Review of Industrial Engineering Letters
2018 Vol. 4, No. 2, pp. 21-35
ISSN(e): 2408-9427
ISSN(p): 2409-2169
DOI: 10.18488/journal.71/2018.42.21.35

APPLYING BUILDING INFORMATION MODELLING PLUS-THE PRACTICE OF SHANGHAI SHIPPING SERVICE COMPLEX

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Article History
Received: 29 June 2018
Revised: 31 August 2018
Accepted: 5 October 2018
Published: 1 November 2018

Keywords
SSSC
BIM+
Case study
Ship lock
3D printing
Internet.

ABSTRACT

Taking advantage of Building Information Model (BIM) to integrate multi-dimensional information, such as time and space information can provide robust guidance for design, construction and operation management, which can produce strong technical support for improving project management. Based on the BIM+ theory and the ship lock construction in Shanghai Shipping Service Complex (SSSC), this paper formulates the stages and contents of the application of BIM technology. Through the implementation of BIM in the planning, design, construction and maintenance of ship lock engineering, the management of the whole life cycle of the project are realised. The application of BIM+ theory in SSSC lock engineering is explored effectively by 3D printing technology combined with Internet technology.

Contribution/Originality: The primary originality of this study is to apply BIM+ theory to ship lock construction in SSSC.

1. INTRODUCTION

With the acceleration of information technology, more and more digital technology is applied in the engineering field. Construction engineering has experienced the Computer Aided Design (CAD) era, where CAD technology releases architects and engineers from manual drawing.. It improves the working efficiency and shortens the period of construction engineering. However, the application level of computer technology in the engineering field is still relatively low. The combination of points and lines in traditional drawing technology can only express two-dimensional information, which is not closely related to the actual building components. The guidance of the participants in the construction of the project is not strong enough. For example, the informatisation degree of the construction industry in China is still in a primary stage. At the same time, the informatisation rate of the construction industry is only 0.03%, and that of the international construction industry is ten times higher, reaching 0.30%. Therefore, the research on the application of BIM in various fields of architecture will significantly accelerate the level of information management of construction industry and improve the degree of modernisation of the construction industry in China.

BIM is a kind of engineering data model. It integrates many different types of information of construction project. Since the 21st century, BIM has been widely used in the field of construction engineering, such as Beijing Water Cube, Shanghai Tower and the Disney land and other vital projects in China.

BIM technology used in Building makes engineering projects visual, and the research, design, construction and even operation management can be carried out in a three-dimensional optical state, such as collision checking in advance during the design phase. Optimization design is used to coordinate the problems between professionals, and the corresponding construction space, pipeline distribution and hoisting simulation can be analyzed after 3D visualization in the construction stage, which dramatically improves the construction progress and quality. It also facilitates the communication between the construction and the various units.

The application of BIM can integrate multi-dimensional information such as time and space data to accurately carry out multi-dimensional simulation and provide strong technical support for the design construction and operation management to improve the level of project management.

To widen BIM technology from technical level to practical production organization, operation management and other fields, this paper puts forward the BIM+ theory and takes the application of BIM+ in SSSC as an example to verify the feasibility of the approach and merits, operation management and other fields.

The remainder of the article is organized as follows. Section 2 reviews the related literature. Section 3 introduces the theory and model of BIM, based on which the BIM+ theory is proposed. Section 4 was the case study of SSC, where the feasibility and efficiency of BIM+ are verified. The last section summarised the findings and identified directions in future research.

2. LITERATURE REVIEW

As early as the late 1970s and early 1980s, some researchers in Europe, especially in Britain, began their research on early architectural information models. In 1975, Chuck published a paper with his research project on Building Description System, identifying some key elements of BIM as parameterization, visualization, and allocation of Calculus Statistics and schedule Resources with BIM [1]. In 1986, Robert first proposed the concept of Building Information. In his paper, the key elements of BIM are described, such as 3D Modelling, automatic generation, parameterized components, system database, schedule simulation and so on [2]. By Van Nederveen and Tolman [3] after further improving the essence of BIM, first proposed the concept of BIM. Then, *Building Information Modelling* was officially proposed in 1999 at the end of the century, which is generally accepted by us today [3].

BIM has a very important impact on the construction industry. In 2011, Shin et al. proposed a project, product lifecycle management (PLM), combined with BIM analysis and design system, and applied the system to bridge reinforced concrete bridge column structure [4]. Ma et al. integrated BIM into the lifecycle of a building project with the introduction of a conceptual framework constituted by BIM Information Flow, BIM Model Chain, BIM Workflow, BIM Institutional Environment, and BIM-based Project Management Information System (PMIS) [5]. In 2004, based on IFC standard, Wan et al. put forward some suggestions on the expansion of BIM standard structure analysis model in the aspects of prestressing load and load combination [6]. Halfawy et al. has completed the research of building integration platform based on BIM technology. The functions of graphic editing, component quantity statistics, budget, project management have been developed [7]. Evans et al. tried to share and transform the building information model among the team [8]. In 2009, Kim et al. researched the application of BIM in bridge construction in South Korea. They carried out visual design and construction, schedule cost analysis and collision inspection based on the Cheongpoong cable-stayed bridge with a main span of 327m under construction. In addition, the construction procedure was simulated by two different methods, and the measurement results of different structures in a specific time are compared, which effectively verifies the feasibility of BIM application [9]. In 2016, McGuire et al. studied the BIM method for bridge detection and tracking evaluation. They uses BIM software to obtain the type, quantity, severity, and location information of damage during bridge construction. Computational software was applied to evaluate the structural performance, checks the bridge load rating, and takes a real bridge case as an example [10]. Ustinovičius et al. discussed the use of a proper BIM design may help the user avoid mistakes and make the building process faster as well as less financial resource intensive and analyzed the difficulties of the BIM design software technology in construction project planning [11].

It is very important to combine BIM with computer technology as well. Lapierre & Cote put forward the construction of the digital city and pointed out that the real digital city can be realized by combining BIM technology with Geographic Information System (GIS) technology [12]. BIM's guidelines should be used in public construction supervision in Brazil. Fountain & Langar aim to identify BIM outsourcing patterns among the general contractors across the US and the perceived impacts it has on construction projects [13]. Mani et al. combine BIM technology with camera technology, and realize the simulation of 3D construction, thus making reasonable plan for the next construction phase [14].

Although individual firms had strong external or internal BIM motivations and visions to adopt BIM innovation, the project networks rarely coordinated to support BIM implementation. Drawing upon the empirical data, other factors affecting BIM implementation and in need of further inter-organizational alignment were corporate compatibility, interfirm knowledge mobility, and interfirm power dynamics [15]. Given that the promotion and application of BIM technology involve organizations, processes, technologies, and other aspects, it is difficult for existing construction information management methods and applications to form a complete BIM model to maximize the value of BIM [16]. Lu et al. believe that the differences in existing building industry system, domestic standards and norms are the obstacles to the promotion of BIM application that need to be broken Lu and Li [17]. Robbert and Craig [18] introduce the advantages of BIM, especially in improving the application and speed, enhancing the fault detection in all construction stages, and the cooperation and visualization of data. A series of problems related to the implementation of BIM are put forward and some explanations are given [18].

3. METHODOLOGY

3.1. BIM Theory and Model

BIM, as a method applied in the field of structural engineering, should be combined with a methodology to carry out the similar research. The technique should be composed of the basic principles of fundamental BIM technology and the BIM model. Since the basic principles of BIM technology determine how to establish and solve the structural model of BIM, this method focuses on the basic principles of BIM technology.

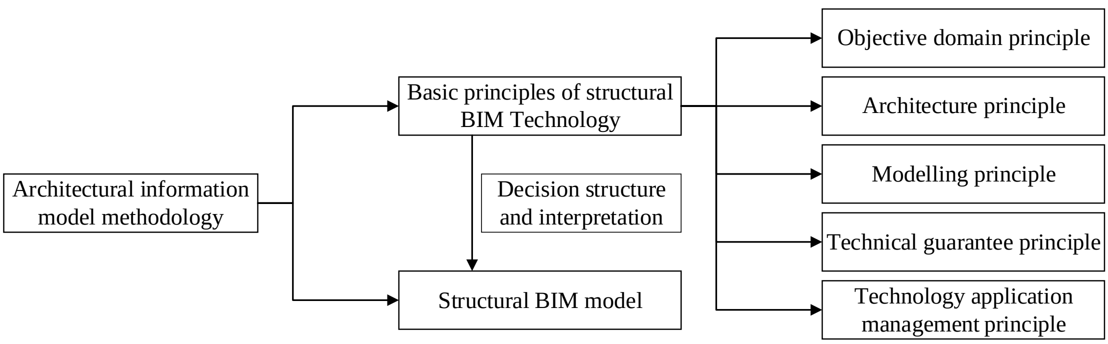

Fig-1. Architectural Information Model

Source: Author's research

(1) Basic principles of BIM technology

Through the research on the application of BIM technology, it can be concluded that the study of BIM technology is mainly composed of five aspects: application purpose, organization structure, Modelling, scientific guarantee, and application. These five aspects are also sub-methods in the theory of BIM methodology, which run through the whole lifecycle management process of engineering structures, so they have the following essential application principles.

① Objective domain principle of BIM model

This part introduces two mathematical concepts:

Neighbourhood: the centre is at point x_0, and the range of acceptable precision radius length is $\delta(\delta > 0)$, and $(x_0 - \delta, x_0 + \delta)$ is $\delta(\delta > 0)$ field of point x_0, denoted as $U(x_0, \delta) = (x_0 - \delta, x_0 + \delta) = \{x \mid |x - x_0| < \delta\}$, namely x, where S is the accuracy corresponding to the current model, and x_0 is the model accuracy reaching the structure ontology, namely the scale is 1:1.

$\lim_{x \to x_0^-} f(x) = A$ means for any positive ε, there is always a positive number δ can be used when $x_0 - \delta < x < x_0$, $|f(x) - A| < \varepsilon$, $f(x)$ is BIM model system. Moreover, the corresponding precision is x, A is a structural entity.

Meanwhile, set the BIM target neighbourhood as taking x_0 as precision target, suppose interval $[x_0 - \delta, x_0)$ as target and target domain with precision δ, record it as $U_B[x_0, \delta)$, that is:

$$U_B[x_0, \delta) = [x_0 - \delta, x_0) = \{x \mid x_0 - x \le \delta\}$$

Suppose the precision x of BIM model be a range of $U_B[x_0, \delta_0)$, and make the system $f(x)$ of BIM model with precision satisfy the expected precision ε for any given model, there is always acceptable radius length δ of accuracy, when $x_0 - \delta < x < x_0$, $|f(x) - A| < \varepsilon$, that is:

$$\lim_{x \to x_0} f(x) = A, x \in U_B[x_0, \delta_0)$$

In the formula, δ_0 is the length corresponding to the precision domain of the model and shall meet the requirements of the specification.

The practical significance of the principle is that the precision of the structural model should be between the minimum precision and the virtual precision, and the precision of the model should be infinitely close to that of the entity itself. Because of the limitation of technology, economy and so on, the precision cannot reach the virtual precision, but it should have the ability to respond at any time under the condition of the user users' requests, which is the outstanding advantage of this model distinguishes it from other 3D bars.

② Architecture principle of BIM model

BIM technology is the method, but it must be carried by software model. The existing research results show that the BIM model is multi-dimensional and can express engineering entities and related activities in multi-dimensional form, and it can form different sub-models through database partitioning and can make corresponding model calls [1]. Therefore, the model is a complex system model, and needs to have the corresponding framework principle. The mathematical expression of the model is as follows:

$$y = f(x)$$

In this formula, y is a BIM model with precise x; f is a mapping function.

The above formula shows that the BIM model is only affected by the accuracy x of the current model, and the other conditions can only be affected by x the influence of the current model. By using this principle, the mapping relationship between the precision of the number set and the entity of the model can be established, and the accuracy of the BIM model can be influenced by the precision.

③ Modelling principle of BIM model

Based on the current technical level, there are mainly two methods for BIM model. One is to construct the BIM model at the macro software level, the other is to build a database to implement the BIM model. However, whether or not these two methods are used, the modular method must be an important part of the BIM methodology theory, and the influence on the application of BIM technology is great. Therefore, the modular method should also be listed as the guiding principle of the BIM method, which is defined here as the modular principle of the BIM model, and its mathematical expression is as follows:

$$g = G(\alpha, \beta)$$

In the formula, g is the organizational form of the computer model under the condition of α and β; α is the measuring parameter of the technical support level, and β is the mapping function of the project complexity level measurement parameter G as the modular method

The construction of the BIM model is greatly affected by the computer software, hardware level, and engineering complexity. The main purpose of the principle is to establish the external technical guarantee condition and the mapping relationship between the engineering complexity and the BIM model, so as to achieve file specification storage and data exchange.

④ Technical guarantee principle of BIM model

The principle of BIM technology guarantee needs to consider the computer software and hardware level of BIM unit, personnel quality, and other factors. With the development of BIM technology, if we can determine the measurement parameters of technical support level, we can realize the match of BIM strength and enterprise qualification, standardize the management of BIM technology, reduce bad competition, and improve the application level of BIM technology.

⑤ Technology application management principle of BIM model

The value of BIM technology is embodied in the application and service of model in practical engineering. Therefore, how to standardize the related Modelling and usage process is one of the important principles in the application of BIM. The principles of BIM technology application management are mainly reflected in the use of models, related norms, laws and other constraints and regulations.

(2) The interrelationship of Fundamental Principles

① External environment

The external environment includes not only the external factors mentioned in the preceding analysis, but also the direct external factors of economic feasibility and engineering demand.

Because the economic feasibility is affected by many factors and has much uncertainty, the economic feasibility of BIM technology is the function of its influencing factors, which can be mapped through the form of function. The mathematical expression is as follows:

$$r = R(r_1, r_2, r_3, \cdots, r_n)$$

r is the technical and economic feasibility control index of BIM, and r_i is the i measuring parameter of the influencing factors of the technical and economic feasibility of BIM.

Assuming that other professional and engineering uncertainties have certain information requirements for the BIM model, this requirement relationship can be mapped in the form of functions to measure the technical requirements of BIM in the external environment.

$$\varphi = \phi(\varphi_1, \varphi_2, \varphi_3, \cdots, \varphi_n)$$

φ is the external demand index of BIM technology, and φ_i is the i parameter to measure the influence factors of external demand.

② The interrelation between the basic principles.

Based on the definition of functional and compound function, it is known that the precision of the model is a definite value, but it is affected by the principle of model formation and the external environment, so there is a corresponding relationship between the precision of the model and the principle of model formation and the external environment. When the corresponding mapping function is established, the model precision and the influence variable constitute a composite function, and when the corresponding mapping function is variable, the model precision becomes the function of the function, thus constituting a universal multivariable function, the mathematical expression of which is as follows:

$$x = \Pi(g, \gamma, \varphi)$$

The Π in the formula is the precision mapping operator. In Figure 2, the relationship between the basic principles of BIM is given.

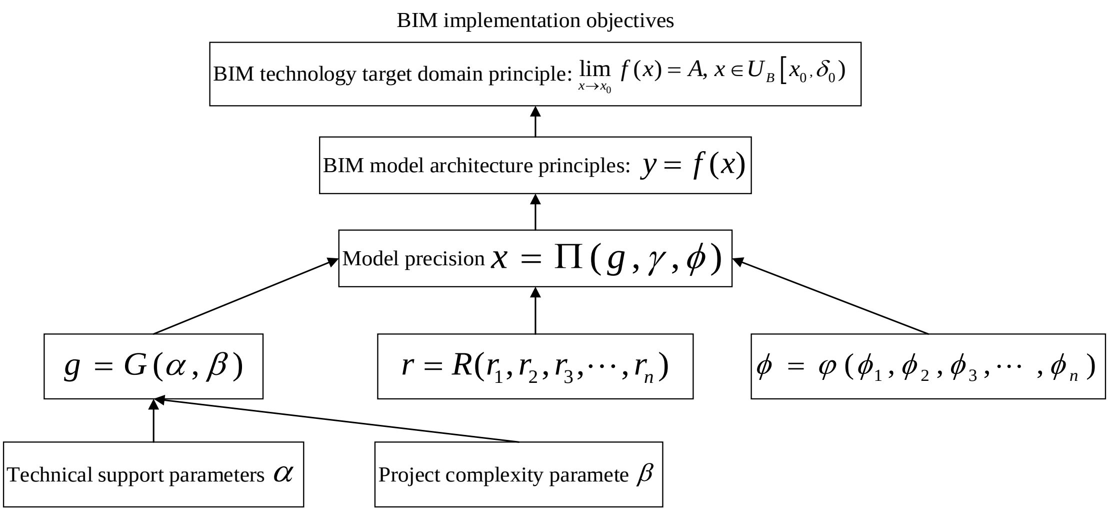

Fig-2. The Relationship between Principles of Building Information Model

Source: Author's research

3.2. BIM+

As a complex waterfront building, the construction of the multiple riverside urban complex involves a variety of specialties and installation techniques, such as a variety of pre-buried parts and reserved holes of ship locks, which can easily lead to construction errors and more rework. The traditional design is planar two-dimensional design, which is extremely unfavorable to the understanding and practical application of the participants. To meet the requirements of accelerating the construction information and the increasingly excellent management of the construction engineering in China, a new BIM+ theory has been put forward, based on the BIM+ technology and the idea of system engineering. BIM+ theory is mainly realised through BIM+ platform, and BIM+ platform is a more open and innovative digital information platform for construction engineering and urban operation management. It is developed from a static spatial digital information model to a dynamic model with a certain "emotional quotient" after continuous integration of other key technologies.

Because of the unique construction mode of BIM+ platform, it has the following outstanding advantages:

(1) Openness: the theory of BIM+ will not be limited to the construction engineering information model, but will become the platform and tool of organisation and management, because of the implementation of more open platform construction mode of BIM+;

(2) Inclusiveness: BIM+ can accommodate all relevant information models, technologies, methods and processes, including building engineering.

(3) Shareablity: BIM+ can share more widely by combining the Internet of things, the Internet of things and GIS, etc. It will be more conducive to project management and goal realisation;

(4) Dynamicity: because BIM+ is more open, inclusive and shared, the platform constructed by BIM+ can realise real-time update, and achieve the real-time dynamic update of information.

4. CASE OF SHANGHAI SHIPPING SERVICE COMPLEX

The Shanghai Shipping Services complex has designed a variety of building blocks, including housing, ponds and locks, etc [19]. Among them, the interior spatial structure of the lock perpendicular to the river bank is extremely complex: it is multi-professional, multi-dimensional intersecting, various "pipes, lines, trenches, corridors" interlaced with special-shaped spatial structures. The technical staff of the participating units only understand the drawings through 2D drawings and cannot accurately establish the relative concepts of the interior space and system of the lock; the professional designers integrate through the BIM model to find out the "mistakes, leaks, bumps, defects" in the design. Optimal design scheme. The project structure is involved, the construction period is tight, and the site is narrow, so there are many technical problems with the construction of the project.

According to the structural characteristics of the most complex ship lock in this complex, based on the BIM+ theory, the paper formulates the stages and contents of the application of BIM technology, including the establishment of the digital model, reporting, design and construction management in stages. Operation management, ship lock construction engineering guidance, through the BIM and 3D printing technology, three-dimensional numerical simulation of water flow, Internet and other technologies organic combination, in the planning, design, construction and operation and maintenance phase. The application of BIM+ theory in SSSC Ship lock Project is explored.

4.1. The Planning Stage

According to the design drawings, the 3D digital Modelling in the scope of the project is completed by CATIA software, and the drawing visualization is realized by the model. After establishing the BIM model of the project feasibility study stage, the viewing of the schematic drawing is accomplished, and the design concept is expressed to demonstrate the scheme (the whole project demonstration, the water cycle scheme demonstration). According to the requirements of the ship lock technological process in the drawing of the design scheme, the simulation of the critical process flow of the project is realised by using BIM technology. In this stage, the necessary technical processes, such as yacht entry and exit flow, (emergency) drainage flow in the port pool, maintenance process for internal and external gates, flow for sluice blowing and siltation prevention, etc. have been simulated. To show the advantages, characteristics, and difficulties of the project more intuitively, it provides a valuable theoretical basis and technical support for the optimization design of the project.

4.2. The Designing Stage

According to the design drawings of engineering feasibility approval, the 3D digital model of the project is completed by REVIT software. According to the BIM application research strategy developed in the early stage, the Modelling depth of the 3D digital model in this stage is required to be beautiful to the level of buried parts, considering the requirements of the BIM work in the later stage of construction. According to the provisions of Modelling depth, this paper discusses the CAD drawing problems encountered in the Modelling process and gives feedback to the design through the BIM work contact sheet to assist the model to deal with the issues. According to the BIM work contact list, a graphics and text analysis report is compiled, including general plan, hydraulic engineering, gold knot, electricity, water supply, and drainage, missing list of mechanical and electrical equipment; as a result, all professions can be coordinated, all kinds of problems that may be encountered during the construction of the project can be eliminated in time, and the resulting design changes can be reduced. Improve working efficiency.

According to the feedback structure, the metal structure, water conveyance system and hydraulic structure are designed and optimized. At the same time, this project adopts 3D printing technology, creates the entity model of the west ship lock, and combines the virtual reality technology to browse and roam the actual plan on the computer, which can find the problems in the design directly and conveniently.

Based on the design optimization of BIM+ theory

Using BIM+ theory, Shanghai International Shipping Service Centre took the lead in creating a 1: 100 3D printable detachable ship lock model, showing the overall structure of the lock visually. At the same time, the precision of the model is up to millimeter level, which can be used to guide the design optimization and construction optimization.

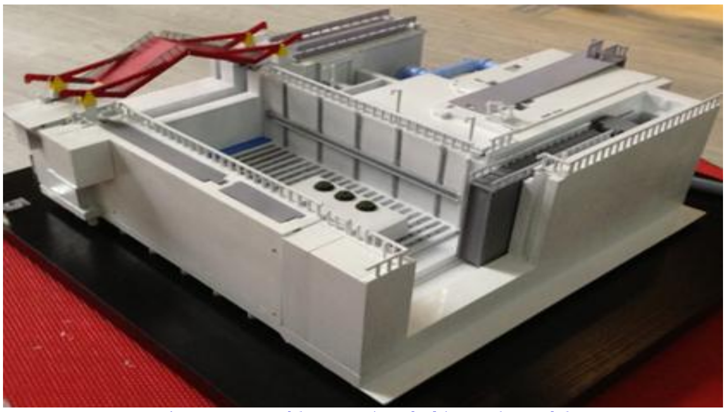

Fig-3. Removable 3D Printed Ship Lock Model

Source: Author's research

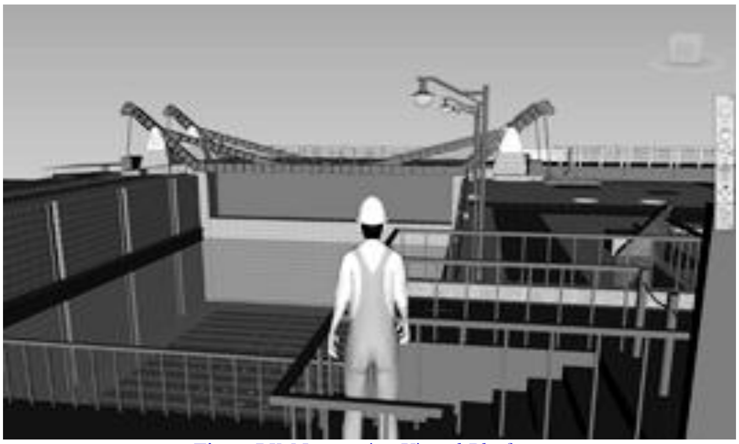

Fig-4. BIM Immersion Virtual Platform

Source: Author's research

Through the BIM+3D printing mode, based on the BIM Immersion Roaming Virtual Platform (Figure 4) and the 3D Printing Removable Lock Solid Model, the combination of virtual model and a real world, dynamic roaming and static entities is realized by BIM 3D Printing mode. The internal structure of the lock is displayed conveniently, and the design and optimization of the lock are achieved. The related achievements are as follows.

(1) Design optimization of water conveyance corridor

Through the BIM+3D printing mode, it is found that the contour chamfer of lock water conveyance corridor is too complicated, which affects the construction of formwork. After design review and checking calculation, the 500 rounded chamfers is changed to 200 precise chamfers, which ensures the smooth installation.

(2) Optimization of metal structure design

According to the design requirements of the overall process flow, after the operation, maintenance and emergency demonstration and disposal of the metal structures such as the internal and external gates, movable bridges and working valves of the lock, it is found that the silt removal devices need to be added at the gateway to ensure the normal operation in the future, as shown in Fig.5.

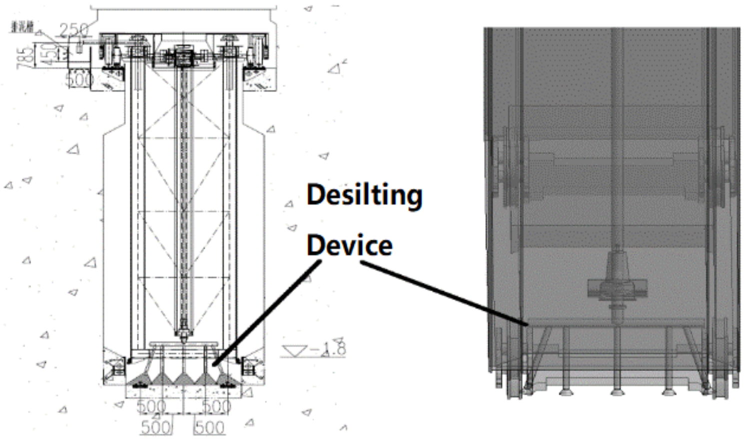

Fig-5. Desilting Device

Source: Author's collection

(3) Optimization of hydraulic structure design

From safety, coordination and convenient construction, using BIM immersive roaming virtual platform combined with 3D printing entity model, the overall outline of ship lock project, the connection section of pedestrian passage and the installation of equipment and facilities are simulated and checked. Finally, the ship lock gate top added a railing and step, connect the top of the east gate (gate storehouse) and lift the height of the top surface to 8.80m, set up the step to connect with the new platform on the east side of the ship lock. Then, the setup of repair holes is adjusted, and the direction of the hydraulic pipeline was changed. The correlation diagram can be seen in Figure 6 and Figure 7.

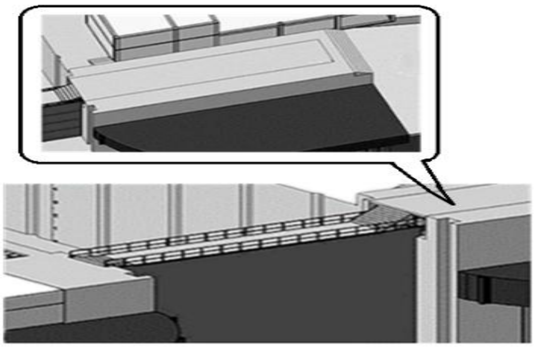

Fig-6. Railings and Steps
Source: Author's collection

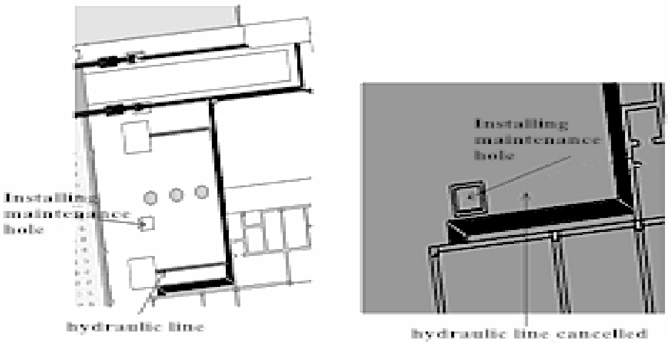

Fig-7. Installation of Manhole and Adjustment of Hydraulic Pipeline
Source: Author's collection

4.3. The Construction Stage

The construction phase of the ship lock involves coordination and cooperation among the construction unit, the owner, the design unit and the supervision unit, the BIM technology are applied in the following aspects:

(1) The quantity statistics of the West Ship lock

With the BIM target to be completed in the construction phase, the area and weight of the waterway in front of the pre-buried parts of the west lock and the front end of the reserved hole list can be calculated by the special BIM software. The quantity of the project can be counted in detail and accurately. It is very advantageous to the later hidden project acceptance, completion acceptance and project settlement.

(2) The critical construction technology of West Ship lock is defined.

Through the integration of BIM model and construction scheme, the crucial area of West Ship lock Project is analysis in a virtual environment. The vital equipment or difficult area can be simulated, the simulation can find the problem in advance, and the corresponding measures can be taken to avoid the problem in the process of construction and installation. The emphasis is placed on the construction technology and simulation of drainage pump chamber, which mainly checks whether the construction procedure is reasonable, whether the operation space is sufficient, and the contradiction between concrete layered pouring and pump installation. The results show that the space size of local template installation and disassembly is not enough, and the structural dimension and construction technology of the guide plate needs to be adjusted.

(3) The design and installation of complex multi-curved special-shaped formwork

This project is a public environmental project, which requires a high level and verticality. The height of the gate wall is high. In order to make the concrete joint surface smooth and smooth, not to grow staggered joints, and at the same time in the second concrete pouring, there will be no slurry leakage, slurry hanging, honeycomb site, taking into account the actual situation of the project, In order to ensure the smooth and timely implementation of the template sub-project, notably the completion of the quality and quantity of the front end water conveyance corridor with the most complex spatial structure and several complex multi-curved surfaces, It is a prerequisite for the successful completion of the whole project and a difficult point in the construction process of the project. It must be visualized, simulated and coordinated through the BIM technology. To ensure the engineering quality, the advantages of optimality and statistics can be thoroughly analyzed and studied on the design, manufacture and installation of this complex and multi-curved heterosexual template. Because the front end of the original design of the project is a complex multi-curved irregular body, the configuration of the construction formwork is exceptionally complex, and the related structures can be seen in Figure 8 and Figure 9.

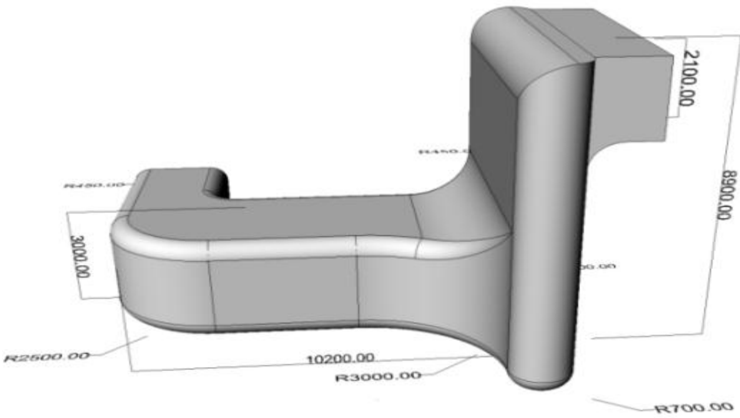

Fig-8. Complex Multi-curved Water Transfer Corridor
Source: Author's collection

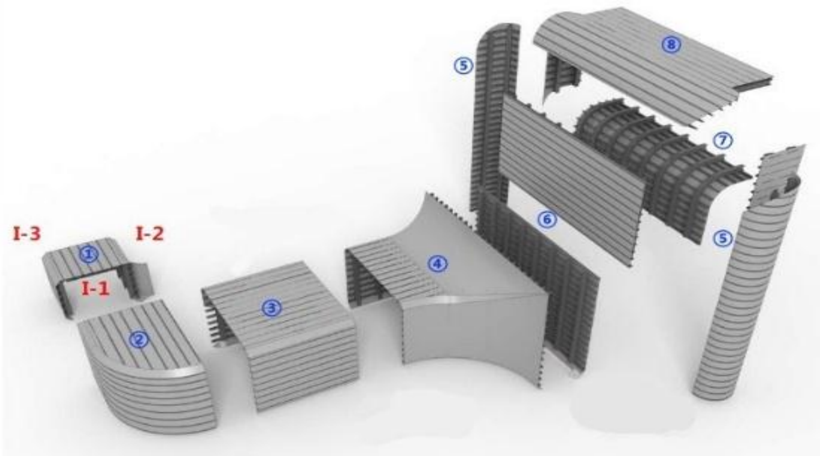

Fig-9. Template Splitting and Safety Analysis Scheme
Source: Author's collection

To solve this technical problem, the project team solved the construction formwork problem of the irregular body by the method of “BIM plus detachable steel formwork”. Before the template processing, the requirements of split, installation and handling were taken into consideration through the BIM digital platform to repeatedly split the template selection. The complex special-shaped multi-curved surface was then divided into eight blocks (Figure 9). According to the specific size, the steel plate and template support are applied to weld and assemble the template.

Through this innovative application, the problems of “mistake, leak, touch, lack” in the installation process of embedded parts are solved, the template processing and convenient installation are realised, and the field machinery can also meet the requirements of lighting and hoisting. At the same time, the eight removable steel formworks can be reused in the subsequent East Ship lock project, and the advantages of economic and technical indexes are undeniable.

(4) Establish the acceptance management information system.

To avoid the problems of installation and leakage of hydraulic embedded parts, to ensure the duration and quality, and to cooperate with the operation and maintenance of the later period, the exclusive development of integrated hydraulic parts of West Ship lock is carried out. The acceptance management information system PPIM (Port Precasting-Units Inspection Modelling), for reserving holes is developed by using the mode of "BIM + Internet + 3D scan + iPad + two-dimensional code scanning", and the hydraulic pre-embedded parts are formed. The acceptance management information system of reserved holes is shown in Figure 10.

(a) System Architecture (b) Site Acceptance (c) Concealed Receipt

Fig-10. Hydraulic Embedded Parts and Reserved Hole Acceptance Management Information System

Source: Author's collection

The system mainly consists of mobile end and database. The method firstly generates 3D images of embedded parts and corresponding standard table codes in a database through BIM. When the embedded components are installed, the 3D scanner can be used to detect the integrated elements and the adjacent door groove structure, and to use the Internet to connect with the database, and the background server can find the corresponding embedded parts graphics, so as to realize the installation orientation and the guiding installation of the integrated components. In the acceptance stage, because each mixed piece has a unique two-dimensional scanning code after completion, and only corresponds to the standard table code of the database, the two-dimension code scanning of the embedded section is carried out through the iPad mobile terminal. By using the wireless network to correspond the field photos with the database images, the system can automatically generate the quality check sheet of the embedded parts and evaluate and feedback the construction quality of the integrated components in time. Through this method, the construction precision and installation accuracy are significantly improved, and there is no difference leakage of the embedded parts in the West Ship lock Project, and the whole lifecycle management of the installation of the hydraulic pre-buried parts is realised, and the excellent application effect is obtained.

The system is based on the premise of not increasing the daily workload of the professional staff, improving the working efficiency of the construction personnel and extending the function as the auxiliary. The core contents of system management are embedded components in hydraulic projects and engineering management elements related to integrated components. Through the establishment of the system, this paper provides the basis for the formulation of the BIM application standard in the general hydraulic engineering reserving and burying engineering.

4.4. The Operation and Maintenance Stage

Based on the practical experience of the whole life cycle management system of embedded parts, this paper extends the BIM information management platform, organically combines with the existing business process system of the company and makes a meaningful exploration to improve the management level of the automation operation. The extended information management platform not only serves the stage of design and construction but also runs through the whole life cycle of a construction project and serves the later stage of operation and maintenance.

With Modelling, design optimization and construction simulation, the 3D BIM model is obtained, which is closest to the real structure. At the same time, there are a lot of primary data and documents about a permanent pipeline, valve, equipment, electrical and so on. Based on the model and related data, a real-time ship lock monitoring system is established by using 3D engine Unity 3D and real-time data acquisition terminal (InTouch HMI), (Figure 11 and Figure 12).

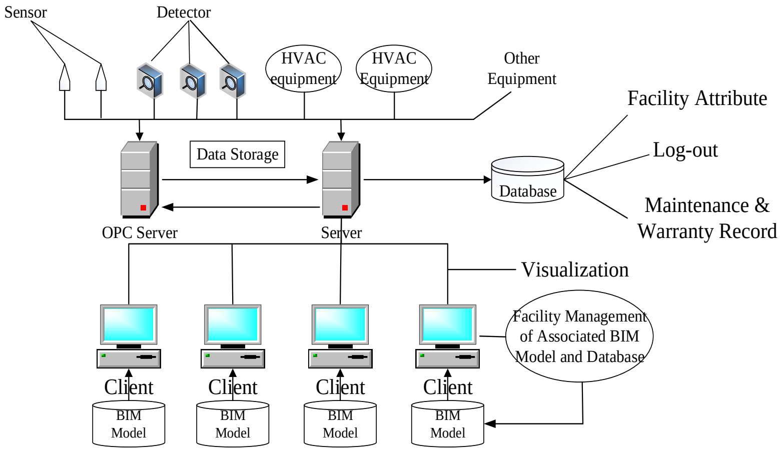

Fig-11. Structure of Operation and Maintenance Monitoring System of Ship Lock
Source: Author's research

Fig-12. 3D Interactive Ship Lock Monitoring and Maintenance System
Source: Author's research

Through the combination of 3D interactive technology and BIM technology, intelligent control of the opening and closing of internal and external gates, the lifting of existing bridges and the inflow and outflow of water corridors, the smart control mode of "BIM + Unity3D + InTouch HMI" ship lock is finally realised. It improves the accuracy and automation level of ship lock system control and makes a successful exploration for the harbour pool and lock automation operation of yacht wharf. The combination of BIM technology and operation management is helpful to the process and maintenance of the yacht club. Automatic yacht wharf management and electronic file exploration.

BIM+ theory can not only save construction period and reduce cost but also improve project quality and become an essential means for enterprises to add value. Using BIM+ theory to construct SSC, the communication efficiency of all parties involved in the construction has been improved, the acceptance rate of the partial subproject is 100%, and the construction period is saved to the greatest extent, compared with the original construction schedule. The application of BIM+ shortened the construction period by 20%, which was higher than that of conventional virtual construction technique (5% or 17%). More importantly, the model covers the stages of engineering design, construction and operation and maintenance, which sets an example for popularising the application of BIM technology and accelerating the informatization of the construction industry.

5. CONCLUSION

Based on the BIM+ theory and the structural characteristics of the most complex ship lock in SSC, this paper formulates the stages and contents of the application of BIM technology, including the establishment, reporting, design and construction management in stages. Through the implementation of BIM in planning, design, construction, and operation, the whole lifecycle management of the project is realized, and the 3D printing technology and the Internet technology are effectively combined. The application of BIM+ theory in SSSC Ship lock project is explored. In the future, we can also study the use of BIM+ theory in green engineering and engineering sustainability, and further verify and expand the application field of this theory.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

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