Case Study of BIM+AR Technology in China Power Engineering Construction Materials Management

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ABSTRACT：Material management is an important part of power engineering construction，because a perfect material management system directly affects the cost, quality and economic benefits of the project. Based on the extensive literature review, the paper investigated a number of construction companies, interviewed with Building information modeling (BIM) experts, etc, and sent a total of 500 questionnaires to the various participants of the project, counted the current state of traditional material management and the application of BIM and Augmented Reality（AR） technology in the engineering field. The paper utilized the information integration function of Building information modeling (BIM) technology and the real and virtual interaction superposition function of Augmented Reality（AR） technology, combined with the actual construction project of electric power engineering, the electric power material management system based on building information modeling (BIM) and Augmented Reality（AR）technology is constructed, and then the collaborative management platform is developed based on the management system. There by achieving high-efficiency management of materials in the construction process of electric power engineering. More specifically, this article provides the following contributions：Increased the efficiency of material entry and acceptance；Reduced the risk of accidents caused by non-standard stacking of materials; Reduced the costs of power engineering construction.

KEYWORDS：Building information modeling (BIM);Augmented Reality（AR）；Power Engineering ; Material management

INTRODUCTION：

Material management of power engineering is an important part of controlling construction costs and an important prerequisite for ensuring project schedule and quality. Efficient material data collection of construction engineering is crucial for project management (Huang et al. 2018). With the development of more and more large and complex projects, the material management work is more cumbersome and the difficulty is increasing (Li et al. 2019). With the standardized management of the power engineering industry, the level of construction management is constantly improving, and power engineering companies strive to develop digital power grids. As long as by continuously strengthening internal management and improving corporate profit levels, we can improve their market competitiveness (Liu. 2018).

Building Information Modeling (BIM) is a complete information model (Zhang.2017) and can integrate the engineering information, process and resources of power engineering projects at different stages in the whole life cycle into one model, which is conveniently used by all parties involved in power engineering (Sebastjan Meža.2014). The research simulates the real information of buildings through 3D digital technology, and provide a coordinated and internally consistent information model for power engineering construction materials management (WANG Jun et al.2017). BIM is applied to material management, which can enhance material management methods, improve management efficiency and reduce construction costs (Yua et al.2019).

Augmented Reality（AR）is known as mixed reality(Huang.2018).It uses computer technology to apply virtual information to the real world. Real-world environments and virtual objects are superimposed on the same screen or space in real-time(Wang et al.2014). Augmented Reality（AR） technology has a predictive role in the management of power engineering materials and can simulate the stacking of materials in a safe and standard environment throughout the construction process(Wang and Hu.2015).

The basic path of applying Building Information Modeling (BIM) technology to the supply chain management of construction projects and the corresponding basic structure of information systems are studied. The basic ideas for using BIM technology to manage materials in the informatization process of construction enterprises are studied (YU et al.); The research developed a BIM-based material management system, through the application of the system, realized the whole process management from model calculation, demand planning, procurement planning, on-site inspection income database, issue and requisition(Jin.2018); The research created a refined management mode of construction materials based on Building Information Modeling (BIM) technology to realize the application of Building Information Modeling (BIM) technology in the fine management of construction materials(Liu. 2018);There are also many applications of Augmented Reality（AR） technology in engineering construction, such as the application of Building Information Modeling (BIM) and Augmented Reality（AR） technology in the automation of construction machinery(DING Ling-hua.2018); The research researched and build the engineering construction and management system of Building Information Modeling (BIM) and Augmented Reality（AR） technology(Zhu.2018); The research researched and build a construction safety management

system for BIM and Augmented Reality（AR）(Yang et al.2018). However, research specifically focused on the management of power engineering construction material is currently rare.

METHODOLOGY AND TECHNICAL ROUTES

Methodology of research

The Methodology of Research used in this paper mainly included four kinds: namely literature search method, expert interview, field research method, and case study method.

Literature search

This paper studies the power engineering material management system based on Building Information Modeling (BIM) and Augmented Reality（AR） technology, involving multiple disciplines and new technologies, including engineering, management, and computer science, including Internet, Building Information Modeling (BIM), Augmented Reality（AR）, Internet of Things, communication. Wait for new technologies. Through the review of relevant literature, the information in the literature is collected, collated and summarized, and the current research status of power engineering, special industry engineering material management and application of Building Information Modeling (BIM) and Augmented Reality （AR） technology in material management is analyzed. The research status outside is helpful to clear the research direction and deepen the research conclusion based on the previous research results.

Experts interview

Based on literature research, do everything possible to contact the authors of the relevant research literature and make a meeting after getting in touch. Targeted put forward the specific status, prospects and technical difficulties of Building Information Modeling (BIM) and Augmented Reality（AR） technology in material management in engineering construction, and record in real-time.

Field research

The innovative method of power engineering material management must be carried out in the current situation and needs of construction project management, and the most authentic information can be obtained through on-the-spot investigation and in-depth engineering construction site. The field research mainly includes three methods: questionnaire survey, field visit, an in-depth interview, and accepts the suggestions of the on-site project staff, so that the conclusions of the research are more realistic and operability.

Case study

The research in this paper not only analyzes the research content from the theoretical level, but also applies it to the actual case to demonstrate, and the theory combines with reality to make the research conclusion more persuasive. After constructing the power engineering material management system based on Building Information Modeling (BIM) and Augmented Reality（AR） technology, it is verified by representative practical application cases, and the conclusions can be generalized from the case application effect.
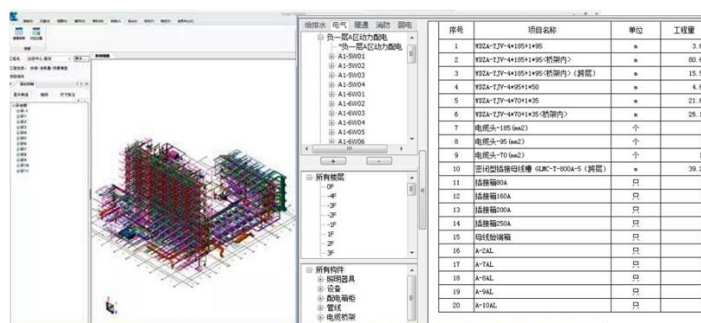
Technical routes

The technical route of this paper mainly includes three stages: preliminary preparation stage, main research stage, and summary stage of results. The preliminary preparation stage is a literature search and project research. The purpose is to summarize the research results of the research direction of this paper, clarify the research objectives, determine the project cases, and then formulate the research route. The main research stage is based on the research of Building Information Modeling (BIM) and Augmented Reality（AR） technology and material management theory, combined with the current status and problems of power engineering materials management and the root cause analysis of the problem, proposes the application of Building Information Modeling (BIM) and Augmented Reality（AR） technology to solve the problem, and builds a power engineering material management model based on Building Information Modeling (BIM) and Augmented Reality（AR） technology. Verify the feasibility and effectiveness of this management system through case. The main research contents in the conclusion stage include analyzing the economic benefits and management benefits of the case application, and then summarizing the research results, and to prospect the future research direction of Building Information Modeling (BIM) technology application.

POWER ENGINEERING MATERIALS MANAGEMENT CONTENT

The application of Building Information Modeling (BIM) and Augmented Reality（AR） technology in the material management of power engineering construction sites should break the original project management system. Only Building Information Modeling (BIM) and Augmented Reality（AR）technology can be interspersed into the daily work of each department related to power engineering, so that Building Information Modeling (BIM) and Augmented Reality（AR） technology can get better application results. The content of power engineering materials management based on Building Information Modeling (BIM) and Augmented Reality（AR） technology: material planning list, material storage, material outbound, material on-site stacking and inventory of warehouse materials.

Material plan list

After receiving the substation construction drawings, the Building Information Modeling (BIM) project workstation personnel converted all the information of the drawings into a Building Information Modeling (BIM) model, and the attributes of each component were completely entered, and the parameters related to material management were added for aggregation, thereby establishing a material database. The database structure is shown in Figure 1:

Fig.1. BIM database structure

Material storage management

When the supplier delivers the goods to the site, the warehouse manager should check the materials. The way materials are put into storage is different from the traditional way of acceptance. First, the material parameters in the bill of materials generated by Building Information Modeling (BIM) are checked one by one; Then, mark each item with a specific signage (such as an RFID chip) to facilitate the management of the later stages of the material; Finally, the bulk materials are transported to the site for stacking, and small items are stored in the warehouse.

Material outbound management

At present, although the quota picking process system in power engineering management is sound, the effect is not satisfactory. The reason is that when dispensing materials, due to limited time and difficulty in querying the reference data, the auditor cannot accurately determine whether the amount of each work consumed on the submitted pick list is reasonable, and can only be estimated based on subjective experience and a small amount of data. Using Building Information Modeling (BIM) technology, auditors can call a large amount of detailed historical data of similar projects in Building Information Modeling (BIM), use Building Information Modeling (BIM) multi-dimensional simulation construction calculations, quickly and accurately split and summarize, and then output the consumption standard of any part of the work, truly realize the idea of limit picking . Material picking process based on Building Information Modeling (BIM) database: The construction team member submits the application for the materials, and the material management department refers to the Building Information Modeling (BIM) database and the material consumption data for review. If the approval is passed, the materials are issued according to the application form. If the review fails, the list is returned. The construction team re-submitted a reasonable application.

On-site stacking based on AR technology materials

At the construction site of power engineering, the stacking of materials is particularly important, and even building safety regulations have introduced a series of standards to constrain the stacking of materials on site. First, because the stacking of materials affects the progress and cost of the project, if the material stacking is unreasonable, it will cause secondary transportation, etc., which is time-consuming, labor-intensive, and affects the progress of the project; Second, if the material stacking is not standard, it is easy to have a safety accident, which is not conducive to the safety of workers. Power engineering material stacking step based on Augmented Reality（AR） technology. Material stacking operation diagram based on Augmented Reality（AR）technology is shown in Figure 2:

Fig.2. Material stacking operation diagram based on AR technology

Inventory of warehouse materials

Inventory of warehouse materials refers to the inventory check of inventory materials, the purpose is to master the inventory quantity and storage, to find problems on time, take effective measures to remedy, to ensure the integrity and safety of materials. The use of Building Information Modeling (BIM) technology to inventory power engineering materials is mainly to use its information integration function, in accordance with the specific mark of the use of inspection materials, accurately clear the warehouse inventory, combined with the total amount of data in the BIM database and the amount of materials used for monthly material clearing. It can be accurately found whether the materials are over-subscribed and whether the materials are in short supply can be found, and the waste can be disposed of. The scarce materials will be automatically alerted in the Building Information Modeling (BIM) database, thus avoiding the shortage of funds caused by excess materials, and avoiding the delay of construction due to a shortage of materials, while processing waste can also reduce costs.

Power engineering material management system

Based on the basic theoretical knowledge described earlier in this paper, combined with literature search, expert interviews, field research and case studies, etc., establish a power engineering material management system based on Building Information Modeling (BIM) and AR technology. material management system is shown in Figure 3:
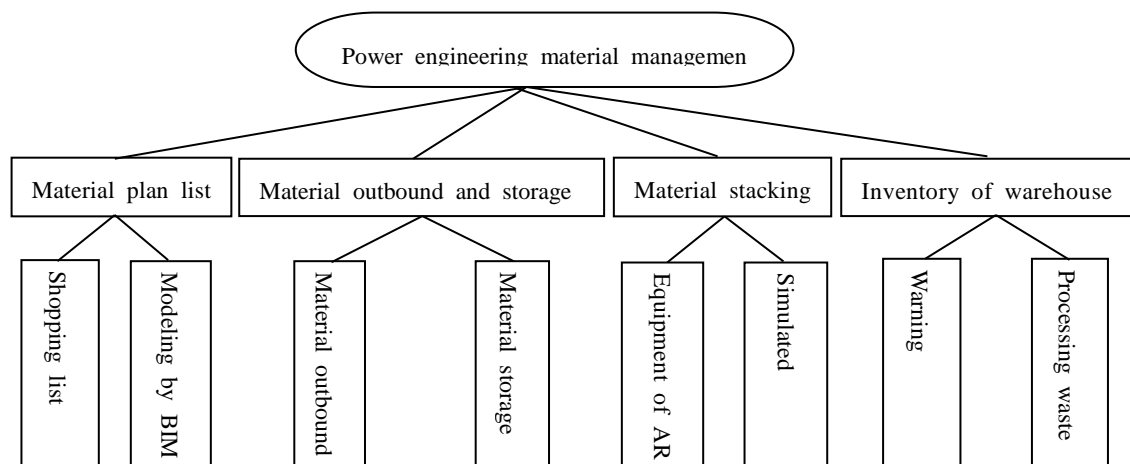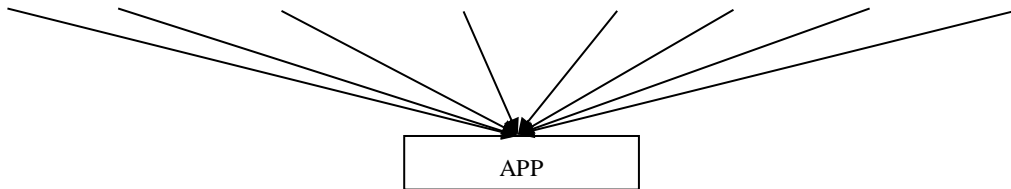
Fig.3. power engineering material management system based on BIM and AR technology

CASE STUDY

Case background

Binhai New City Fourth Station 110 kV Substation, Located in Binhai New City Southeast Digital Data Industry Park and Covers an area of 1.58 acres, Tianjin, China. The total investment of the project is about 9.66 million dollars, which is the main force of power supply in the core area of Binhai New Town. Binhai New City Fourth Station 110 kV Substation adopts prefabricated construction, and not only powerful but also very smart and environmentally friendly. After the substation was commissioned, the power supply standard in the core area of Binhai New Town was raised to A+, it is the same as the core areas of Fuzhou and Xiamen, providing strong power security for the development of Binhai New City. The effect of the substation built with BIM and AR technology is shown in Figure 4.

Fig.4. The effect of the 110 kV substation at the four stations of Binhai New City

Material collaborative management platform

Based on the power engineering material management system shown in Figure 3-7, the power company adopts a cooperative approach with experienced software development companies to customize and develop a Building Information Modeling (BIM) and Augmented Reality（AR） collaborative management platform that meets the needs of enterprises and

projects. First, research needs and form a research report, and then deeply analyze the power enterprise's demand for material management, develop a development plan, and confirm it by the power enterprise management personnel, and then carry out targeted Building Information Modeling (BIM) and Augmented Reality（AR） collaborative management platform development. The use of custom development can ensure the relevance and effectiveness of the collaborative management platform, and help to control the workflow adjustment and optimization in the development process. The interface of APP is shown in Figure 5:

Fig .5. Interface of power engineering materials collaborative management platform based on BIM and AR technology

Analysis of application benefit

Material consumption control economic benefit

By using the material management system based on Building Information Modeling (BIM) database，Achieved the effect of high synergy in project material management、low consumption and Fine management The early warning mechanism for excessive consumption of materials can take timely corrective measures and keep the material loss rate at a low level. Taking the analysis of steel consumption of some infrastructures as an example. The collaborative management platform was not used in March 2019, and the collaborative management platform was used in April. The Rebar dosage data of the substation in March and April are shown in Table 1:

Tab 1. The rebar consumption rate for March and April

Rebar specification	Unit	Dosage for March	Consumption for March	Consumption rate for March（%）	Dosage for April	Consumption for April	Consumption rate for April（%）
Φ32	t	189.2	5.17	2.73	31.25	0.44	1.41
Φ25	t	8.02	0.21	2.62	121.53	1.68	1.38
Φ20	t	17.19	0.47	2.73	16.78	0.21	1.25

| Φ16 | t | 10.13 | 0.27 | 2.67 | 11.22 | 0.19 | 1.69 |
| Total amount | t | 224.54 | 6.12 | 2.73 | 180.78 | 2.52 | 1.40 |

It is found from Table 1 that the consumption rate of Rebar in the material inventory in March is too large, exceeding the contracted consumption rate limit of 2%. However, due to the lack of early warning mechanisms for material over-consumption, the problem of material over-consumption has occurred in the process. And for a long time, it is not conducive to the management of material costs.

After adopting Building Information Modeling (BIM) and Augmented Reality（AR） collaborative management platform, when the inventory is in April, plus the material over expenditure warning mechanism, which conducive to timely discovery of unreasonable material consumption， and responding at the fastest speed, the Rebar consumption rate can be kept at a low level, which can be reduced by about 1% compared with the traditional material management method.

AR technology assists stacking materials to reduce accidents

By comparing similar substation projects for comparison and statistics of accident occurrence data, the following results were obtained：The total number of accidents in similar projects in the past four months reached 124, of which 20 were accidents, accounting for 16.13% of the accidents; In the four months of using the collaborative management platform, the total number of accidents reached 129, of which only 8 were accidents, accounting for 6.2% of the accidents. It can be found by comparison：After the use of the collaborative management platform, the incidence of accidents caused by materials is reduced.

CONCLUSIONS

Based on the problems existing in the management model of power engineering traditional materials, this paper proposes a power engineering material management model based on Building Information Modeling (BIM) and Augmented Reality（AR） technology, and validates the results through case application. The research conclusions are as follows:

·Based on the whole life cycle of power engineering construction, the research established a power engineering material management system framework based on Building Information Modeling (BIM) and Augmented Reality（AR） technology through a series of material management processes.

·From the completion of the design drawings, through the Building Information Modeling (BIM) modeling, material statistics, procurement, acceptance, warehousing, on-site stacking, and material inventory process, based on this process, the establishment of power engineering materials based on Building Information Modeling (BIM) and Augmented Reality （AR）technology Management system architecture.

·Based on the framework of power engineering material management system based on Building Information Modeling (BIM) and Augmented Reality（AR） technology, the software developer is selected to develop a collaborative management platform, which is applied to the

actual substation construction project, which realizes considerable economic and management benefits and is beneficial to the power enterprise to control costs.

FUTURE RESEARCH DIRECTIONS

This paper draws on the above research conclusions by studying the power engineering material management system based on Building Information Modeling (BIM) and Augmented Reality（AR）technology, and carrying out case analysis and verification, combined with the author's knowledge of power engineering materials management and Building Information Modeling (BIM) and Augmented Reality（AR） technology. The research area of this paper contains limited areas and limited research depth, and there are still many aspects to be further studied:

• This paper mainly studies the application of Building Information Modeling (BIM) and Augmented Reality（AR） technology to power engineering materials management. It is aimed at data statistics, procurement, acceptance, storage, storage, stacking and inventory of materials. There is no research on the source of the material capital, because the source of the material and other reasons will also affect the cost of materials, so the future research on power engineering materials management based on Building Information Modeling (BIM) and Augmented Reality（AR）technology focuses on the updating and control of material source information.

• The research on power engineering material management based on Building Information Modeling (BIM) and Augmented Reality（AR） technology is still in a very beginning stage, so this paper only conducts pilot application research on the latest substation project of Tianjing Electric Power Company, therefore, the results of the study may not be applicable to the entire power engineering industry. In the future, power engineering can select general projects for research, thus promoting the power engineering material management system based on Building Information Modeling (BIM) and Augmented Reality（AR）technology.

• In this paper, only a little mention of the use of RFID technology to assist management, in fact, subsequent research should focus on a combination of high-tech, such as Building Information Modeling (BIM) and Augmented Reality（AR） technology, combined with RFID technology, GIS technology, Internet of Things and large Data and other technologies gradually realize the smart site management model.

DATE AVAILABILITY STATEMENT

Data generated or analyzed during the study are available from the corresponding author by request.

REFERENCES：

Huang Weiwen , Gao Laixian , Zhang Yongyu and Li Jiayu.（2018）."*Research on electrical engineering equipment material information management based on BIM technology."* C,The

4th National BI M Academic Conference,120-123.

Li Xin, Yu Xin, Jiang Wei, Liu Diankun and Chen Binjin.(2019).*"Research and Application of Construction Material Dynamic Management System Based on BIM Technology."*J, Civil engineering information technology，11（2），56-58.

Liu Zuxiong.(2018). *"Application Research on Fine Management of Construction Materials Based on BIM Technology."D, Wuhan University of Technology, Eng. Manage,19-39.*

Zhang Lishan.(2017). *"Application of BIM Technology in Building Construction."*J, Building Construction,10(1).

Sebastjan Meža , Žiga Turk and Matevž Dolenc.(2014）."Component based engineering of a mobile BIM-based augmented reality system."J, Automation in Construction,2-11. http://dx.doi.org/10.1016/j.autcon.2014.02.011

WANG Jun,CHE Jun-bao and ZHANG Yi-fan.（2017）. *"The Whole Process Management of Material Based on BIM Technology in Construction Stage."*J, Value Engineering,74-76. http://10.14018/j.cnki.cn13-1085/n.2017.22.030

Qunzhou Yua, Kaiman Lia and Hanbin Luoa. *"A BIM-based dynamic model for site material supply."C, Creative Construction Conference 2016，528-532，*http://creativecommons.org/licenses/by-nc-nd/4.0/

Huang Taojuan.(2018). *"Development and Application of AR Technology in Building Construction Field."*J, Digital Construction，40（10），1831-1832.http://10.14144/j.cnki.jzsg.2018.10.053

Jun Wang, Xiangyu Wang, Wenchi Shou, Bo Xu, (2014) *"Integrating BIM and augmented reality for interactive architectural visualisation"*, Construction Innovation, 14(4),454-465.https://doi.org/10.1108/CI-03-2014-0019

Wang Tingkwei and Hu Panhui.(2015). "Application and Evaluation of Construction G uideline Based on BIM and AR." J,Construction Technology,44(6),55-58. http://10.7672/sgjs2015060054

YU Qiyuan，LV Yuhui and ZHANG Shang.(2016). *"Application of BIM in Supply Chain Management of Construction Projects."*J,Construction Economy,37(3), http://10.14181/j.cnki.1002-851x.201603099

Jin Fengcheng.（2018）. *"R&D of the BIM-Based Material Management System for Construction Enterprises."*J, Civil engineering information technology,10（1），79-81. http://10.16670/j.cnki.cn11－5823/tu.2018.01.14

DING Ling-hua.(2018). *"The Use of BIM, AR and other Aupporting Technologies in the Construction Machinery Automation."*J, Value Engineering,149-150. http://10.14018/j.cnki.cn13-1085/n.2018.12.062

Zhu Feng.(2018). *"Construction of BIM+VR/AR Engineering Construction and Management System."*J, Architectural Design Management,2018(6),87-89. http://10.3969/j.issn.1673-1093.2018.06.020

CAO Yang，SU Zhenmin and JIN Shaojun.(2018). *"Establishment of an Safety Management System on Construction Based on BIM and AR."* Jou Rnal of Wut(Info Rmation & Management Engineering),40(6),601-603. http://10.3963/j.issn.2095－3852.2018.06.002

Zhao, D., A. P. McCoy, T. Bulbul, C. Fiori and P. Nikkhoo. (2015). *"Build-ing colla borative construction skills through BIM-integrated learningenvironment."* J. Constr, Ed uc,11(2): 97-120. https://doi.org/10.1080/15578771.2014.986251

Uhm, M., G. Lee, and B. Jeon. (2017). *"An analysis of BIM jobs and com-petencies based on the use of terms in the industry."* J,Autom, Constr. 67-98. https://doi.org/10.1016/j.autcon.2017.06.002

Davies, R. and C. Harty. (2013). *"Measurement and exploration of individ-ual beliefs about the consequences of building information modellinguse."* J,Constr Manage,31(11), 1110-1127. https://doi.org/10.1080/01446193.2013.848994

Eadie, R., M. Browne, H. Odeyinka, C. McKeown and S. McNiff. (2013).*"BIM imple mentation throughout the UK construction project lifecycle:An analysis." J,*Autom Con str,145–151.https://doi.org/10.1016/j.autcon.2013.09.001

A. Dey, M. Billinghurst, R.W. Lindeman and J.E. Swan II.(2016). *"Systematic review of usability studies in Augmented Reality between 2005 and 2015, Mixed and Augmented Reality (ISMAR-Adjunct)."* C,IEEE International Symposium, 49–50.http://dx.doi.org/10.1109/ISMAR-Adjunct.2016.0036

A. Fazli, S. Fathi, M.H. Enferadi, M.Fazli and B. Fathi.(2014). *"Appraising effectiveness of building information management in project management."* J,Procedia Technol,1116-1125. http://dx.doi.org/10.1016/j.protcy.2014.10.126

R. Volk, J. Stengel, and F. Schultmann,.(2014). *"Building information modeling for exi sting buildings - literature review and future needs."J,*Autom,Constr,109–127.http://dx.doi.org/10.1016/j.autcon.2013.10.023