DEVELOPMENT OF BUILDING INFORMATION MANAGEMENT SYSTEM USING BIM TOWARD STRATEGIC BUILDING OPERATION AND MAINTENANCE

YUKI NAKAMA¹, YASUNOBU ONISHI² and KAZUHISA IKI³
¹,²,³Kumamoto University, Kumamoto, JAPAN
¹nakama@tech.eng.kumamoto-u.ac.jp
²,³{onishi,iki}@arch.kumamoto-u.ac.jp

Abstract. Facility management is aimed at energy saving, increasing the lifespan of buildings, enhancing the satisfaction of facility users and reducing running costs. To that end, it is important to grasp the conditions of the building in detail, and to analyze them one by one in order to execute building operation and maintenance strategically. However, conventional CAFM is insufficient. Therefore, we developed a system (called Building Information Management System) to utilize BIM data made in BIM-CAD on a Web site. We used groupware to support the system and an information platform that enables flexible management of a great variety of maintenance information. In addition, we developed an environmental measurement module and built a structure to sensor information automatically by using a development system. For quality maintenance, detailed information of building operation and maintenance is both from human input and sensors. The proposed method analysis of a building and provides the foundation for strategic control of maintenance.

Keywords: BIM, FM, Groupware, Web application, Sensor

1. Introduction

The purpose of building operation and maintenance is energy saving, increasing the lifespan of the building, enhancing the satisfaction of facility users and reducing the running costs of the building. This requires information of the facility to be collected and stored in one place (Saengratwatchara and Elsworth, 2008; Wyatt and Ralphs, 2003, pp.140-143). CAFM supports management and analysis by database construction of building op-
eration and maintenance. One type of CAFM automatically creates tables and charts using a database of building operation and maintenance in accordance with the intended operations and another type of CAFM promotes the intuitive understanding of the facility manager by connecting drawings and the 3D model made by CAD with the database of building operation and maintenance, and expresses maintenance visually in CAFM. However, CAFM is inadequate to support strategic maintenance.

2. CAFM has problems in building operation and maintenance

CAFM cannot support strategic maintenance due to the following problems:

- **Problem 1: Low frequency of updating information in CAFM** — The facility manager mainly performs the input work for CAFM. Therefore CAFM cannot reflect changes rapidly because the input of maintenance information is delayed. As the latest information is not immediately available, CAFM cannot be used continuously. However, we could raise the update frequency of the information and reduce the input burden of the person in charge of inputting building operation and maintenance information.

- **Problem 2: High running cost of CAFM** — CAFM is divided into “Solution service” and “Custom-made,” and each is sub-divided into using BIM or not using BIM. The details of each system are shown in Table 1. CAFM of the solution service has a much lower initial cost regardless of the possibility of using BIM compared to custom-made CAFM because the solution service is a building service based on the format of the development of the vendor’s CAFM. The functions that the CAFM vendor provides do not meet all the facility manager’s demands for building operation and maintenance (e.g., the formats of the report vary according to the company.). On the other hand, custom-made fully demonstrates the capability of the CAFM to meet all the demands of the facility manager. On the other hand, custom-made fully demonstrates the capability of the CAFM to meet all the demands of the facility manager. However, the development of CAFM not using BIM requires A: construction of a database of the whole building; or B: the figure of CAD and cooperation with 3D model data; this makes it costly and time consuming for IT specialists to operate all the development processes even just to make small changes. Therefore, we aimed to reduce the work process of B, by introducing BIM.

- **Problem 3: Strategic building operation and maintenance requires collection of a large amount of information** — The maintenance information is obtained by patrolling and checking and then inputting information to the CAFM, both of which tasks are labour intensive. It is preferable to collect the
great variety of information automatically and to reflect it in CAFM immediately for strategic building operation and maintenance.

Table 1. Classification of CAFM.

<table>
<thead>
<tr>
<th>Solution service</th>
<th>Using BIM</th>
<th>Not using BIM</th>
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<tbody>
<tr>
<td>Custom-made system</td>
<td>EcoDomus FM • PM (Teicholz, 2013a, pp.203-204), ARCHIBUS, etc.</td>
<td>Maintenance connection, FM:System-IWMS (Teicholz, 2013b, pp.7-8), etc.</td>
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</table>

3. Solution

We will aim at utilizing big data that covers all information of the building for building operation and maintenance. Analysis of this big data should enable preventive maintenance of the building and optimization of the running costs of the building. To that end, grasping as much detailed information as possible on the state of the building is the first step toward strategic building operation and maintenance. Therefore we attempted to solve the problems in Solutions A — D shown below.

- **Solution A: Web system for groupware** — In order to use CAFM for strategic building operation and maintenance it is important to enable the input of information from the perspectives of all persons concerned with the buildings including the facility manager, building owner and the construction company. Therefore we developed the CAFM Web system as "groupware". The utilization of groupware also reduces the burden on the administrator of facilities compared to when using conventional CAFM, and sharing of input maintenance information can increase the quality of building operation and maintenance (Fig. 1).

- **Solution B: Development of CAFM using BIM** — Attribute information is related to the material object of a 3D model in BIM, and it can function at the same time as the database in the building makes the 3D model (Eastman et al, 2008, pp.70). This should reduce the running costs of CAFM. Our proposed system builds a database that integrates operative information with maintenance information using BIM. 3D models can be linked to the system and it works on a Web site on which attribute information can be browsed and edited.

- **Solution C: Labor-saving of the entry work and diversification** — We developed a low-cost facility sensor module that uses a sensor network to easily perform automatic input of information to the Web system developed in this study, which makes the system relatively cheap to operate. In addition, we aim at diversification of the maintenance information by obtaining infor-
mation from sensors that cannot be grasped by checking and patrolling. Furthermore, it is possible for the facilities maintainer, building residents and the construction company to input information from their respective viewpoints, and the maintenance manager can analyze the data using 3D modelling to show information visually and activate maintenance by group work (Fig. 1).

- **Solution D: Support in making automatic reports** — We developed a function for automatically making reports in the format in which we process building information input according to the building operation and maintenance depending on the purpose of the work and the format requirements of facility owners and facility managers. In this study, a general-purpose report is made, which can be expanded to a variety of reports and formats by programming.

We developed a Web system (called the building information management system) that integrates maintenance duties using BIM data in consideration of above-mentioned Solutions A D. In this study, strategic maintenance is assumed to be group work that all people concerned with the building perform as well as facility managers. Therefore the building information management system supports building operation and maintenance as groupware. We developed Solution E and Solution F to realize group work by the development system. In addition, as an example of the information collection method of a great variety of buildings, we measured the information of the building with a sensor and developed the sensor module, which inputs to the building information management system automatically.

- **Solution E: Access control function to information of building operation and maintenance** — Building operation and maintenance involves a great variety of main constituents. We input the maintenance information produced by each constituent into the development system appropriately and assumed group work in pursuance of maintenance while sharing the information between the people concerned. Therefore there is the need to limit browsing, inputting and editing of specific information depending on the main constituents concerned. Then, we developed a function that could set access re-
strictions to information of building operation and maintenance based on log-
in ID to the development system.

- **Solution F: Communication function between people concerned with building operation and maintenance work** — For function expansion as groupware, we developed a bulletin board function to enable communication with the text. This function is intended to record and to share “Notices” to indicate important aspects of the work, although we do not record it as official information of building operation and maintenance. This feature points to the specific object of the 3D model used as the object of building operation and maintenance, and the display state of the camera settings and other objects is recordable together with a message. When a message is chosen from a list which equals time series, smooth communication can reproduce camera setting and the indication situation of the 3D model, and can understand the message.

In this study, we developed a building operation and maintenance information system that gathers the great variety of maintenance information and can correspond to the work of building operation and maintenance flexibly. The wide range of challenges is shown in Fig. 2. The scenario was applied in this developed system which operated by different actor, described as follows; we assumed that a maintenance administrator in the building using this system mainly for the operation and maintenance information sharing work. First, the developed system share information of several buildings and check it from another place. Second, the information was shared used as sharing information within groups in a network which two or more maintenance administrators have stand by (such as in a large-scale building). Third, we assumed that a facility manager suggests to the maintenance administrator and the building owner, based on the strategic planning of the building operation and maintenance, which they have to plan an analysis function that designed for the future maintenance. At last, we assume that the users of the building have read and understand about the building operation information system (such as utilizing status of the room and indoor environment guidelines) and then apply the communication tools to remark they level of satisfaction improvement.

![Development roadmap of strategic building operation and maintenance](image)

*Figure 2. Positioning of the study*
4. Development of Building Information Management System

4.1. OUTLINE AND FEATURES OF SYSTEM

We show the interface of Building Information Management system and explain the function of A-F as described in chapter 3 at Fig. 4. In this study, we developed a simple environmental sensor module as an example of the sensor apparatus aiming at labor saving of the entry work and diversification of the kind of information. A similar system includes BEMS, a study on efficient pay back technique is done because introduction cost is high (Choiniere and Corsi, 2003; MOD, 2001). In recent years, measurement devices equipped with various sensors that can send data by wireless networks have become cheap and readily available because the development environment of open source hardware such as Arduino has been maintained (Kumar, Hiremath and Rakhee, 2012). We developed a simple environmental sensor module to control the temperature/humidity sensor: illuminance sensor and CO2 sensor by using Arduino measuring data, which is transmitted by Zigbee communication (Fig. 3).

4.2. THE DATA FLOW OF THE SYSTEM

The development system enables the handling of attribute information of building operation and maintenance made from BIM data by BIM-CAD, and also stores new building operation and maintenance information that has been entered or edited on the development system for each object of BIM data as attribute information. In the case of the enlargement of a building and renovation involving changes to the building shape itself, input and repair work of the system is reduced.

Figure 5 shows the technical framework of the constitution or data flow of the database of the development system. First, in the case of an existing building, a model for exclusive use of the maintenance in Revit can be made.
When designing a new building in Revit, the model of maintenance duties is based on a design model (Figure 5A). Next, the setting and the attribute information (called “Shared parameters” in Revit) of the attribute information item needed for the building operation and maintenance work is input by using Revit. The "attribute information database" (Access) is exported using DBLink and uploaded to the system server. Furthermore, exporting the 3D model file of a DWF form from BIM data can be uploaded similarly (Figure 5B). After that, data on building operation and maintenance work is input from the Web (Figure 5C). In the system, a 3D model is loaded through Design Review by the Web browser of the client, and it is displayed as 3D model synchronizing with attribute information on the screen. In the Web server, the "attribute information database" and "system database" cooperate with the 3D model by using the inherent ID number (called object ID) of each object of the 3D model and are realized by the interface shown in Fig. 4 (Figure 5D). The attribute information in BIM data can be updated when construction with the change of the building shape occurs while attribute information for BIM data can be imported from an attribute information database using DBLink, whilst changing the 3D model (Figure 5E). After the change, the opening sentence of the attribute information database is performed using DBLink and the opening sentence of the 3D model in the DWF forms again and is uploaded to the system server, and the new information is available in the reflected system (Figure 5F).

Furthermore, we developed a simple sensor module that cooperates with the building information management system, and promotes intuitive understanding. The sensor module of the slave measures it every time and the data relays to the master module in conjunction with the sensor ID allotted to each, and is recorded in the sensor database (Figure 5G). In addition, the building information management system enables the effective range of the value of the sensor to be modelled. The sensor beforehand using BIMCAD and set the setting of the sensor ID and the sensor measurement item and the sensor ID corresponding to the sensor model of 3D more in the attribute information item. In this way, coordination becomes possible with the “Sensor ID” attribute information database of the sensor database and architecture information management system having a common value. Accordingly, the movement that the sensor data and 3D model interlock in the development system of the 3D model and attribute information interlock can be materialized (Figure 5H).

4.3. OPERATION EVALUATION OF THE SYSTEM

The Web browser is ASP system and the loading speed of 3D model indication would become the main point of inspection. We measured the time
needed before it displayed by a Web browser to develop a system while changing the scale of 3D model (Fig. 6). As the result, we found that, exponentially, boot-time increases as number of objects increases. For example it takes time of about 10 seconds at 6000 objects. From the practical use side, noticed that it’s important to reduce the number of objects because it necessary.

<table>
<thead>
<tr>
<th>Model Navigation</th>
<th>Facility Information</th>
<th>Registration View List</th>
<th>System Menu</th>
<th>Communication List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in the camera setting of the 3D model and changes in the indication state of the material (semi transparency, non-indication).</td>
<td>Information about the whole institution is displayed. It corresponds to the project information on BIM-CAD.</td>
<td>A system user can register the view setting (camera setting + material indication setting) of the 3D model to use in work frequently. When the title of the view is selected the registration view is reproduced.</td>
<td>There are link buttons from material attribute information indication (initial state) for searching attribute information, a report page and system setting.</td>
<td>The view of the 3D model to supplement it is connected with comments and can enroll in a list of communication. Click the title view of the 3D model when the registration comment is displayed to register and reproduce the comment.</td>
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<tr>
<th>List of member attribute information</th>
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<tr>
<td>It displays the material information that corresponded to the search condition by a list every single element. In addition, an attribute information item arbitrary as a key on the list line up, and can input a substitute and attribute information by a lump.</td>
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<tr>
<th>Component attribute information</th>
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<td>When the department material of the 3D model is selected, the department material attribute information is displayed and is list. Inputting and editing is enabled. Also, it is displayed directly into the listing, when the picture file was able to associate.</td>
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<tr>
<th>Search of attribute information</th>
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<tr>
<td>Input search conditions according to the menu. Then, choose the indication method of the material which is non-targeted for a material targeted for a search, a search (indication, emphasis, semi transparency, non-indication). After a search, the result is reflected by 3D model indication screen.</td>
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<tr>
<th>Visual representation of the sensor data</th>
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<td>The sensor data relates sensor data to a 3D model as well as the expression of the graph and expresses the analysis visually.</td>
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</table>

Figure 4. Introduction of interface with building information management system
5. Conclusion

We proposed a system for managing all building information flexibly and developed a building information management system that supports report making. In addition, we developed techniques for inputting maintenance information from a sensor into the development system automatically. The system enables acquisition and management of the information necessary for strategic building operation and maintenance. We utilized accumulated information in the development system to predict the future of the building and aim to accomplish building
operation and maintenance strategically in future. Therefore, we
developed an analysis algorithm to analyze the accumulated in-
formation into a development system, and to grasp the features of
the building. In addition, the control of the building equipment
can reflect the features of the building automatically, and the de-
velopment of artificial intelligence that can indicate the state of
the building to the building user is our aim.

Acknowledgements

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Endnotes

1. Revit plug is by Autodesk Company, and attribute information can be exported/imported from the Revit file in
MS Access.
2. The attribute information database is a relational database which includes the attribute information of the mate-
rial object. Object ID is assigned to all material objects. This material ID is common with the 3D model object
ID corresponding to each material object.
3. The system database is a relational database that saves the setting information enabling the systems to be used
efficiently. The information that the user preserves except for attribute information is controlled with this en-
tire database. PostgreSQL is used as the database management system.

References

Saengratwatchara, S.; Elsworth, D.J.: 2008, Antecedents of Intention to Adopt the Web-Based
Computer Aided Facility Management System, Family and Consumer Sciences Research
Journal Volume 36, 350-357.
Teicholz, P.: 2013a, BIM for facility managers, John Wiley & Sons, U.S.
Teicholz, E.: 2013b, Technology for facility managers, John Wiley & Sons, U.S.
"Web page without author info": 2014, "The #1 Solution for Real Estate, Infrastructure, and
Facilities Management in the World". Available from: ARCHIBUS website
Information Modeling for Owners, Managers, Designers, Engineers, and Contractors,
John Wiley & Sons, U.S.
Choiniere, D.; Corsi, M.: 2003, A BEMS-ASSISTED COMMISSIONING TOOL TO IM-
PROVE THE ENERGY PERFORMANCE OF HVAC SYSTEMS, Proceedings of the Third
International Conference for Enhanced Building Operations, Berkeley, California. ESL-IC-
03-10-09.
MOD; 2001, Building Energy Management Systems, Ministry of Defence: Defence Es-
tates Design and Maintenance Guide 22, U.K.
Kumar, S.; Hiremath, V.; Rakhee, K.: 2012, Smart Sensor Network System based on ZigBee
Technology to Monitor Grain Depot, International Journal of Computer Applica-
tions 50(21):32-36.