SMART BUILDING INFORMATION MODELLING: THE USE OF ANN-COBIE FOR HVAC INFORMATION CAPTURE AND EXCHANGED

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ABSTRACT

Building Information Modelling (BIM) has implications for all processes and activities related to construction supply chain and can, thus, make significant contributions to lean construction process. It can be argued that BIM, as a design-centric technology with emphasis on sharing and collaboration, can be the ultimate solution to multiple challenges on today's construction sites by improving and coordinating construction supply chain. The existing dimensions of BIM not only attend to most aspects of the construction work and processes, but the technology also has the potential to add further dimensions responding to other existing or future challenges. Most stakeholders with different BIM definitions endorse the centrality of design and the use of BIM as currently appropriate design technology, but it also needs to be recognized that all these processes and applications can work efficiently and effectively in construction with regard to many other dimensions of work by reducing design errors and by better information management, thus controlling cost, delays, and damages. The buildingSMART Alliance is developing an open standard approach to integrating facility management handover using the COBie spreadsheet to BIM. When the graphical model is used to perform energy analysis, two of the most common formats are IFC1 and gbXML. This paper will look into ways in which Artificial Neural Network (ANN)-COBie can help architects and engineers to perform HVAC analysis with the support of a BIM platform. Other applications e.g. HVAC load analysis and life-cycle cost analysis for any system or component associated with a building may be conducted using the ANN-COBie system that can be stored in the BIM authoring application and exported using IFC or gbXML to any analytic software. These applications' associated future challenges will be briefly discussed.

Keywords: Building Information Modelling (BIM), COBie, HVAC.

1. INTRODUCTION

In construction, there is a prevalence of the application of BIM (Building Information Modelling) in the processes and activities that which contribute to a better output of lean production within construction projects, but there is still little emphasis on its application during the operation and maintenance stages. This paper proposes to discuss how the use of BIM can capture and knowledge through the provision of a new information capture and visualisation tools for design, operation and maintenance stages in construction. In order to investigate this, a review of numerous literatures spanning multi-sectors has been undertaken by the authors. This paper addresses the issues of uses of knowledge during design, operation and maintenance stages, and COBie's application at those stages and the limitations during its applications. Finally, this paper introduces the concept of ANN-COBie and its form of visualization, through which its use can facilitate a better HVAC information management. This is mainly regarding the generation, capture, use and retrieval of BIM information, as well making optimized decision with provision of reliable, accurate information throughout design.

2. BIM AND DESIGN INFORMATION CAPTURE AND EXCHANGE

The UK Government's Office of Government and Commerce (OGC) stressed the importance of provision of "firm information", with its as part of a well- prepared brief that is as the basis of the subsequent project actions, resulting in a significant influence to the results of the outputs of these actions; i.e. production information, tendering, Construction Work. In the BSI BIM Strategy Report-BIM Task Group 2011, it is emphasized a non-prescriptive design while the "timely information" must be made available during its creation, exchanging and transferring within BIM's implementation to enable correct decisions to be made. The design decision made by the exploitable "timely information", as a key driver, can help improvement of the building performance, in terms of two variables identified: Whole Life Cost and Carbon Performance. This is important, as by the provision of this information, and as a more effective and transparent design decision making process that can take place by removing the needs of making assumptions, which mostly produce uncertainties and additional risks for the project during and after the design stage (BSI, 2011).

BIM (Building Information Modelling) is changing the way buildings are designed and constructed; in other words, this technique is changing the way buildings are operated and maintained. BIM is intended to be "*a breakthrough in individual and industry transformation that embraces and facilitates innovation, integration and collaboration*". *Our challenge is to integrate a collaborative innovation culture* (Tang, 2012). BIM in construction is *a" set of information (a digital model of a building) that is structured in such a way that the data can be stored and shared. It can be 3D, 4D (integrating time) or even 5D (including cost) – right up to 'nD', which is a term that covers any other information"* (Nisbet and Dinesen, 2010), or "*is an extension of the BIM that incorporates multi-aspects of design information required at each stage of the lifecycle of a building facility*" (Lee et al, 2005). Lip service is paid to information management, yet the cost of managing this complex structured information, or using it incorrectly, is extremely high. In addition, complex information management tools are available, yet they make a fundamental assumption that the right information is freely available e.g. Asite, Aconex, BIW, CLEVER, KnowBiz (Bowden et al., 2006).

The proposed Information Maturity Evaluation Assessment Tool (IMEAT) is an information evaluation assessment tool, based on a number of information attributes, was firstly developed with the use of Bayesian Network Theory (BNT) and conditional probability statistical data (Zhao et al., 2008). This assessment system impacts on existing practice from different stakeholders' perspectives (designers, engineers and information managers) on determination of high value information so that the maintenance cost of archiving large amount of information can be decreased in both sectors. An in-depth comparison between leading engineering and construction companies was undertaken to understand the issues and challenges of information evaluation in these two sectors (Tang et al., 2010).

In particular BIM acts as the design information for different stakeholders along the construction supply chain to support sustainable design decisions for the life time of a built asset. This has extended the work and responsibilities as well as influence of the designers, requiring greater communication and higher collaboration among different actors and key stakeholders (e.g. owners, surveyors, constructors engineers and facilities managers) for achieving desired outcomes, which are cost-effective and efficient, and at the same time, meeting other project requirements such as, time, quality, environment, logistics, buildability and safety (Dwyer et al., 2013). As mentioned previously, the generation of informed decisions at every individual stage is critical for the success of a construction project. The generation of informed decisions for design and energy analysis cannot be done without a good understanding and management of uncertainties existing at each stage of a project lifecycle. The concept of information maturity was developed by Zou and Tang (2011) with the purpose to satisfy this need. This concept highly promotes co-operative design and design collaboration at conceptual design stage, and is greatly functional on this basis and on the ground of application of modern digital design and energy analysis tool such as BIM.

The collaboration and communication between designer and client is central towards ensuring that the distinct interests of both parties are met and that successful project outcomes and client satisfaction are achieved. In various studies carried out in the early 1990's (Kaya 2004), researchers criticized the lack of thoughtful consideration in regards to the requirements of end users. Kaya (2004) suggests that little has improved since the early 1990's and highlights the communications gap that still exists. Figure 2 demonstrates the communication gap between user clients, paying clients and designers. The gap between the designer and user client often leads to a lack of occupancy consideration (ibid).

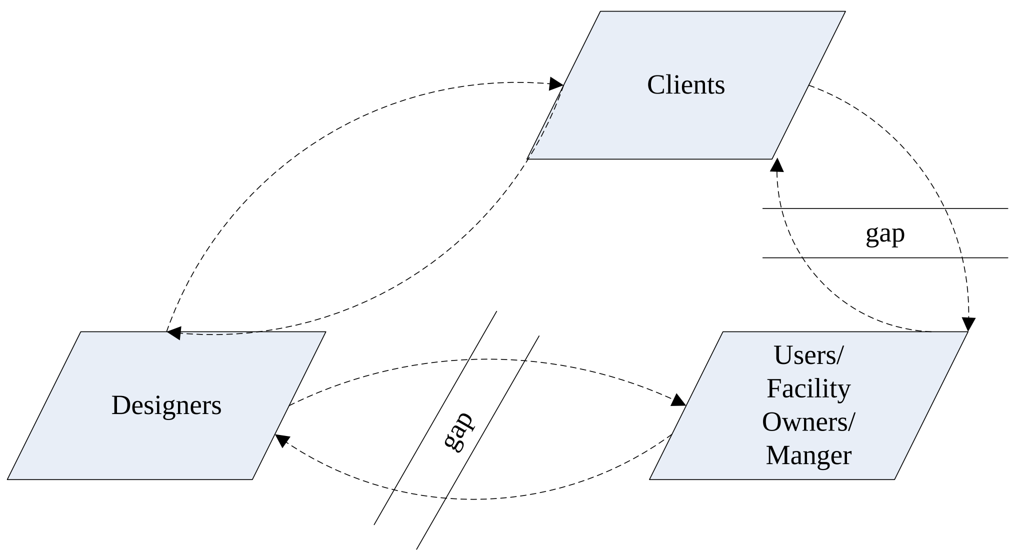

Figure 1: The Communication gap between designers, clients and users

Moreover, development of the communication of mature information on the basis of this inspires the project participants to contribute to the project design at concept stage; and particular, it takes value on the end-users' needs and the contribution of e.g. HVAC engineers' expertise and knowledge. It is an approach distinct from the traditional approach, high interactively interactivity between multiple participants and working on the same platform using the same lens to look at a project. With addressing this, it supports effective information exchange for collaborative design, it is beneficial to the design and the stages after, such as the construction and the operation and maintenance stage.

3. CONSTRUCTION OPERATIONS BUILDING INFORMATION EXCHANGE (COBIE)

Recently, the official version of the Industry Foundation Class (IFC) is the IFC4 covering eight domain areas. Initially we investigated IFC2×3 final version then updated some changes according to IFC4 release (ISO 10303-11, 2004). IFC was developed by building SMART and is a common data 'schema' intended for holding interdisciplinary information for building lifecycle in a building information model, and exchanging it among software applications used in AEC (BuildingSMART UK 2010). A schema, often called 'Product (Data) Model', is captured in IFC specification, and composed of (1) entities or classes, (2) attributes, and (3) relationships between entities. Schema defines the way by which population of these entities and relationships needs to be represented. Building information model may be also called 'populated data model' or 'project data model', and constitutes a population of a schema. The model follows the patterns, templates and any constraints defined by the schema and contains the actual instances of the entities (BuildingSMART UK, 2010).

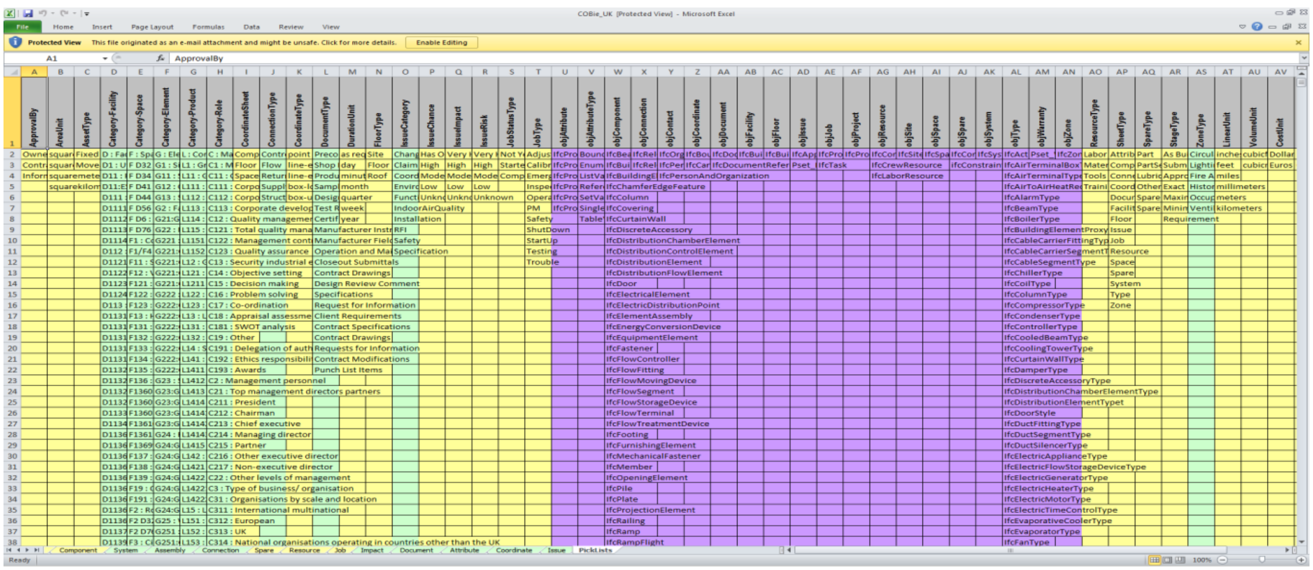

Figure 2: A sample COBie worksheet (being provided by AEC3 UK Ltd.)

COBie stands for 'Construction Operations Building Information Exchange'. Figure 2 shows a sample COBie worksheet. The COBie approach is *"to enter the data as it is created during design, construction, and commissioning. Designers provide floor, space, and equipment layouts. Contractors provide make, model, and serial numbers of installed equipment. Much of the data provided by contractors comes directly from product manufacturers who can also participate in COBie"* (East 2007). The functions of BIM also support capturing and transferring facility information from design and construction stages to operation and maintenance stages. Currently, some commercial building management systems have been developed, such as COBie, which allows facility information to be transferred automatically from BIM system to other Computerised Maintenance and Management Systems (CMMS) or Computer Aided Facility Management Systems (CAFMS). Basically, COBie creates a platform for architects, engineers, contractors and manufacturers to input data with a computer interpretable format at the early stage of a building lifecycle when it is established. By these means, information users who are applying the same data down stream do not need to recollect or recreate the necessary facility management information (East, 2007).

Furthermore, COBie supports facility information export from BIM, such as maintenance plan and system instructions with a spreadsheet format, and then importing to other computerised systems, like CMMS or CAFMS (East et al., 2009). Through the application of COBie during operation and maintenance stages, it mitigates necessity of recapturing, recreating the facility information by architects, engineers and contractors, it minimises the needs of converting information formats for diverse information users (Gallaher et al., 2004). As a result, it creates the potential for huge savings during design, operation and maintenance stages.

4. AUTOMATICALLY INPUTTING GEOMETRY, OPERATION AND COST DATA TO BIM IN BUILDING DESIGN STAGE

Heating ventilation and air conditioning (HVAC) system responds for both pursuing high quality living and working environment and at the same time, addressing the issue of sustainability. HVAC systems are the most energy consuming building services representing approximately half of the final energy use in the building sector and between one tenth and one fifth of the energy consumption in developed countries (Pérez-Lombard et al., 2008). Design of HVAC system is therefore an important part of building design.

Design of HVAC system involves large amount data of geometry, operation and cost of the system (Haines and Myers, 2012). These data are useful for installing a HVAC system in the building, analyzing the cooling/heating load of building and predicting the cost for the installation and maintenance of the system. In the design stage, the most critical consideration is to optimize HVAC system so that it is able not only to achieve thermal comfortable environment in the building but also to minimize the cost. However, inputting large quantities of HVAC system data to BIM always consumes BIM-users' energy and time. Besides, if using manpower, the optimization will be even more difficult because the energy consumptions of all HVAC systems which meets the requirements of cooling/heating load need to be compared and the lowest one will be picked out. In the optimization process, the geometric data of the HVAC system should be also regarded to avoid any conflict in the design, especially in the determination of system and pipeline network location.

Automatically inputting data of HVAC system to BIM in the design stage can reduce time usage and energy consumption. The program proposed in the paper contains a component for inputting data of HVAC system to BIM and also the optimization of the HVAC system so as to minimize the cost. An indicative flowchart, as shown in Figure 3, demonstrates the process of running the program. Firstly, based on the building envelope data and the climate condition data, the cooling/heating load for a building will be predicted. Secondly, HVAC systems which can meet the requirement of cooling/heating load will be selected and their geometry, operation and cost data will be induced to an excel workbook of BIM, such as COBie2xml (Building SMART, 2013). Thirdly, cost and geometry data of the HVAC systems in COBie2xml will be compared to find out the best for not only cost reduction but also installation analysis avoiding the conflict in design.

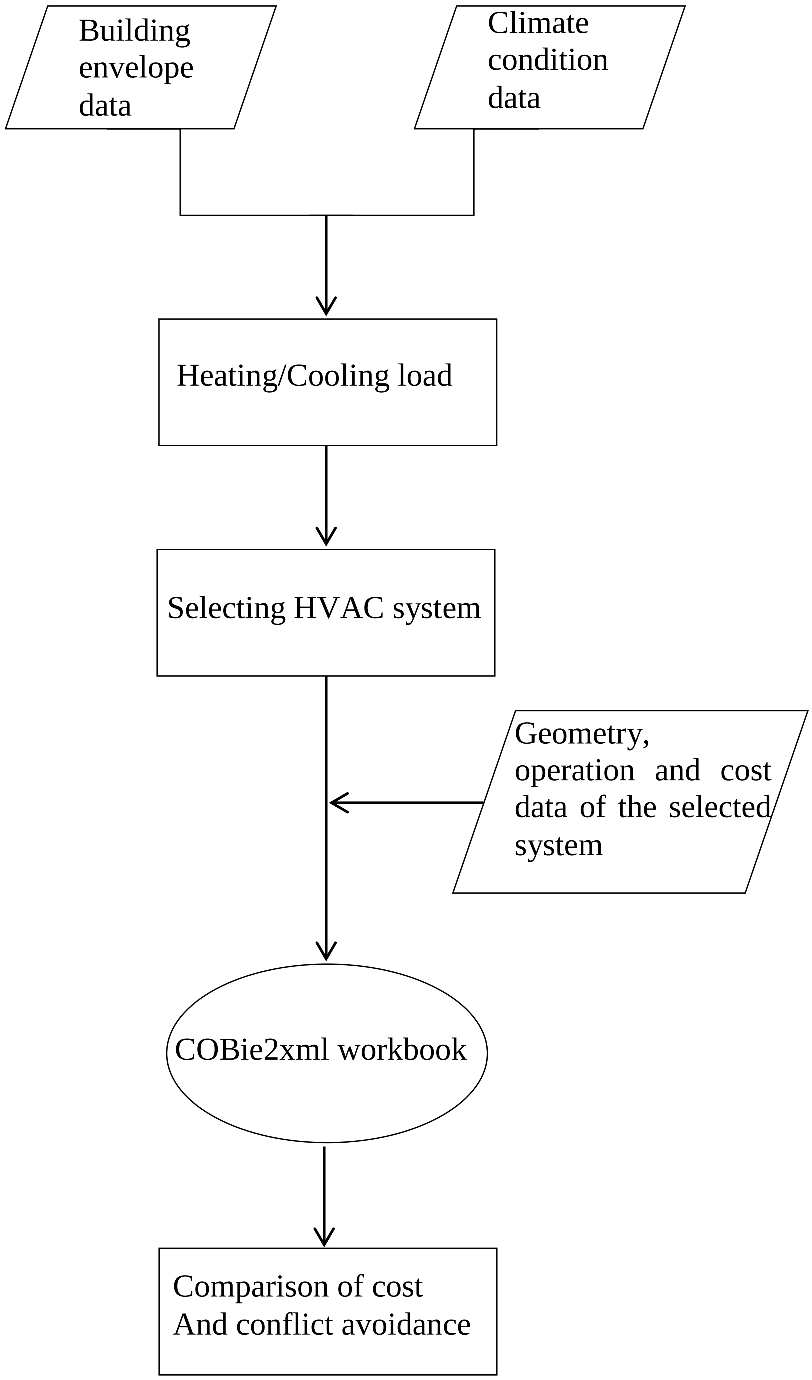

Figure 3: Flowchart of running the program

5. AUTOMATICALLY CONTROLLING THE PERFORMANCE OF HVAC SYSTEM

When HVAC system is being used, saving its energy consumption is always a major concern. There have been extensive publications to develop control strategies for maintaining HVAC system operating energy-efficiently and achieving thermal comfort as well (Mahdavi and Kumar, 2010). Yet, function of controlling performance of HVAC system has not been included in BIM. Control of the performance of HVAC system involves collection, monitoring, analysis and feedback of large amounts of data, which can be fit into BIM. An approach for HVAC system control in BIM is developed in this paper. In order to fulfill the control, the operating data such as supply/return air temperature and relative humidity (RH), etc, should be firstly collected and monitored by sensors. The second step is analysis of these data which will be conducted by using an artificial neural network (ANN) model.

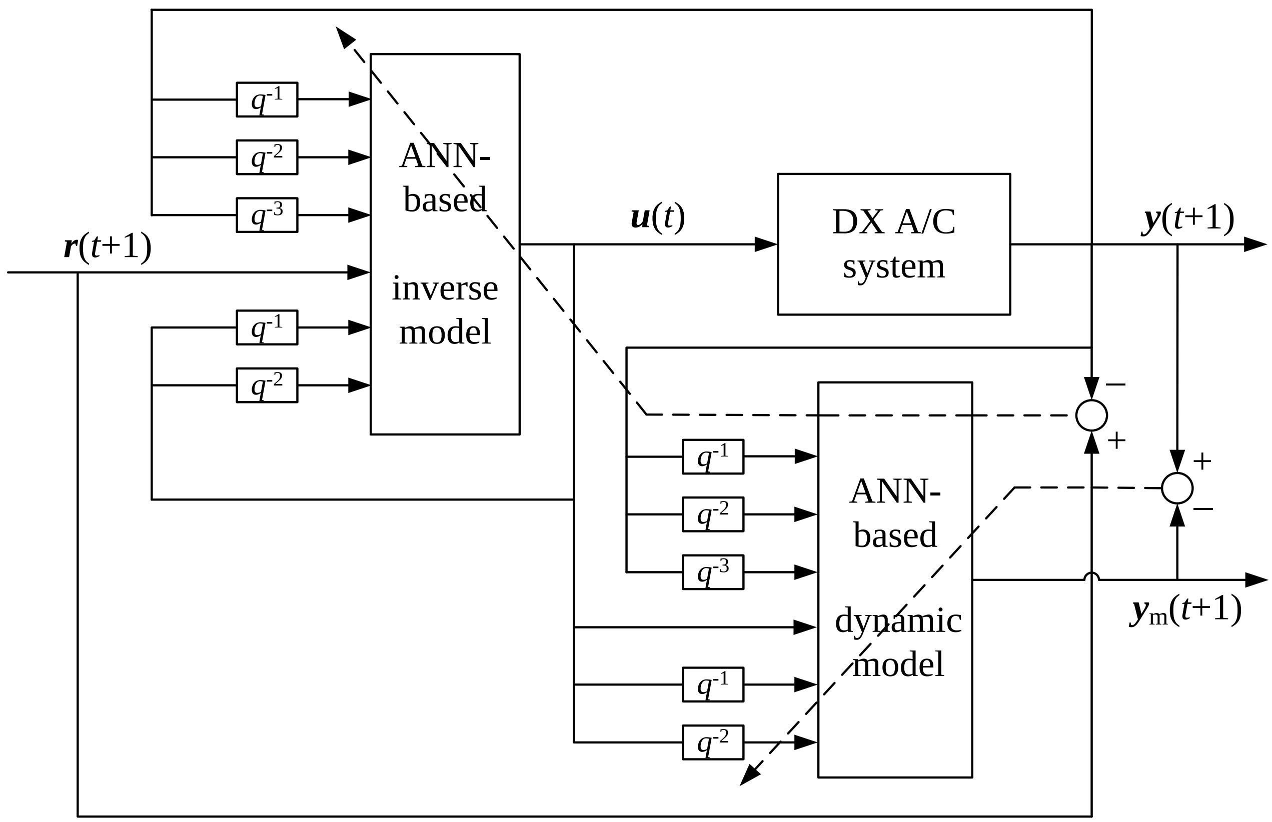

Figure 4: Controller composed of the ANN model and reverse ANN model for a DX A/C system (Li et al., 2013)

ANN in particular appears to be the most popular data-driven modelling method (Kim et al., 2010). ANN is a computing tool made up of a specific number of highly interconnected processing elements, or neurons, and can be used to model a wide range of complex and non-linear systems (Mujtaba and Hussain 2001). Unlike a physical-based model, an ANN-based model only uses experimental data to identify the input-output relationships and, thus, is always simpler than the conventional approaches used in establishing physical-based models. Therefore, the use of ANN for modelling a system should be preferred when the physical processes [to be modelled] are complicated (Norgaard et al., 2000; Yang, 2008).

It should be mentioned that the ANN model should be self-adaptive ANN model so that it can analyze operating data with the performance of HVAC system changes. A controller which is consist of the ANN model and a corresponding reverse ANN model which adjusts the performance of HVAC system is to be developed and therefore the feedback step is finalized. Both the ANN and reverse ANN will be trained by using Back Progress (BP) algorithm (Li et al., 2013).The controller composed of the ANN model and reverse ANN model, which should be similar as the one developed for controlling a direct expansion (DX) A/C system, as shown in Figure 4 (Li et al., 2013).

To realize the control strategy in BIM, all the measured data by sensors will be automatically transferred to and recorded in BIM. If needed to be analyzed by ANN model, the recorded data shall be delivered from BIM to ANN model. The adjustment as results from ANN model based controller will be also recorded in BIM and simultaneously used to control the operation of HVAC system. As a result of controller implementation, variation of performance data of the HVAC system will be also transferred to and recorded in BIM. As a result, the controlling performance of HVAC system is realized in BIM through this process and it should be mentioned the entire process would be completed automatically.

The design and control of HVAC system automatically by using BIM makes BIM more powerful and saves a great energy and time of BIM users. The data collected in BIM can also be shared by different users and at different times. As a result BIM data for existing building can be used to design guidance and the control of HVAC system for new building for the purpose of energy and cost savings.

6. CONCLUDING REMARKS

Because of its advantage in large data collecting, processing and sharing, BIM has attracted more and more attentions in building design. However, designing a HVAC system, which is the largest energy consumer among all the building service facilities is not sophisticatedly operated in BIM. This paper has proposed a method on automatically collecting, processing and sharing: geometry, operation and cost data of HVAC system design using the BIM platform. Using this method, the design of HVAC system should be optimized for cost minimisation. A flowchart is developed and presented to indicate the procedure of applying the method.

In this paper, an approach of modelling and controlling the performance of HVAC system in BIM is also reported. Following the approach, modelling and control the performance of HVAC system can be automatically conducted on BIM platform. It can be expected that the automatic data processing in designing, modelling and controlling HVAC systems using BIM should make these data be more useful in improving the building design and transferring the knowledge gained in current building design project to future ones.

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