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Research paper

BIM-based integrated delivery technologies for intelligent MEP management in the operation and maintenance phase

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ABSTRACT

Incomplete building information in delivery and the lack of compatible tools for Operation and Maintenance (O&M) have hindered the development of the intelligent management of Mechanical, Electrical and Plumbing (MEP) systems. In fact, the information related to the O&M management of the MEP system conventionally comes from the completion documents in the forms of hard copies or unstructured digital files, making it hard to search for useful information in the "sea" of documents and drawings. Therefore, digitalization of information is an urgent task to facilitate the intelligent management of the MEP system. As a project deliverable, the as-built information model shall not only contain geometrical information and necessary construction-related data, but also built-in information useful for the intelligent O&M management. In the present study, based on the Building Information Modeling/Model (BIM) technology, a set of solutions including the automatic establishment of the logic chain for MEP systems, an equipment grouping and labeling scheme and an algorithm to transform BIM information to GIS map model, is proposed to digitalize and integrate the MEP-related information into the as-built model. Subsequently, a cross-platform O&M management system is developed using the MEP-related information in the as-built model to run routine O&M tasks and to effectively response to MEP-related emergencies. The developed system is applied to aid the O&M management of MEP engineering in a real project, showing that the developed system facilitates the intelligent O&M management and guarantees the security of the MEP system and its subsystems.

1. Introduction

In buildings, the Mechanical, Electrical and Plumbing (MEP) system provides services to people's daily needs, and hence plays a critical role in creating a comfortable and safe environment for building occupants. MEP engineering is a general term referring to the management of non-structural functions of a building. It consists of management of plumbing, Heating, Ventilation and Air-Conditioning (HVAC), electricity, energy conservation and elevator maintenance, etc. In fact, MEP engineering concerns the lifecycle of any MEP subsystem, including the design, construction, operation and maintenance (O&M) of the MEP system and its subsystems.

The O&M phase takes most of the time, resulting in the highest cost among various phases within the lifecycle of a building. In fact, previous studies [1] indicated that, the cost associated with the O&M could take up to 60% of the total project cost. In addition, it is shown in a National Institute of Standards and Technology (NIST) report [2] that American building industry wastes around 15.8 billion USD every year, and approximately 10.6 billion USD of the waste occurs in the O&M phase. As a main target of the O&M management, improving the efficiency of the MEP system is critical for the success of a construction project. In fact, the cost associated with the MEP engineering can be up to 50% of the total investment in some large-sized public projects [3]. The popular O&M management software, however, usually comprises only modules pertaining to financial management, data management, customer service, warehouse management, engineering equipment, office management, and procurement management, lacking a dedicated component focusing on the MEP system. Such a deficiency pronounces when an emergency occurred in the MEP system, the useful information about a specific equipment can only be found manually from the bulk of the project completion documents (in the form of either electronic files or hardcopy documents). The low

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efficiency of manual search may lead tremendous losses of properties and even life causalities in the worst case.

One of the reasons lying behind the low level of intelligence in managing the MEP system in the O&M phase is that the MEP management does not fully utilize new techniques emerged along with the development of information technology, such as the Building Information Modeling/Model (BIM) technology. For example, incomplete building information in delivery and the lack of tools dedicated to the O&M management of MEP engineering are the two reasons explaining the delay in the development of the intelligent O&M management of MEP engineering. Consequently, the digitalization of the MEP-related information and the development of an intelligent system to manage the MEP system in the O&M phase are not only the direction to improve the O&M management but also an important task in the lifecycle management of a building.

Significant progresses have been made regarding the BIM technology in the past decade. As a trend, BIM has gain common acceptance in the community. The reason why BIM has grown so quickly is that it benefits participants in the lifecycle of a building, i.e. in the processes of planning [4], design [5,6], construction [7,8] and O&M [9–11]. The BIM technology, when applying to integrate MEP-related information in the delivery and to aid the management, is a viable way to improve the intelligence level of the O&M management. However, the delivered as-built model always tends to be difficult for O&M personnel to directly utilize because it lacks some key MEP-related information, such as the logical relationships among MEP components. To provide better support in the creation and delivery of the as-built model with these key information, the paper proposes a set of solutions including an approach to automatically build the logic chain, a mechanism of identifying and grouping equipment, and an algorithm to generate the GIS map based on the building information available during delivery.

The rest of the paper is organized as follows. A literature review concerning both the BIM technology and the O&M management of the MEP system is presented in Section 2. Afterwards, three key techniques for applying the BIM technology to integrate the MEP-related information into the as-built model for delivery are discussed thoroughly in Section 3. Then, a set of solutions to implement an intelligent O&M management system, which is based on the web-service technique to achieve platform-independency, is suggested in Section 4. In Section 5, a description of the developed BIM-based intelligent facility management system (BIM-FIM) and its application to the real project is presented. Conclusion remarks are presented in Section 6.

2. Literature review

Recently, the BIM technology keeps its pace going forwards in the aspects of standards, tools and applications. The studies concerning the application of the BIM technology in the O&M management, on the other hand, are still relatively rare [12]. The related literatures are reviewed from two aspects: BIM applications in the O&M management and particularly in the management of the MEP system.

2.1. Applications of BIM in O&M management

A surveying of 125 facility managers shows that the majority of them considered that the application of the BIM technology would reduce the information search time, and three-dimensional (3D) visualizations are useful in the property management [13]. Unclear adaption procedures and large investments, on the other hand, are the concerns preventing the widespread of the BIM technology in the O&M management. For instance, although transmitting MEP-related information created in the design and construction phase into the O&M phase would ultimately improve the management efficiency, it certainly changes the conventional procedures to apply the BIM technology in building management due to the additional MEP-related information. To this end, scholars have shown their concerns in the integration of additional information in the as-built model for the use in the O&M phase. For example, Yu et al. [14] created a set of facilities management classes, which was essentially an embryonic formation of information description standards for the O&M management. Hassanain et al. [15] extended the Industry Foundation Classes (IFC) to enable relevant information, such as requirements for specific equipment to properly function, running status of an MEP subsystem and inspection routines of air ventilation tunnels, be integrated into the IFC. El-Ammari [16] studied the IFC-based property management model, which was built through sharing the design and construction information generated based on the IFC standard via the eXtensible Markup Language (XML) within the O&M management. Wang et al. [17] created the IFC-based building property management information model via combining equipment monitoring information with property management system using middleware technology. In addition, the National Institute of Building Science (NIBS) of United States instituted Construction Operation Building Information Exchange (COBie) [18], which standardizes the final information that created in design and construction phase to be transmit to the O&M phase.

Besides inheriting the information created in the design and construction phase, the information pertaining exclusively to the O&M phase, such as the repair, maintenance and running status information of particular equipment, should also be integrated in the BIM for the O&M management. In this field, Liu et al. [19] proposed an approach using SensorML standards to describe characteristics of sensors. In addition, IFC standards were employed to describe physical information of sensors. The standardized information can then be used to support decision-making for facility managers. Supplementing to the IFC standards, Lucas et al. [20] explored an object-oriented O&M management model and looked into the data structure needed in the O&M management process. In addition, Motawa et al. [21] developed a Revit-based BIM knowledge system, acquiring the operation information at the decoration and fit-out phases to facilitate the O&M management. Orr et al. [22] developed an intelligent property management system. Lin et al. [23] devised an indoor path planning method, which used the IFC data as inputs to provide geometrical and non-geometrical expanded semantic information, supporting the indoor path planning. Kang and Choi [24] developed a database based on the BIM metadata to connect external facility management (FM) with the BIM data by analyzing the practice of FM. Kang et al. [25] proposed a software architecture for the effective integration of BIM into a geographic information system (GIS) -based FM system.

Open BIM standards and data specifications such as IFC and COBie have been accepted as data sources and information exchange formats by several countries and organizations in the project delivery and the O&M phases [26,27]. According to the roadmap proposed by the BIM Task Group [28] for the implementation of BIM in the UK [29], fully collaborative BIM Level 2 (with all project information, documentation, and data in an electronic format) has been basically achieved for all public projects [30]. Particularly, COBie was adopted as information exchange schema by the UK Government for BIM Level 2 [31–33]. In the USA, COBie was also selected to be an important element in the National BIM Standard (NBIMS) [34,35]. ISO, on the other hand, proposed the standard ISO 15686-4 for service life planning information using the IFC4 standard and the COBie data specification [30,36]. Some researches and case studies were conducted to assess these stan-