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Benefits of Building Information Modelling in the Project Lifecycle: Construction Projects in Asia

Regular Paper

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Abstract Building Information Modelling (BIM) is a process involving the creation and management of objective data with property, unique identity and relationship. In the Architecture, Engineering and Construction (AEC) industry, BIM is adopted a lot in the lifecycle of buildings because of the high integration of information that it enables. Four-dimensional (4D) computer-aided design (CAD) has been adopted for many years to improve the construction planning process. BIM is adopted throughout buildings' lifecycles, in design, construction and operation. This paper presents five large-scale public and financial projects that adopt BIM in the design, construction and operational phases. Different uses of BIM are compared and contrasted in the context of the separate backgrounds. It is concluded that productivity is improved where BIM is used to enable easy sharing and integration of information and convenient collaboration.

Keywords Building Information Modelling, 4D, Construction, Building Lifecycle

1. Introduction

Building Information Modelling (BIM), as a powerful set of tools, has been widely applied in the Architecture, Engineering, and Construction (AEC) industry. The inherent nature of AEC makes it a suitable application domain for virtual reality, particularly for design and planning [1]. Schlueter and Thesseling defined three major types of information involved in BIM – geometric, semantic and topological [2]. Geometric information means the 3D modelling of a building, and semantic information includes the properties of components. Topological information describes the dependency relationship between properties and components. A BIM model could comprise individual 3D models of each building component, with all associated properties such as weight, material, length, height, etc. [3]. Beyond the inherent information, BIM also includes external associations between building components. BIM has been applied in the areas of structure, energy, disaster prevention, construction planning and scheduling, project control, construction safety, and maintenance [4]. BIM has also been implemented with Augmented Reality (AR) to improve the productiveness of on-site work [5]. BIM is a revolutionary technology that is transforming the way buildings are designed, planned, constructed and managed [6]. This paper will present and analyse five BIM projects in terms of building lifecycles. The adoption of BIM is at different stages within different backgrounds; the methodology of analysing, comparing and contrasting the cases is therefore presented in the following section.

2. Methodology

This paper will present and study five construction projects that have adopted BIM in different phases of the building lifecycle in various circumstances, and ask how BIM is adopted in the design, construction and operational phases. Since these projects have different backgrounds, a case study structure is developed to allow each case to be analysed and compared in different aspects (Figure 1).

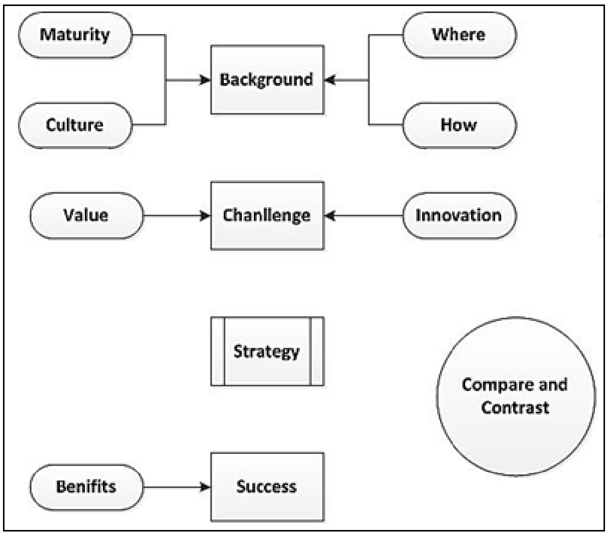

Figure 1. Structure of case studies

Firstly, some background information on the projects should be presented. Since how and where BIM is adopted depends on the problems of specific projects, differences of background should be identified. The effect of different backgrounds and maturities of BIM on problem and solutions should also be analysed. Secondly, the challenges of each project should be discussed to identify why the case is worth being analysed. The research gap regarding BIM in this area should be identified. The main problem should be illustrated as well as the disadvantages of adopting traditional methods. This process will reveal the value and the innovation of the project. The third part of case study will present the strategy adopted in the projects to overcome the challenges. For the purpose of evaluation, the following questions should be answered: "What is the difference between this project and others?" "What is the main problem of the target case?" "What is the conventional solution?" "What is the reason for adopting BIM?" "Is this approach a good solution for the problem?" For the purpose of comparing and contrasting, the following questions, among others, should be answered: "For the same problem, what would the solution be on a different background?" "Is there any effect of the background on the difference of approach?" Finally, the success of otherwise of the project will be discussed. Any benefits provided by BIM should be discussed. Questions to ask include: "Does the solution improve productivity compared to conventional approaches?" "If the solution was adopted in another project, would the productivity be improved or not?". After this four-step analysis, the unique background of each project will be identified. Challenges, aims, strategies, benefits of different projects will be compared. A conclusion will be made as to which phase of the building lifecycle benefits most from BIM and which phase has the most potential to adopt BIM in different districts. The maturity of BIM adoption in the AEC industry in different countries will also be discussed.

3. Case studies

As stated above, five projects will be described in this section focusing on different phases throughout the building lifecycle – design, construction and operation. BIM could be adopted in all these three phases to enable easy sharing, integration and visualization of information to improve productivity [7].

3.1 Chong Qing International Circus City

3.1.1 Background of project

Large-scale public projects account for a large proportion of China's infrastructure. Some projects are related to people's livelihood. In recent years, China's fixed assets investment scale has reached RMB 10 trillion, of which 65% rely on basic construction. With the implementation of the proactive fiscal policy and other policies to expand domestic demand, investment in public works projects has grown rapidly. Therefore, it needs to be facilitated with advanced technology and scientific management. However, because of the particularity of large-scale public projects, there are many difficulties in management. (1) These projects involve a large amount of investment and long cycles, which indicates late reclaim of investment and high risk. (2) Collaboration needs take place across many fields. This makes for potential management risk may affect the schedule and quality of projects. (3) They all have a great influence on the society. If there is an accident, it will have a large negative impact on the general public. (4) They share the same aim of offering comprehensive benefits for society. Chongqing International Circus City is located in Chongqing Danzishi town, partition A. The total land area is 3.333 hectares with a total construction area of 37,200 square metres. Building features include the main performance hall, ancillary services and facilities, the domestication of animal space and office apartments. The Circus City is one of the top ten cultural buildings in Chongqing. The main performance hall construction area is 21,847 square metres with a building height of 49.78 metres and a seating capacity of 1,489. The architectural form of the main performance hall generates two mutually wrapped surfaces through two sets of curved spaces which enclose the circus theatre space. The inside surface is round and full, gently stretching the outer surface with a natural extension of the roof ribbon integrated with the ticket booth and the catering, retail and other commercial facilities.

3.1.2 Challenge – complex model

In the theatre building, the lower part of the auditorium, the lobby, stage and other parts form a complex-shaped space. Thus, the conventional 2D design consists of many curved sections to show the details of each part precisely [8]. Since positioning in 2D drawings is difficult and lacks precision [9], it is hard to create an accurate as-built plan for on-site construction workers. BIM can improve the precision of the design and construction of such complex spaces with 3D models [10]. Analysis tools such as SAP2000 and CATIA should be adopted together with Revit Architecture. For example, as shown in Figure 2, the outside curtain wall of the main performance hall is a complicated double-curve surface, which is hard to model. The designer of this building needs to integrate the parameterized model of the curtain wall in CATIA with the room model in Autodesk Revit to generate a complete building information model.

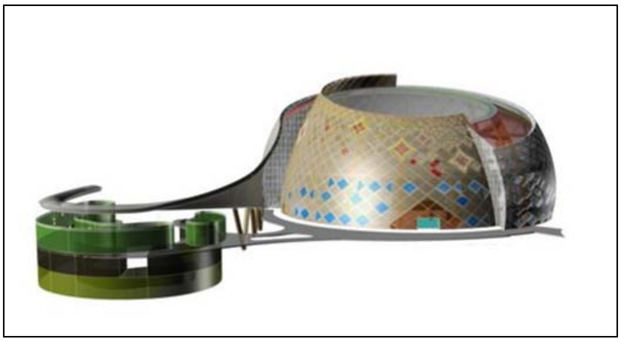

Figure 2. Outside curtain wall of main performance hall [17]

3.1.3 Strategy

BIM is treated as the one of the standard streamline processes to generate drawings in the construction phase. It has been proven that visualization tools can enhance design comprehension and support collaborative work [11]. Massive software companies are providing new concepts for BIM solutions. Autodesk Revit, CATIA, AutoCAD, SAP2000, Midas and Fluent are chosen as the design and analysis tools in this case study.

The adoption of BIM includes the following five processes:

1. Create the building structure, facility and MEP 3D model based on Autodesk Revit software;
2. Integrate the parameterized model of the curtain wall in CATIA with the room model in Autodesk Revit to generate a complete building information model;
3. Conduct the structural analysis in SAP2000 and Midas software;
4. Conduct the calculation of material consumption and budget of building structure, facility and MEP qualitatively and quantificational based on the 3D information model aided design;
5. Conduct corporation with sub-contractors based on the 3D model.

In the initial design phase, CAD drawings are imported into Autodesk Revit software to create the BIM model of Chongqing Circus City. It includes a structural model, facility model (HVAC, water supply and drainage and fire extinguisher systems), electrical model and site model. Through the function "copy and monitoring" in Autodesk Revit, real-time information updates can be conducted in an inter-model way. Through the creation of 3D models, designers can understand the complicated construction space clearly, thus avoiding the disadvantages of 2D design. With 3D models, construction work can be guided precisely.

1) Optimization and visualization of outside curtain wall
The outside curtain wall of the main performance hall is a complicated double-curve surface. In the deep level of the optimization plan, CATIA software is adopted to create the model of the outside curtain wall, including the metal sheets, keel (Figure 3), ring beam structure, the curved structural column (Figure 4) and other components relevant to the curved surface of the curtain wall. Rhinoceros software is adopted to integrate all those components into Autodesk Revit.

2) BIM-model-aided complicated space design
As explained above, the lower part of auditorium, the lobby, stage and other parts form a complex-shaped space. The availability of this space needs analysis with the help of the three-dimensional modelling. The Circus

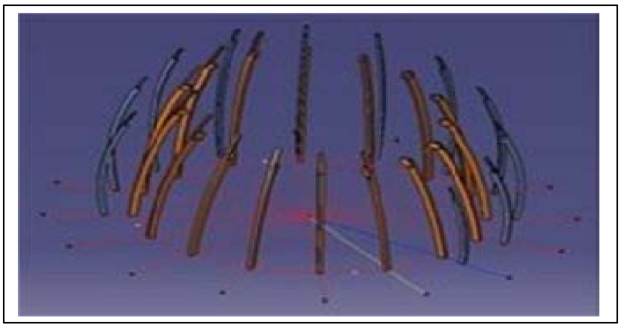

Figure 3. Main structural column [18]

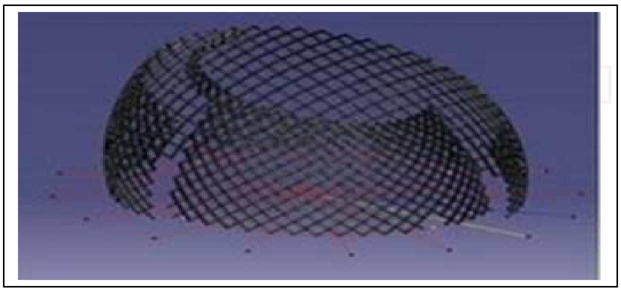

Figure 4. Keel of curtain wall [19]

performance hall is separated by a curved wall, which is both the structural element and modeling element. The curved wall positioning constraints are subject to a number of conditions. Firstly, the curved wall in the first floor needs to ensure the reasonable width of cloakroom and shop. Secondly, the curve line of the curved wall on the second floor needs to guarantee an effective width and height of the audience lounge to avoid pressure. Last but not least, the intersection of the curtain wall and the curve wall should be below the structure of the roof. Based on the functionality of generating multiple planes and bisects, designers could achieve a satisfactory location of the curve planes to achieve the final space effect of the front hall. Structure, equipment, electrical and other sections need to be imported into professional analysis software for qualitative analysis and quantitative calculation of the building programme. A BIM model is interoperable and comes in different formats. Integrated information in the model could be exported to other software. This reduces repetitive tasks in the traditional design process, which improves the efficiency of the work of the designer. With the import of an AutoCAD Autodesk Revit model into Fluent software, architectural numerical simulation of wind loads are used to determine the actual wind pressure distribution to provide an accurate basis for the structure, curtain wall and structural design. In SAP2000 and Midas, structure calculation and structural deformation analysis of the construction of the main structure are analysed. Models are corrected in Autodesk Revit based on the calculation results.

3) Composite design and clash detection of line pipe

The aim of composite design and clash detection of line pipe is to avoid clash and confliction. Conventional line pipe in 2D design draws key sectioning planes to coordinate each section. However, in 3D design, BIM could be adapted to reflect the conditions in each section. Autodesk software is adopted to conduct clash detection in order to improve the productivity of design and clash detection of line pipe. The performance hall of Circus Santo's electromechanical space is mainly related to the mechanical and electrical line in the basement of the two-story underground ventilation. It includes air-conditioning systems, air-conditioning water systems, drainage systems, fire safety systems and electrical systems. 3D model clash detection will produce a large number of collision errors. In order to make clash checks clear, separate clash detection is conducted between civil structures, mechanical and electrical systems and electromechanical systems.

3.1.4 Benefits of adopting BIM

BIM is adopted in this project to conduct complicated modelling for construction site. Compared to conventional 2D design drawing, precision of positioning is improved for design and on-site construction work. The complexity of this model makes it very difficult to build the model with normal BIM design tools only, such as Revit architecture. BIM analysis tools are also adopted to facilitate the complex modelling. This also enables collaboration work with other software to create models more accurately. The process of clash detection is also simplified through pre-handling with BIM software.

3.2 Wuhan New City International Expo Centre

3.2.1 Background and challenge

Wuhan New City International Expo Centre is planned to cover a total area of 6253 acres and a net area of 4270 acres. The central area of the planned construction area is 1.2 million square metres. An overview of the as-built plan for this project is shown in Figure 5. The exhibition hall of the first term has been completed for the final phase. Similarly to the last case, Wuhan New City International Expo Centre is a large-scale public project. There are traditional investment, duration and coordination problems in the project. Additionally, there are issues of public safety and a requirement for comprehensive benefits. The following characteristics of BIM could help to solve these issues: (1) BIM could simulate the construction phase to find potential issues; (2) a BIM model could facilitate collaboration with a visualized platform and central database; (3) BIM could integrate the facility management information with the 3D model to guide the asset management and transportation.

Figure 5. As-built plan of Wuhan New City International Expo Centre

BIM applications in this case are mainly focused on operation and maintenance. According to the actual progress of the International Expo Centre and the digital expo service requirements, the adoption of a BIM model will focus on investment, exhibition, traffic signs, guidance, equipment and other aspects of emergency services.

3.2.2 Strategy

According to the BIM regulation of planning [12], the BIM construction plan of Wuhan New City International Expo Centre needs to be created first. The BIM model is created based on the construction plan (Figure 6). The properties are embedded into the BIM model based on the operational purpose.

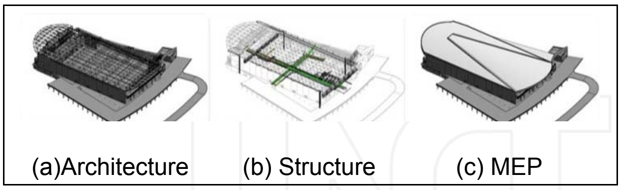

Figure 6. BIM model of Wuhan New City International Expo Centre

1) Analysis of traffic organization
Navigation systems are embedded into the integrated model, which includes information on category, ID, location of installation, materials, technology, text messages, font size and position, indoor logos, outdoor logos and car-park logos. BIM also enables checking of the clarity of view at the entrance and exit. The usability of signs for guidance could be observed in the simulated scenario. For example, as shown in Figure 7, the walk-through in a third-person viewpoint experience proves that the glass protective structure located in the broad platform of the second floor plays a very important role in guiding people's navigation.

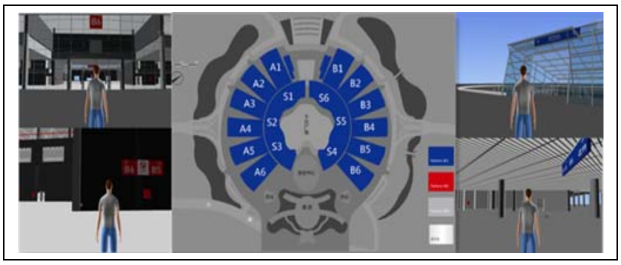

Figure 7. Using BIM for guiding transportation

2) Space management
In the operation phase, the main purpose of the pavilion is for exhibition. Thus the space management includes both the conventional space for MEP equipment and the partition of the pavilion's interior space. The properties and status of space change over time. For ease of management, properties relevant to the exhibition are assigned for different partitions. These properties include the location of the partition, status of lease, lease holder, etc. (Figure 8)

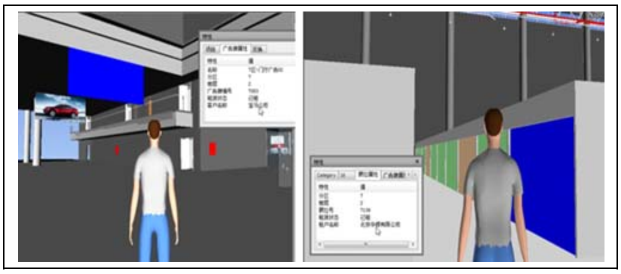

Figure 8. Exhibition partition properties

3.2.3 Benefits of adopting BIM

The BIM model of Wuhan New City International Expo Centre facilitates the rescue of equipment in emergencies, investment for exhibitions, and access to information via a central database. An operational management module based on this model provides support for emergencies and digital expos. Operational safety and security are improved and the public are able to learn about the project. Thus the overall value of the project is improved.

3.3 Chengdu Financial City

3.3.1 Background of project

The Chengdu Financial City is located in the City of Chengdu, on TianFu Avenue. It covers 170,000 square metres with a height of 210 metres, including offices in the South Tower, dormitories in the North Tower and a basement level. The core-tube system is applied in the South Tower and the frame core-tube system in North Tower. The total investment for this project was RMB 1.3 billion. The financial city consists of trading market, public plaza, shopping mall, office buildings, living quarters, etc. This project includes three sections: architecture construction model, structural model and Mechanical, Electrical and Plumbing (MEP) model. Navisworks is adopted to conduct clash detection and visual collaboration for the large integrated BIM model. Please refer to Figure 9 for the adoption of BIM in the construction phase. As the financial city is used comprehensively for different purposes, it is important to ensure every part will be occupied. Otherwise, vacancy will consume a huge amount of funds. The adoption of BIM could enable the user to view the as-built plan and the function of each part. The visualization function of BIM can attract potential contractors in the design stage as well. Merchants such as Wal-Mart have their own regulations for space. Adopting BIM in the design stage can thus also enable the owner to arrange the functionality of different parts corresponding to their different rules.

3.3.2 Challenge

In order to ensure every part will be occupied after the construction phase, the whole BIM model of this massive financial city must be built in the design phase. Arrangement of different functionalities for each part should be completed in this phase as well. It is a great challenge to adopt BIM throughout the construction phase, including creating an infrastructure model and MEP model and a clash detection and construction plan. Massive problems may occur when keeping all the data classified efficiently and synchronized in real time.

3.3.3 Strategy

1) Creation of infrastructure model

This part is mainly focused on the structural model for checking collisions of MEP. It consists of foundation, raft foundation, retaining wall, concrete beam, steel column structure, slab, shear wall, partition wall, curtain wall, stair, door and windows. The structural BIM models are all referred to the type of steel column, including flange, web and R angle. If there are any changes, the type of steel column can be changed efficiently. Drawings from different professions can be updated synchronously to avoid nonsynchronous problems.

2) Creation of MEP model

The MEP model includes power distribution, telecommunication, ventilation of air conditioner, water supply, protection of fire and water gutter system. Different tasks are assigned to engineers in different areas in a collaborated way. They can work on the same model synchronously. Engineers check the model for collisions between pipelines and mark up the model for discussion in the next meeting. To execute editing and inspection tasks in BIM software, a colour scheme is distributed to each type of MEP component. For example, red is assigned to power distribution components; yellow is assigned to water supply and green is assigned to fire protection.

3) Clash detection

Conventional clash detection in the synthesis process of pipelines is conducted by professional engineers manually. It is a massive and time-consuming job. Carelessness and mistakes always occur in manual work. The result is wastage of both time and budget. Thus, plans need to be revised in real time on site. Through clash detection in BIM software, hard collisions can be identified visually and automatically. The time needed to change plans can be potentially reduced and the value of space could be improved by optimization. In this project, a 30% Return on Investment (ROI) is achieved through BIM.

4) Construction plan

The construction plan can be simulated in 4D BIM software. For example, simulation of the working route of a crane can be simulated visually. The plan can be simulated and visually displayed on the projector for collaboration and discussion, in a highlight colour for easy recognition. The schedule can be updated with the BIM model. There are even 5D simulations which include the budget based on materials. The client is developing a standard database for the calculation of total cost of materials.

5) BIM model for facility management in operational phase

After the construction phase, an as-built BIM model is adopted for facility management. This model serves as a central database. The platform needs to be developed for different areas. Basic facility management is split into three sections: maintenance plan, assessment management and space management. The advantage of adopting BIM to conduct facility management is the 3D environment, which visually displays all the objects clearly. All of the maintenance documents can be updated in real time. Relevant manuals can be searched efficiently and specific components can be located effectively. BIM is adopted throughout the construction phase of this project. Most parts of the structure and pipeline are digitalized. Pre-handling of clash detection with integrated rules reduces costs and time. The as-built model can also be treated as a digital asset of the building, which can be used throughout the operational phase.

3.3.4 Benefits of adopting BIM

BIM is adopted in this project to design the whole BIM model corresponding to different regulations of merchants and to arrange various functions for each part. Most of the financial city will be occupied as soon as it is ready to avoid vacancy and waste of funds.

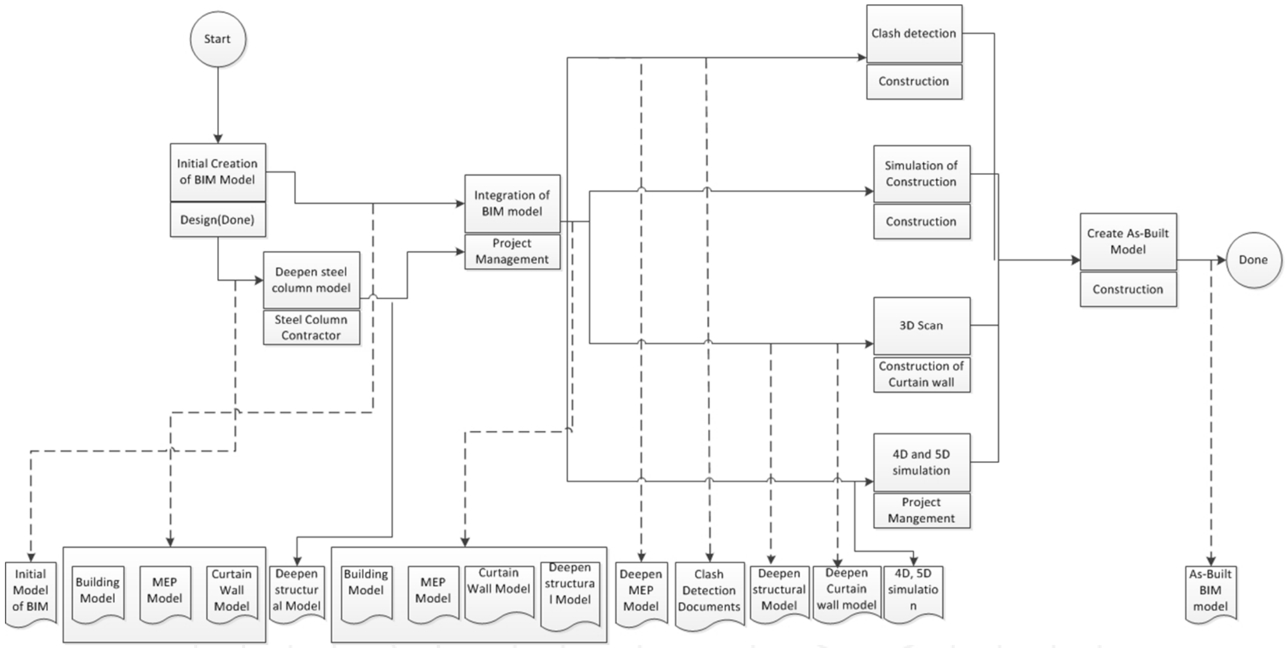

Figure 9. The adoption of BIM in the construction phase

3.4 Shanghai Disaster Control Centre

3.4.1 Background and challenge

Shanghai Disaster Control Centre is one of the most important information systems of the State Grid Corporation. It consists of five floors covering 28,124 square metres, comprising one underground level and four above ground. Total investment in this project is RMB 300 million. The basement level will be occupied by early warning equipment. The ground floors comprise of computer rooms, air-conditioning rooms and a command centre for emergencies.. The early warning equipment is of vital importance and needs to run all the time. It is critical to monitor the status of all the equipment in order to provide urgent support quickly.

3.4.2 Strategy

Traditionally, sensor and warning systems are embedded into disaster control centres [13]. When an emergency happens, the facility manager will be warned in the command centre. However, it is difficult to identify which type of disaster is occurring and in which facility. It is difficult to recognize the real-time status of a facility. A BIM facility management system can achieve visualization and real-time monitoring of all facilities with communication to sensors embedded in facilities. Wang and Chen developed an approach to conducting tele-inspection based on virtual space [14]. Operation management involves not only facilities management, but also management of space, traffic and so on. The establishment of the operation management platform will be a complex and arduous task. To avoid development risks and shorten the development cycle, the development of a BIM operation management platform only focuses on the centralized management of the facilities, including the air-conditioning and ventilation systems, water-chilling systems, water-cooling systems, water-supply and drainage systems and electrical power systems. This project aims to develop an integrated platform to manage the operational information of this building, in two ways: equipment information monitoring and dynamic data display and warning [15].

1) Equipment information monitoring

Equipment information monitoring mainly refers to the monitoring and control system in the context of the whole building, including a regional view, a sub-system view, a system information view and a facility information view, and the corresponding auxiliary functions. The BIM operation management platform in the Shanghai Disaster Control Centre is divided into five regions according to the floors: B1 subzone, 1f subzone, 2f subzone, 3f subzone, and 4fp subzone. Zones are defined on each floor according to the function of the rooms. B1 includes five areas: cooling tower water inlet and air-conditioning rooms, fire-control pump rooms and life pump rooms, refrigerator rooms, UPS and battery rooms, and distribution rooms. The Centre of Disaster Recovery is thus divided into 17 partitions in the BIM operation management platform. In the process of BIM model processing, each partition is highlighted. When any area is selected, the main interface of the BIM operation management system shows all the system in the area. From each regional view, it is shown clearly whether the partition within the system and the equipment is working properly. Through the development of auxiliary functions such as translation, zooming, and roaming, the user can find any devices in the partition efficiently and conveniently. Then the user can read the physical parameters and real-time operation parameters to understand the working state of the equipment. The system interface is shown in Figure 10.

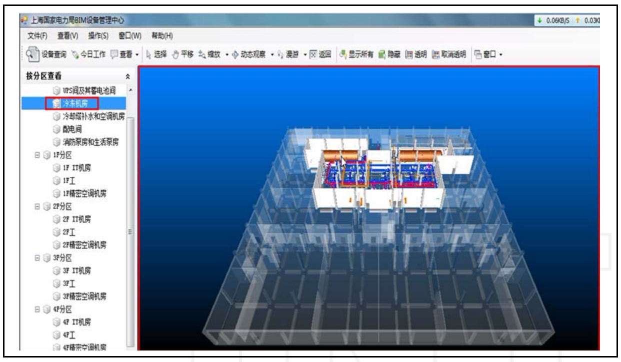

Figure 10. System interface of the BIM-enabled FM system

The subsystem view mainly divides up zones according to the MEP system for the convenient supervision of the system's running status. As in Figure 10, the MEP system in the BIM model is divided into 15 big systems: water supply and drainage system, VRV air-conditioning system, mechanical smoke-extraction system, mechanical pressed-air supply system, emergency exhaust system, gas-extinguishing exhaust system, normal exhaust and gas-extinguishing exhaust system, air-conditioning and fresh-air system, K(X)-1 fresh-air system, TEF-RF-1 system, basement fresh-air system, basement fresh air system without processing, basement ventilation system, water cooling system, and water freezing system.

2) Dynamic data display and warning

The dynamic representation of data and alarms include searches of the facilities, dynamic location, display of the facilities and the maintenance routes, relative records of the daily maintenance work and the alarm information of the facilities. The facility manager can search and check the facilities by type, number, name and time of purchase. People can also check the attributes of the facilities, the maintenance routes and records, and previous data directly. When choosing any facility, when clicking the viewing button, a user can find the relevant facility in the BIM model. Attributes and the current time operation situations of the facility are listed in the attribution column. Figure 11 shows the 3D model and dynamic data information of the previously checked switch cubicle. The images imitates real eyesight from the spatial location. The checked switch cubicle is highlighted as differing from other facilities. The right attribute column shows the relative information, such as the number, the name, the type, the current floor and room, the date bought and last maintained, the maintenance cycle, the information of the switch, the line, the actual three-phase current, the three-phase voltage values, the P value and Q value, etc. With this information, the worker can judge the operation state of the switch cubicle rapidly and directly. Meanwhile, they can find the accurate location, check the maintenance records and check whether the part needs maintenance.

Figure 11. 3D model and dynamic data information of the previously checked switch cubicle

If any facility is chosen, the system will match the corresponding maintenance routes in red. These routes are typed into the backstage database in advance. Workers can refer to or print the routes to find the facilities' location, which is very convenient. Another important function is facility alarm. When facilities break down, the BIM operation management platform will get a notification and obtain details about the hardware and the alarm in good time. On the alarm interface, workers can find basic information such as the current floor and the current room, which will help workers to find the facilities quickly.

3.4.3 Benefits of adopting BIM

Adoption of BIM enables the real-time monitoring of facility status. Thus, the user will discover issues quickly. Positioning and navigation could also be realized in a BIM database. With the assistance of BIM, a facility manager can get to the right spot quickly. Time is saved and additional losses avoided. A BIM operation management platform will also automatically connect the maintenance database and come up with the relevant plans.

3.5 National Synchrotron Radiation Research Centre (NSRRC)

3.5.1 Background and challenge

The Taiwan Photon Source (TPS) project aims to create the most advanced third-generation synchrotron acceleration facility in the world. The budget is TWD 6.885 billion, including RMB 2.78 billion for civil engineering and MEP and RMB 4.105 billion for the acceleration facility. Figure 12 shows the as-built model of this project. There will be another TWD 8 billion for the experiments in this research centre. As shown in Figure 13, the buildings constitute an administrated lapping building, the YiGuang Building, the Taiwan Light Source, an electromechanical building, a research centre and a TPS-administrated operation centre.

Figure 12. The as-built overall view of TPC [20]

A large number of valuable facilities are found in this centre. Similarly to the Chengdu Financial City, this project requires real-time positioning and a high level of safety in order to keep all facilities in good status. The difference between them is that this project is focused more on maintenance and space allocation. Since all of the facilities are precise and valuable, working conditions are very strict. For example, small issues such as leaks may damage the facility and cause big losses. Thus, maintenance of the working environment such as waterproofing materials for building should be changed regularly. Manual handling of the maintenance schedule is imprecise and unreliable [16]. Space allocation is also critical in order to avoid inappropriate design of space or negative effects on researchers' sense of well-being. Space allocation will be designed with the help of the researchers and engineers themselves. Thus, a collaborative platform is needed to visualize the as-built plan.

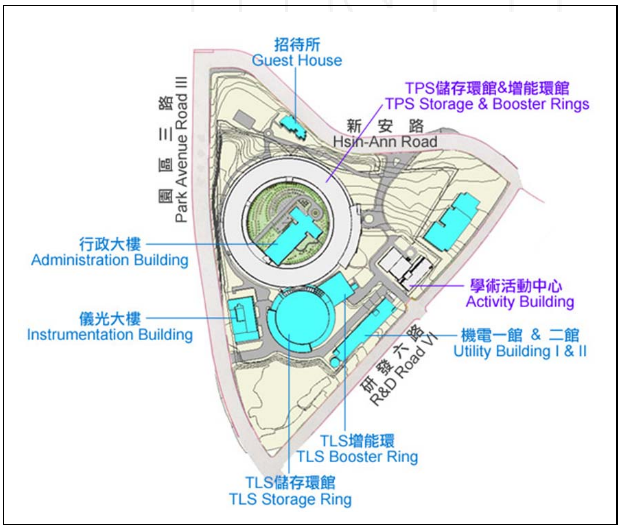

Figure 13. Functions of different zones of TPS [21]

3.5.2 Strategy

1) BIM-enabled maintenance schedule and warning

The lifecycle of buildings could be as long as 40 to 50 years. However, materials in buildings cannot survive for that long. Maintenance schedules for different materials vary. The facility manager cannot remember all the lifecycles of different materials. Conventionally, maintenance is conducted after issues arise. Facility managers may also be changed during the lifecycle of a building, resulting in incomplete delivery of maintenance documents. BIM integrates all the maintenance documents in a 3D model, linking each material, component and facility with maintenance schedules, properties, manufacturers and other relevant information. This project adopted BIM to ensure early warnings about scheduled maintenance and provide reminders about materials whose lifecycles were ending. Cost information was linked to different types of materials for budget calculation. Detailed information on manufacturers, specifications, etc., is attached to objects as properties. These data are used to arrange work and impose order on materials of the same type. For ease of access to different information, a search engine is developed to retrieve information by name of building, name of facility, code of facility, etc. Once a part of the building requires maintenance because a cable is damaged or materials expire, detailed information could be identified efficiently from this engine. A user will be guided to the specific position in the BIM model.

2) Space allocation and modification

Light sources in a synchronous acceleration facility are indispensable in basic scientific research. For a limited budget, space designers are not employed for all laboratories. To avoid inappropriate design of space or negative effects on researchers' well-being, space allocation will be designed by the researchers and engineers themselves. Without the adoption of BIM, this allocation must be conducted with 2D drawings. However, most of the researchers are not from a civil engineering background. Due to the lack of sense of space, BIM is thus adopted to provide an immersive feeling. They can then mark into the model an appropriate working space before the integration of a complete plan of space allocation.

3) Asset management

The NSRRC project involves massive research facilities. It is hard to identify whether any part of these facilities is damaged. However, with the technology Radio Frequency Identification (RFID) and BIM, a unique identification can be assigned to all the facilities. They can be tracked remotely in the system. If they do not remain in the initial place, a warning will be sent to the manager automatically. A 2D barcode system and mobile devices such as mobile phones and PDAs could be integrated into this system for search references of all facilities.

3.5.3 Benefits of adopting BIM

Adoption of BIM in this project enables collaboration in the pre-design stage taking account of researchers' own demands for space allocation. BIM is also adopted in this project to monitor the real-time status of facilities, similarly to the Shanghai Disaster Control Centre. Unlike the last project, BIM is applied to manage the maintenance schedule more efficiently with automatic notification. This ensures a good working environment for all the facilities and avoids ageing materials causing damage to facilities.

4. Conclusion

This paper has presented five cases of BIM adoption in the design, construction and operational phases under different circumstances. Methodology is developed to analyse, compare and contrast BIM use in these five projects. By comparing the five construction projects in Asia, it is concluded that in the design phase, BIM is mostly adopted to conduct complicated modelling for construction sites and to enable non-constructors to change plans based on their preferences. The analysis function of BIM software facilitates the improvement of the precision of drawings. In the construction phase, positioning will be more precise with the adoption of BIM. Building plans can be simulated and optimized to improve safety and productivity. Drawings from different professions are imported into BIM software to conduct clash detection. Clash detection is implemented in BIM simulation software in order to check if there is any collision in the MEP model. In the operational phase, BIM helps to monitor the equipment in real time and ensure it works normally to avoid losses caused by disaster. Digital expos and public emergency support are assisted by BIM through improved operational management. Moreover, the as-built model can be treated as a digital asset of the building, which could be used throughout the building life cycle.

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6. References

[1] Wang, X. and Dunston, P.S. (2006). "Compatibility Issues in Augmented Reality Systems for AEC: An Experimental Prototype Study". Automation in Construction, Elsevier, 15 (3), 314-326.

[2] Schlueter, A. and Thesseling, F. (2009). "Building information model based energy/exergy performance assessment in early design stages". Automation in Construction, 18, 153-163.

[3] Bormann, A. and Rank, E. (2009). "Specification and implementation of directional operators in a 3D spatial query language for building information models". Advanced Engineering Informatics, 23, 32-44.

[4] Wang, X., and Love, P. (2012). BIM+ AR: Onsite information sharing and communication via advanced visualization. Computer Supported Cooperative Work in Design (CSCWD), 2012 IEEE 16th International Conference, 850-855.

[5] Wang, X. (2007). "Using Augmented Reality to Plan Virtual Construction Worksite." International Journal of Advanced Robotic Systems, 4 (4), 501-512s

[6] Hardin, B. (2011). BIM and construction management: proven tools, methods, and workflows, Wiley Publishing, IN, Indianapolis.

[7] Singh, V., Gu, N. & Wang, X. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Automation in Construction, 20, 134-144.

[8] Syal, M., Parfitt, M. K. and Willenbrock, J. (1991). Computer-integrated Design Drawing, Cost Estimating, and Construction Scheduling. Pennsylvania State University, Department of Civil Engineering, NAHB/NRC Designated Housing Research Centre

[9] How, H. (2002). Precision data acquisition using magnetomechanical transducer. Google Patents.

[10] Wang, X. (2012). "Extending Building Information Modelling (BIM): A Review of the BIM Handbook." Australasian Journal of Construction Economics and Building, 12 (3), 101-102.

[11] Dunston, P.S. and Wang, X. (2005). "Mixed Reality-based Visualization Interfaces for the AEC Industry." Journal of Construction Engineering and Management, American Society of Civil Engineers (ASCE), 131(12), 1301-1309.

[12] Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. Wiley. Hoboken (New Jersey).

[13] Igarashi, A. and Kobayashi, T. (1990). Disaster prevention monitoring and control facility. Google Patents.

[14] Wang, X. and Chen, R. (2008). "An Empirical Study on Augmented Virtuality Space for Tele-Inspection of Built Environments", Journal of Tsinghua Science and Technology (Engineering Index), Elsevier Science, ISSN: 1007-0214, 13 (S1), 286-291.

[15] Wang, J., Li S., Wang X., Mao C., and Guo J. (2013). "The Application of BIM-Enabled Facility Management System in Complex Building."

International Journal of 3-D Information Modeling (IJ3DIM), 2(3), 16-33.
[16] Akcamete, A., Akinci, B., and Garrett, J. (2010). Potential utilization of building information models for planning maintenance activities. Proceedings of the International Conference on Computing in Civil and Building Engineering, 151-157.
[17] Zhulong BIM (2013). Outside curtain wall of main performance hall. [image online] Available at: http://bim.zhulong.com/case/read171253.html Accessed on 25 May 2013.
[18] Zhulong BIM (2013). Main structural column. Available at: http://bim.zhulong.com/case/read171253.html Accessed on 25 May 2013.
[19] Zhulong BIM (2013) Keel of curtain wall. Available at: http://bim.zhulong.com/case/read171253.html Accessed on 25 May 2013.
[20] TPS (2013) The as-built overall view of TPC. Available at: http://www.nsrrc.org.tw/english/tps.aspx Accessed on 25 May 2013.
[21] TPS (2013) Functions of different zones of TPS. Available at: http://www.nsrrc.org.tw/english/tps.aspx Accessed on 25 May 2013.

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