Analysis of the Application of BIM in the Whole Process of Engineering Costing-Taking a Fire Station as an Example

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Abstract. In order to increase engineering quality and lower engineering costs, novel scenarios involving the integration of BIM technology and engineering costs can be realized. Examples include sharing engineering cost data and information and managing dynamic controls. As a result, this paper analyzes and summarizes the shortcomings of the fire station project's whole process cost management as well as the benefits of BIM as they relate to the current state of the fire station project's whole process cost management. Using the fire station project in Shenzhen as a case study, it describes the specific applications of BIM technology in the project's decision-making, design, construction, and completion stages. This serves as the foundation for similar fire station projects to carry out the full process cost management practice of BIM.

Keywords: BIM, the Whole Process of Engineering Costing-Taking.

1 Introduction

In 2002, Autodesk made the initial suggestion for BIM (Building Information Modeling) technology, which can assist in realizing the integration of building information from the design, construction, and operation of the building to the conclusion of the entire life cycle of the building. The main goal of BIM is to create a digital, three-dimensional model of the construction project in order to provide a comprehensive knowledge base that is accurate to the scenario at hand. The main goal of BIM is to create a virtual 3D model of the construction project and utilize technology to provide a comprehensive knowledge base of the project that is accurate to the current state.

The Ministry of Housing and Urban-Rural Development published two documents in the field of project costing: the Guiding Opinions on Further Promoting the Reform of Project Costing Management in 2014 and the Notice of the Thirteenth Five-Year Plan for the Development of the Project Costing Business in 2017. Both documents propose to strengthen the comprehensive development and utilization of various types of costing information in various specialties, such as information on market prices, It is suggested to make use of "cloud + big data" technology to expand the range of specialized information services, foster whole-process engineering consultancy, build a

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solid system of cooperation, and encourage the healthy growth of diverse businesses. It is proposed to vigorously promote the application of BIM technology in the project costing business and vigorously develop advanced technology represented by BIM, big data, and cloud computing, so as to enhance the information service capacity and build an information service system. The top-level design of costing reform points out the direction of data-centered development for the field of engineering costing and also indicates the direction of digitization.

Numerous academics have undertaken in-depth research on the issues that are present throughout the entire engineering costing process. In order to achieve accurate costing and increase the efficiency of costing work, Bai Yifan[1] incorporated the application needs of water conservation project costing into the BIM design process. She then presented a "three-phase" development scenario for the combination of water conservation project costing and BIM technology application programs. In order to provide examples for the whole-process management of costing and refinement management, Chen Anqi[2] analyzes the II bidding section of a city's medical complex project as an example. She then investigates the working principles and application status of BIM technology in cost management by using the concept of integrated collaborative management. By considering the high effectiveness of BIM technology in data storage and retrieval, Shujie Zhang[3] analyzes the significant application value of BIM technology in project costing and management and offers improvement recommendations for the challenges encountered in carrying out the functions of a BIM system. Alzraiee Hani[4] proposes a system to develop a cost estimate for building projects using a Structured Query Language (SQL). The approach leverages SQL to create an interoperable information management system that effectively transacts data with BIM elements.Alasmari Esam[5] discusses the merging of BIM into LCC through four prevalent aspects; methodology, design software used, benefits, and challenges. A total of 20 studies were reviewed upon filtering process using PRISMA method. Wang Yin[6] uses an actual project as an example and conducts theoretical analysis and comparative case studies to demonstrate that BIM has the application value of cost control and program selection in pre-construction cost management, contrary to the status quo of less application of BIM in this area.

In China, the BIM development trend is getting stronger every year. However, there are now some gaps in China's BIM technology development and the entire engineering cost process: (1) There is a delay in the entire costing information process because of the quick changes in the pricing of materials, labor, machinery, etc., as well as the existence of regional disparities. As a result, the quota is not updated in a timely manner. (2) The absence of a consistent procedure and digital support results in a wide range of project features. (3) BIM's entire process stage model information is inconsistent, is not timely updated, and other problems result in repeated modeling and inefficiency.

There are currently more studies on the integration of BIM with actual engineering projects than there are on the use of comprehensive BIM technology across the entire engineering costing and integration process. This paper explores how BIM can increase work efficiency in the decision-making stage, design stage, construction stage, and completion stage. It then takes the development and benefits of BIM as the entry point, takes the application of BIM in the entire process of engineering cost as the main research line, and provides solution ideas for the better implementation of dynamic management based on the advantages of visualization, coordination, simulation, and optimization. Finally, the feasibility of BIM in the whole process of project costing is analyzed through the example of fire station.

2 Deficiencies in whole process cost management of fire stations

2.1 One-sided costing

The structures for fire station projects must meet strict standards. The complexity of a whole fire station's building operations, including firefighting, equipment administration, fire training, life support, etc., makes the entire cost management process more challenging. China is still utilizing the conventional cost management approach, which places an excessive amount of emphasis on the construction phase. One-sided attention to the construction stage and ignoring the other stages will lead to fragmentation of the management of the other phases, and it is difficult to unify the entire process of project cost control. The decision-making stage is the starting point for the project cost. The design stage is the leading stage in construction cost control.

2.2 Poor whole process cost management

2.2.1 Lack of experience.

Due to the size of the fire station project, which includes a fire garage, ready room, training tower, physical training room, restroom, and student room, among other things, cost control is crucial. Construction units frequently overlook the entire cost management process because of poor communication between cost consulting and construction units and a lack of experience in managing the entire process. Additionally, quota design is still used in China's traditional cost control paradigm. There is a delay in the process of gathering cost information, and other problems prevent calculations from being made in accordance with the overall process due to the rapid change in the price of materials, labor, machinery, etc. and the existence of regional differences. Resulting in the quota has not been updated in a timely manner, there is a lag in the whole process of cost information, and other issues, cannot be calculated in accordance with the whole process of cost control of the total cost of consumption of the project.

2.2.2 Lack of full investment effectiveness.

Fire stations are considered social utilities and are typically funded by government grants, charitable contributions, and self-funding, with investment serving as the primary source of funding. When there is no fire, the investment's benefits are not completely realized in the short term, leading to low investment efficiency, which in turn has a detrimental effect on the entire cost-management process.

2.2.3 Lack of a system of standards.

The approval procedure for fire station costs is intricate and demands a thorough examination of the site selection, renovation plan design, and fire plan design. Thereafter, the drawings are reviewed, the designs are submitted for review, the renovation is approved, and so on. However, the slow and unreliable approval process encourages fraud in the hiring of staff, the purchase of goods and services, and the leasing of equipment, among other areas.

2.3 Serious isolation of information throughout the process

Because of its structural complexity, the fire station project calls for a high level of uniformity. The structure must adhere to the standards of internal closed management and exterior open design, as well as the demands for simultaneous privatization and quick response to police calls. Different dark designers are involved in these designs, but each one is focused on maximizing their own profits rather than improving the situation overall by managing costs and communicating information effectively.

3 The advantages of BIM applied to the whole process of cost management of fire stations

3.1 Realization of information sharing throughout the process

A dynamic BIM database can be created by using BIM Revit series software, which also enables 3D modeling, the model serving as the BIM's information carrier, the building model being integrated into the platform, progress, cost, and other multi-dimensional uses. In order to better project visualization management, design analysis, build and update processes more efficiently, and simply realize building information management, the BIM database is in line with a specific data structure to inherit, store, and manage the BIM data warehouse. The BIM database is a storage facility that inherits, holds, and manages BIM data in accordance with a predetermined data structure, enhancing the project's management of visualization, design analysis, construction, and update processes and realizing the management of construction information more effectively and conveniently. It establishes a connection between each participant in a construction project and each time period, allowing each participant to access, save, and exchange all information at any time. It also offers comparative references for related projects, realizing information sharing throughout the whole building process.

3.2 Realization of collaborative management throughout the process

Collaborative management, a result of the marriage of digital architectural design technology and the quick growth of network technology, enables designers of various specialties to collaborate through the network from various geographical places. The development of BIM has changed the nature of collaboration from a straightforward document reference to one that is fundamentally supported by technology and has significantly improved technical content. With the benefits of BIM technology, the scope of collaboration is also increased from the straightforward design stage to the entire process of the life cycle, from planning to building and operation, depending on the involvement of all parties to the project.

Through the BIM5D platform, many stakeholders in a construction project collaborate in real-time data transfer, efficiently controlling construction progress, project cost procedures, etc. Models and data from all parties involved in the real-time data filling create a dynamic database of indicators. For businesses, applying BIM to the entire process of collaborative design management results in data that is implemented in accordance with the same standard, increases the statistics' timeliness, and decreases unneeded human error. Additionally, it lessens the needless statistical labor that is performed by project construction staff, branch offices, or departments on all levels. When there is a communication breakdown between the numerous professional designers working on the fire station project, it causes the various professions to collide. Pre-production BIM building information modeling can be used to manage the actual construction of the collision of the many professions. In order to provide a more comprehensive benefit of a higher level of augmentation, the collaborative design of BIM has a larger meaning.

3.3 Realization of dynamic control throughout the process

In engineering and construction, component prices and designs frequently change. Particularly in the project for the fire station, the design is intricate, the structures are many, and more adjustments keep coming. For instance, the appropriate experts will update the BIM data as needed, and all the project's construction parties will share the updated data in real time when the functions of the fire garage, ready room, training tower, and other special areas frequently used by daily firefighters change. In addition, it is possible to analyze several design or construction programs in light of the necessary information and choose the most sensible and cost-effective option.

4 BIM applied to the whole process of cost management of fire station arithmetic example analysis

4.1 Overview of the project

The Dapeng Peninsula, Longgang District, Shenzhen, is the location of this project, which has an infrastructure for battling fires. The overall area of the property is 4628.06 square meters, and the main building's height is 14.4 meters, while the secondary building's height is 12.1 meters. There is a 7-degree earthquake intensity. The project is a standard frame structure, with functional spaces like equipment storage, a firefighting garage, firefighting preparation, and office meetings placed in the main building and cooking and dining areas, equipment and fitness areas, and family visiting rooms located in the secondary building. To meet the demands of standard design and construction and green building, roof gardens are provided in both the primary and secondary buildings, with proper regard for the possibility of future tenancy.4.2 Application of BIM in the decision-making phase of this project

4.2 Application of BIM in the decision-making phase of this project

The most fundamental phase of capital construction is the decision-making phase. Only when integrated with BIM at the project's decision-making stage can decisions be made with more objectivity, accuracy, and efficiency, lowering project costs and maximizing resource utilization. Using BIM modeling software during the fire station's decision-making process: To begin creating the axis network elevation, first import the CAD file in accordance with the drawings. The first floor and standard floor are then finished by establishing the columns, beams, floor slabs, walls, doors, and windows in accordance with the drawings. then decide to duplicate upward layer by layer to finish the main drawing in accordance with the peculiarities of the drawings. The main structure, auxiliary buildings, and corridors were positioned in the site of the north, south, and east layers of the enclosure into a partially open courtyard, serving as a fire training site, as illustrated in Figure 1 for the use of Revit to finish the fire station model. Based on the user's point of view, to fully express their views, improve the design of the requirements, and reduce rework in the later stages of construction, the fire station staff can intuitively review the reasonableness of the spatial design through the three-dimensional model created by BIM technology. decreasing rework in the later stages of construction.

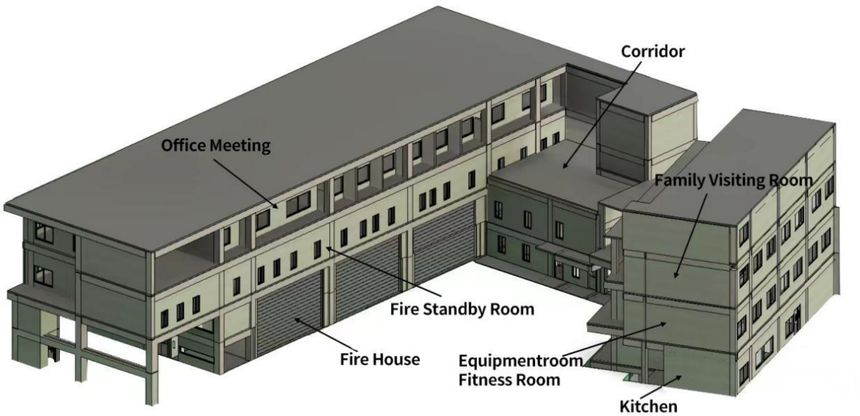

Fig. 1. Fire station BIM modeling diagram

The entire VR production of the fire station may be finished using the BM model and the game engine. Participants in the project put on virtual reality helmets and feel the impact of a fire station that will be built in the future through immersive roaming browsing. In order to fully appreciate the design and layout of the entire fire station, gain a thorough understanding of the functions and characteristics of each room, and provide a visual basis for decision-making, this project can be switched to four different perspectives: the passer-by perspective, the fire truck driver's perspective, the overall perspective, and the households in the surrounding area. Figure 2 displays the main view of the VR representation of the fire station.

Fig. 2. Fire Station VR Rendering

4.3 Application of BIM in the design phase of this project

The most crucial phase of capital construction is the design phase. The fire station project is a huge and complex computation, and the existing traditional management technique of list quantity calculation relies primarily on human calculation. Calculation is not only labor- and time-intensive, but it is also frequently prone to error. With the advent of BIM5D technology, this issue may be easily fixed. After creating the model and generating the necessary bill of quantities utilizing automatic metering in Revit. The masonry walls, doors, windows, railings, columns, and other complex detailing components required by the fire station according to the corresponding engineering quantity names such as area, perimeter, volume, etc., will be required for the fire station, as shown in Table 1 for the total physical volume of the fire station model of the part of the bill of quantities. To clearly present the amount of work in the list, eliminate manual operations, keep the project budget within acceptable bounds, and perform a quick and accurate analysis of the budget estimate, it will be necessary to use the name of the quantity of work, such as area, perimeter, volume, etc. The bidder transmits the bill of quantities to the bidding unit after exporting the list, and the bidding unit combines the price information and the progress schedule to create quotes. The designers continue to refine and modify the design program as they receive timely project cost data and design constraints. In addition to ensuring accuracy, it also updates the cost of labor and equipment in real-time, allowing for more sophisticated management.

Table 1. List of quantities of some components

Name of component	output name	Quantity Name	formula for calculating the quantity of work	project volume	unit of measure
masonry wall	masonry wall	Area of internal wall wire mesh	GSM+GSMZ	86.56	m2
masonry wall	masonry wall	Masonry wall area	QM+QMZ	5888.01	m2
masonry wall	masonry wall	Masonry wall volume	IIF(JGLX='curtain wall' OR JGLX='false wall',0,VM+VZ)	1490.89	m3
classifier for lessons, subjects, branches of technology	classifier for lessons, subjects, branches of technology	Door frame circumference	U	371.8	m
classifier for lessons, subjects, branches of technology	classifier for lessons, subjects, branches of technology	Door frame circumference	U	450.08	m
classifier for lessons, subjects, branches of technology	classifier for lessons, subjects, branches of technology	Door frame circumference	U	201.32	m
classifier for lessons, subjects, branches of technology	classifier for lessons, subjects, branches of technology	Door gage area	SMT+SZ	132	m2
shutter	shutter	Window frame circumference	U	727.36	m
parapet	parapet	Net length of railings	L	197.74	m
spine	spine	Area of over-height part of column formwork	SCCG	64.43	m2
spine	spine	Area of over-height part of column formwork	SCCG	2.22	m2

4.4 Application of BIM in the construction phase of this project

The most crucial stage of capital construction is the construction phase. The crosswalk diagram method and network plan method are the foundation of the conventional management mode. The crosswalk diagram method lacks sufficient information to convey the absolute construction cost variance. The network planning method will take a lot of time and be ineffective since it is difficult to quantify resource usage and typically requires significant professional experience. BIM technology can quickly produce a balanced representation of the consumption of tools and materials in the construction process in the progress plan, precisely simulate the actual construction progress, and make policy adjustments at any time in accordance with changes in the curve and the display of the construction period in order to more effectively utilize the resources.

Figure 3 depicts the fire station progress plan simulation, the construction network diagram created using the BIM5D model, the import of the progress plan's project data into the BIM5D model to create a three-dimensional animation demonstration diagram, and the project's construction flow view. Construction on the project is expected to begin on September 1, 2022, and be completed on March 1, 2023. The project's progress plan schedules the construction work for the fire station's main project, the wall structure, the door and window structure, and other related tasks ahead of time to allow site operators and engineers to more easily carry out the project's three-dimensional technical alternation. In order to ensure that the cost of each node is more in line with its own financial condition, it is important to swiftly develop the relevant deployment of resources, including persons, cash, machines, materials, and procedures. The job can be completed on schedule and precisely.

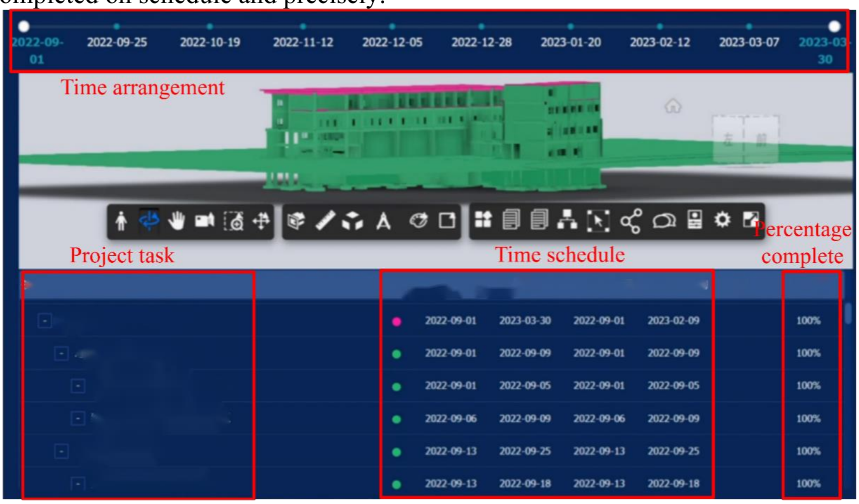

Fig. 3. Screenshot of schedule simulation

It is possible to create a three-dimensional field cloth model utilizing BIM technology's visualization capabilities. A three-dimensional model is created based on the two-dimensional blueprints, and it is then integrated into rendering software to mimic site occupancy during the fire station's subsequent development. Figure 4 illustrates the components needed to set up a temporary office, living quarters, construction area material stacking and lifting, material transportation, pro-establishment, and construction area transfer based on the simulation of the fire station building site. To speed up construction and lower expenses, an optimized solution was created.

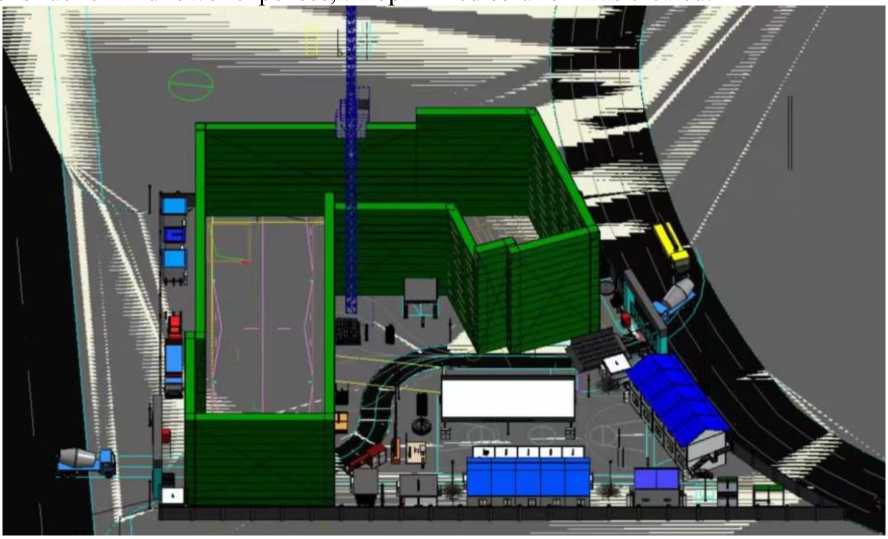

Fig. 4. 3D field cloth construction diagram

4.5 Application of BIM in the as-built phase of the Project

The capital construction is currently at the finishing stage. The main goal of the project is to complete the settlement audit, however traditional cost management issues like data accounting omissions frequently arise. The employees may easily access the acceptance at any moment because the BIM database contains all the works and all the cost information. Additionally, it prevents the loss of important contract agreements, change data, and other data.

Quality engineering has always placed a strong emphasis on both quality and safety. This fire station project had a lengthy building time and subpar construction circumstances, which resulted in significant pressure during the completion stage and limits in construction technology and management. On the basis of this, BIM technology effectively resolves this issue. When the appropriate staff members discover quality issues on the job site, they can use cell phones to take pictures, audio recordings, and text records of the potential problem areas and upload them to the BIM information base, as shown in Figure 5, which illustrates the simulation of quality issues on the job site using the BIM5D platform. And the workers discovered issues with rotting columns, off-set column tendons, exterior wall plastering drums and cracks, and door apertures with excessive height and promptly took photos to document the corresponding defects. The damage is uploaded to the data base so that it can be fixed. The software can synchronize data between computers and mobile devices, and it can save documents inside models as pins, helping the appropriate technical staff to oversee project quality and safety concerns.

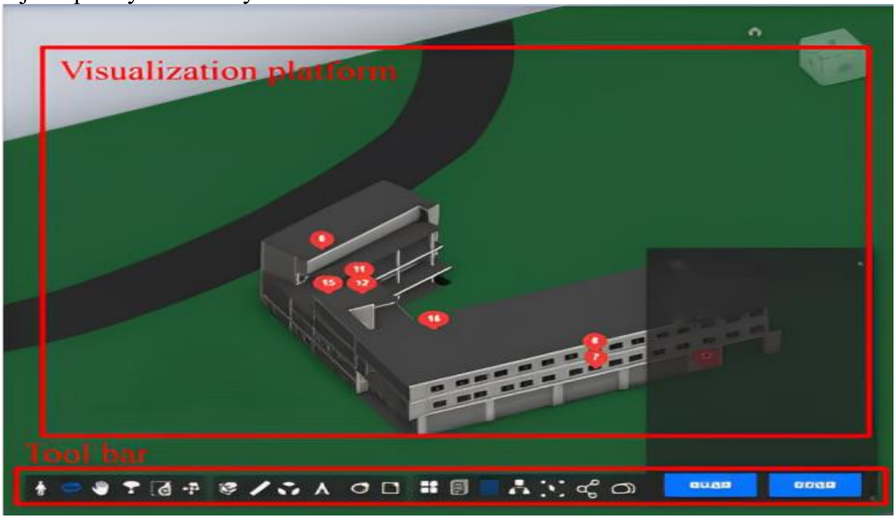

Fig. 5. Quality and safety management chart

5 Concluding

The following conclusions are reached after this paper analyzes and summarizes the drawbacks of the fire station project's overall cost management system and the benefits of maintaining the status quo while using BIM technology. It also introduces in detail how BIM was used throughout the project's decision-making, design, construction, and completion phases.

(1) All-process, all-specialty, all-around depth BIM applications can make up for the shortcomings of the traditional costing whole process management. BIM technology can significantly improve information sharing, collaborative management, and dynamic control of the project, as well as increase the accuracy and sensitivity of the dynamic management of the entire process.

(2) The integration of BIM technology and whole-process cost management creates significant economic and quality benefits for the project. The application of BIM technology in the whole process of the fire station project not only saves time and manpower, but also greatly reduces the cost, and at the same time improves the level of whole-process cost management.

(3) With the increasing improvement of BIM technology, the application of BIM in the costing of fire stations and other such construction projects will surely become a powerful support and guarantee to promote the high-quality development of infrastructure construction.

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