A Data and Knowledge Management System for Intelligent Buildings

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Abstract: This paper describes a novel prototype of lifecycle information management and knowledge utilization of intelligent buildings. There is a comprehensive summary of the types of information and knowledge of intelligent buildings in their lifecycles based on literature review and professional experience. With the prototype, it originally introduces the concept of lifecycle information management and knowledge utilization of intelligent buildings. The lifecycle of intelligent buildings is divided into three main stages: design, construction, and utilization. The concept is then developed to an integrated model for web-based information supply and sharing, and some key points of the construction of an information platform and a knowledge system portal are discussed. It is expected that the integrated model can not only effectively support the information management and knowledge utilization of intelligent buildings, but also supply necessary data to digital cities.

Key words: Intelligent building; Assessment; Methodology; Information system

1. INTRODUCTION

It is the development and application of modern technologies in the areas of information, communication, materials, and machinery in the construction industry that facilitate intelligent buildings (IBs) emerging and growing into fashion with high efficient devices and systems. The IB is an organic integration of evolving architectural system, structural system, and facilities system of buildings. According to our literature review [12], key technologies that support IBs include sustainable architecture, building structure control, building facility control, computer and network, information and communication, safety and security control, multimedia application, and structured cabling and comprehensive electrical system, etc., which involve many subjects such as architecture, structure, construction, mechanization, computer and network, information and communication, and electrification, etc.

Accompanying the development of these modern technologies, the information management of IBs has been being paid high attention to. Turk [19] put forward the concept of life-cycle information system for IBs, and made an information model for IBs which can be used for information management at four stages of IBs including planning, design, construction and utilization. In the middle of the 1990s, the Lawrence Berkeley National Laboratory, operated by the University of California for the U.S. Department of Energy, put forward the conception of life-cycle information management system for building performance assurance [9]. However, this concept hasn't been put into practice to follow up the fast development of information and communication technology. As mentioned by Boyd [3] IBs aim to provide the most efficient utilization for occupants by means of using the most effective lifecycle resource management of buildings, most research into IBs info management have focused on how to enhance levels of informationlization and automation at the utilization stage of buildings [17], and how to manage information at separated life-cycle stages of IBs [8,13,14]. For example, the Building Information System developed by the New York City Department of Buildings can only provide limited information [11]. Based on an extensive literature, there is still no research into an integrated life-cycle information management of IBs. It is the authors' initiative to put forward an integrated methodology for lifecycle information management and knowledge utilization of IBs. The methodology will be described by using a novel prototype based on a comprehensive summary of IB information (IB info). The lifecycle of intelligent buildings is divided into three main stages, including design, construction, and utilization. The concept could be further developed into an integrated model for web-based information supply and share. It is expected that the integrated model can not only effectively support the information management and knowledge utilization of intelligent buildings, but also supply necessary data to a digital cities.

2. AN INTEGRATED PROTOTYPE

The relevant information of intelligent buildings, hereafter refers to IB info, include all data and knowledge that can be collected from various stages of IBs such as design, construction, operation, and deconstruction etc. during their lifespan. Generally speaking, IB info is separately managed by various sectors in the construction industry. For example, architects may possess design information of IBs, contractors may maintain construction information of IBs, while facilities managers may hold operation information of IBs. In fact, it may take much effort to retrieve useful information for specified purposes such as IB assessment from various sources if there is not an information pervasive platform to effectively and efficiently coordinate different ways of data or knowledge acquisition and reuse. In this regard, the concept of an integrated *IB Data and Knowledge Management Platform* (IBIMP) is presented in Figure1.

There are two purposes for introducing the IBIMP (see Figure 1). First of all, this model provides a conceptual design or an architectural plan for information management of IBs. In the meanwhile, it regulates the process of IB assessment by using various approaches including the Analytic Network Process (ANP) approach [15], the Artificial Neural Network (ANN) approach [6], the Knowledge-based Information Visualization (KIV) approach [18], and commonly used building rating approaches, etc. As a result, all information relating to IBs can be shared on an IB data and knowledge management platform supported by an IB database and an IB knowledgebase which are ultimately sustained by information acquired by knowledge workers from IB data and knowledge providers or users whose daily work focus on IB design, construction, operation or study etc.

The IB assessment requires detailed tools to facilitate its process. As mentioned above, there are four IB assessment approaches including ANP approach, ANN approach, KIV approach, and rating approach (see Figure 1). Details about these tools are introduced below:

2.1 Rating Approach

The rating approach, generally called building rating method, relies on a series of factors/indicators related to the design and the performance issues together with their defined scales to rate IBs. Based on literature review, there are about six rating approaches specially designed for IB assessment, including

- AIIB method [1] developed by the Asian Institute of Intelligent Buildings (AIIB), Hong Kong, China,
- BRE method [2] developed by the Building Research Establishment Ltd., UK,
- CABA method [4] developed by the Continental Automated Building Association (CABA), Canada & USA,
- IBSK method [10] developed by the Intelligent Building Society of Korea (IBSK), Korea,
- SCC method [16] developed by the Shanghai Construction Council (SCC), China, and
- TIBA method [20] developed by the Architecture and Building Research Institute, Ministry of the Interior, Taiwan, China.

Among these six IB assessment methods, there are six commonly used assessment clusters of indicators centring on Architecture, Engineering, Environment, Economics, Management, or Sociology. It has been further identified that the AIIB method, i.e. IB Index method [1] is the most comprehensive one that covers all of the six assessment clusters, and the SCC method [16] is mostly focused on the one assessment cluster, i.e. Engineering. The CABA method [4] aims to benchmark the IB assessment in a more general way but is still under construction. And the BRE method, i.e. MATOOL [2] and the IBSK method [10] have less coverage of assessment clusters than the IB Index. Therefore, the AIIB method is currently the most comprehensive method for IB assessment. Other proposed IB assessment approaches, i.e. the ANP approach [15], the ANN approach [6], and the KIV approach [18] will adopt indicators from IB index.

2.2 ANP Approach

The ANP approach will employ a multi-criteria decision-making model for IB assessment in their lifespan. The decision-making model called IBAssessor is developed using an ANP method [15] and a set of key performance indicators of IBs selected by a novel quantitative approach called Energy-Time consumption Index [21]. As mentioned above, the authors make use of previous research achievements including the Asian IB index, and a number of relevant publications in order to improve the quality of decision-making. Practitioners can use the IBAssessor ANP model at different stages of an IB lifespan for either engineering or management. oriented IB assessments. Case studies to demonstrate how to use IBAssessor ANP model to solve real-world design tasks will be conducted in other papers.

2.3 ANN Approach

The ANN approach will employ a novel prototype of intelligent decision support system for IB assessment. The prototype is called Tactical Intelligent Building Evaluation and Renovation (TIBER) model, which is developed to integrate an ANN process [6] with the IBAssessor ANP model in order to facilitate the adoptions of ANP approach in IB assessment. The ANN model will adopt the same group of key performance indicators adopted by the ANP model, and will be trained by using assessment results from ANP approach. Based on this agreement, the ANN approach can actually facilitate the application of ANP approach, which is too complex to be used by practitioners directly, but assessment results are more convinced than rating approach due to its consideration of interrelations among each two indicators.

2.4 KIV Approach

The KIV approach will employ a KIV [18] toolkit to facilitate the implementation of rating approach such as the Asian Intelligent Building Index [1]. A spreadsheet and a knowledgebase of IBs will be developed to support the KIV process in IB assessment. The spreadsheet use Microsoft Excel with its figure function to visually show status of an IB with respect to each of ten modules adopted by the IB index including Green Index module, Space Index module, Comfort Index module, Working Efficiency Index module, Culture Index module, High-tech Image Index module, Safety and Structure Index module, Management Practice and Security Index module, Cost Effectiveness Index module, and Health & Sanitation Index module. The spreadsheet aims to establish correlations within an IB with regard to each of these ten modules based on its scores measured by the IB index [1]. To further support cased based knowledge acquisition and reuse about IBs, all IB nodes on the spreadsheet will be linked to relevant cases inside an IB knowledgebase.

Interrelations among these IB assessment approaches can be summarized as followings:

- The ANP approach will use ETI to select a group key performance indicators from all indicators adopted by the IB index;
- The ANN approach will use the same group of key performance indicators adopted by the ANP model, and will be trained by using results from ANP approach;

The KIV approach will use ten modules adopted by the IB index as ten measurement dimensions for IB assessment. Hyperlinks will be set up to link each IB node on the diagram of ten dimensions to an IB knowledgebase, where results from either ANP approach or ANN approach will be verified.

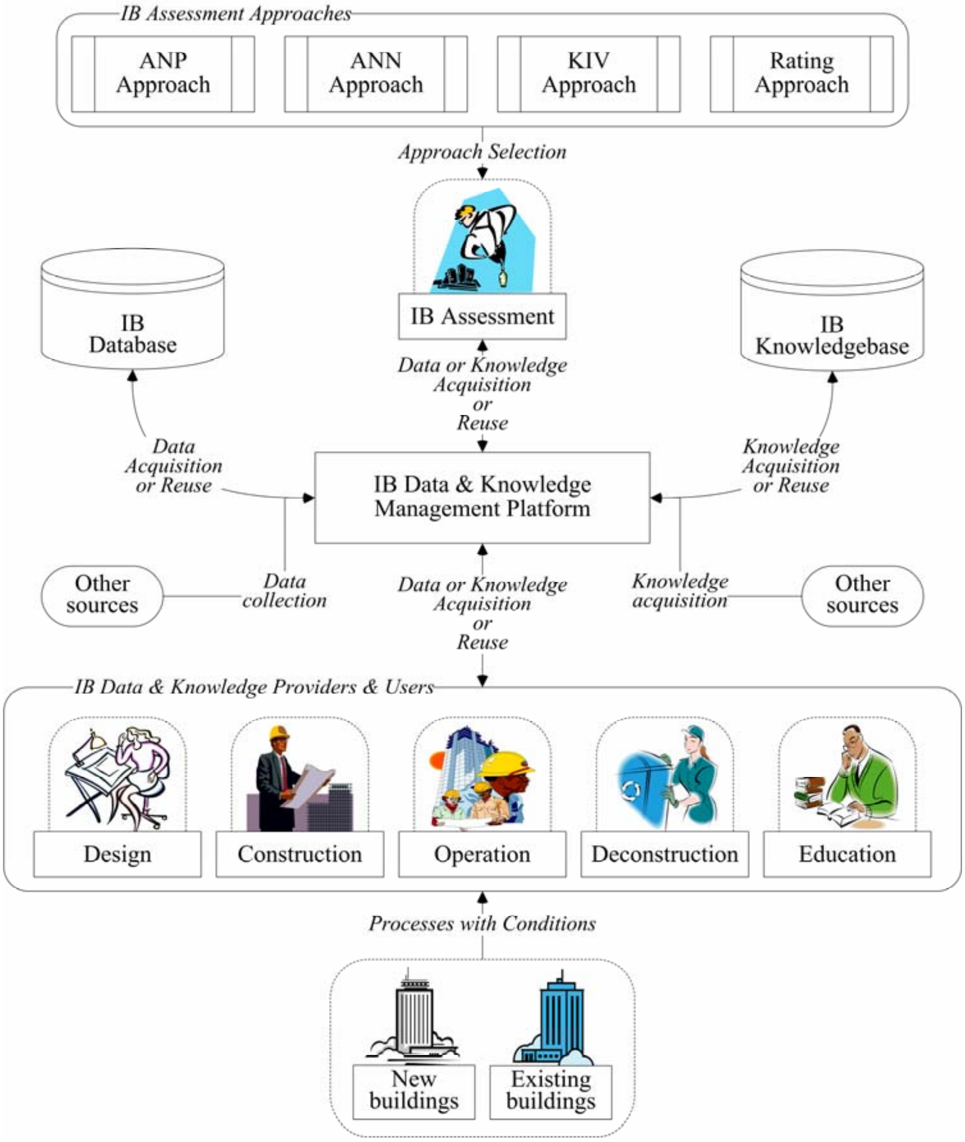

Fig.1 The prototype of knowledge-driven assessment for IBs

3. The Relevant Information of IBs

As mentioned above, IB info including all relevant data and knowledge of IBs are generally separately managed by various sectors in the construction industry. It will take much effort to collect enough information for IB assessment regarding many indicators adopted by various assessment approaches. In addition, relevant information required in IB assessment are generally in different ways of representations, and this will take much effort as well to regulate information with an uniform format for further use in IB assessment. The adoption of IBIMP (see Figure 1) will definitely streamline the process of IB info acquisition and reuse in IB assessment as well as IB info share across various sectors in the construction industry. Further to these particular applications, the platform also has its potentials to provide reliable information to digital platforms for city management and urban development. Therefore, it is necessary to make a classification standard of IB info to facilitate the process of IB info acquisition and reuse in IB assessment. According to the variety of information yield and reuse, IB info can be divided into the following three main types, including design information, construction information, and utilization information etc.

3.1 Design Information

The design information of IBs comprises all sorts of information based on various design documents such as design contracts, blueprints, CAD files, and instruction booklet of designs, etc. which are yielded during the design stage of IBs but can be potentially useful and reusable in other building designs and building studies.

3.2 Construction Information

The construction information of IBs comprises all sorts of information based on various construction documentations such as construction contracts, official documents, bidding documents, assurance contracts, loan agreements, briefings of management team, sub-contracting teams and labour teams, construction diary or minutes, blueprints and CAD files with alterations for new construction, order forms or bills of materials and equipments for construction, instruction booklets of processes, materials or equipments, and bills of resource consumptions during building construction, etc. which are yielded during the construction stage of IBs but can be potentially useful and reusable in other building construction and building studies.

3.3 Utilization Information

The utilization information of IBs comprises all sorts of information based on various property management documentations such as property management contracts, official documents, bidding documents, assurance contracts, loan agreements, briefings of property management team, sub-contracting teams and labor teams, property management diary or minutes, blueprints and CAD files with alterations for renovations, order forms or bills of materials and equipments for building renovation, instruction booklets of processes, materials or equipments, and bills of resource consumptions during building utilization, etc. which are yielded during the property management stage of IBs but can be potentially useful and reusable in other building property management and building studies.

3.4 Information Acquisition and Sharing

The information acquisition aims to collect data or knowledge from each life-cycle stage of IBs. The IBIMP (see Figure 1) will be used as an open information platform by system users including Building Designers, Construction Contractors, Property Managers, Recyclers or Manufacturers, and Educators, etc. when they have new data or knowledge to share with the community or their peers. Meanwhile, system administrators will also undertake maintenance work at both system level and content level, which means that the IBIMP will be operated by the system administrators who have sound knowledge and techniques about IT system maintenance and IB info acquisition and storage. Generally speaking, the IBIMP will lead all potential participants from each life-cycle stage of IBs to release and to share relevant data and knowledge via Internet; and the process of information acquisition will follow an established agreement between parties regarding their right levels in online information acquisition and sharing. Users of this system are not only information providers but also information retrievers. For example, a Building Designer may use the platform to describe his design about an IB; in the mean time, he or she may want to know more to improve a building design based on data and knowledge from other Building Designers, Construction Contractors, Property Managers, or even Educators. In this regard, the IBIMP will definitely provide effective, efficient and economical support. In fact, the function of information acquisition and sharing from the IBIMP can provide huge potential for us to manage IB information.

4. CONCLUSIONS

This paper presents a novel prototype of life-cycle information management of IBs. The research has been conducted based on an extensive literature review and solid professional experience of authors. The usefulness of this model and standard format of information has been discussed. This model can be further used in system analysis and development of a web-based IB Data and Knowledge Management Platform (IBIMP), and to support effective IB assessment.

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