety accidents [17].

3.2.6 Operation and maintenance stage

In this stage, modular buildings are also at a critical juncture in the life cycle, and it is also a key component of progress management. Maintenance personnel can grasp detailed component information through BIM technology, accurately locate components, and grasp the specific route of embedded pipelines, thereby avoiding damage to pipelines or components during maintenance [18]. Based on BIM technology, a complete database can also be established, allowing maintenance personnel to grasp reference data for maintenance work. For example, when the building electrical system has a fault, the sensor in the component can transmit the information in time, which is sent to the computer terminal, and the property company can understand the specific location of the fault based on the three-dimensional modeling, and eliminate the fault in time[19,20]. When the fault leads to a fire, the property company can also use this to plan the best evacuation route for personnel, thereby avoiding significant economic losses and casualties caused by the fire[21,22] .

The analysis of the above six stages, combined with the specific cases we give, can be a good link between these measures and our reality. Through the implementation of these measures, we can better manage and monitor the progress of the project in the construction phase.If we can make good use of the benefits brought by digital technology, we will reduce the impact on the social environment and nearby residents during the construction process.

4. CONCLUSION

In prefabricated buildings, schedule management is one of the three objectives of project management. Based on the development status of assembly construction, this paper analyzes the problems affecting the progress management of prefabricated construction projects from the aspects of construction information integration, progress management process, personnel and machinery level and construction participant management. Then, through analyzing each stage of the whole life cycle of the project, the factors affecting the project progress are obtained, and corresponding improvement measures are proposed.In the information age, the application of digital technology will make up for the current management information lag and other problems. The purpose of establishing a sound progress management system is to ensure construction quality, improve work efficiency, reduce progress deviations, ensure that the expected progress targets are reached, promote the standardization and digitalization of progress management, and provide a scientific basis for the construction management of prefabricated buildings. The progress management measures mentioned in this paper can provide reference for the progress management of prefabricated construction enterprises.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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