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A Review of the Data Collection and Management Technologies for the Operational Stage of Facilities

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Abstract

Buildings are considered to have an ongoing life if thought together with the human-beings living/ working in. Buildings pass through several maintenance and operation activities during the life cycle of any facility. Several types of information technology tools are used in the operational stage of facilities. For example, the activities are directed by facilities managers and the results are registered with Computer Aided Facilities Management (CAFM) programs. CAFM programs store data in specialized file formats or databases. However, in order to use and manage all kinds of data that appear through the life cycle of a building project, the concept of Building Information Models (BIM) which depends on intelligent object has begun to be used. Therefore, it has become possible to share all kind of building related data from shared building models.

Embedded technologies are another technology to facilitate the building management process. With these technologies it has become possible to collect real-time data from the operation field and to record the maintenance - operation data of several service equipments. These data are written to the intelligent chips locally and sometimes a remote database is populated. If Building Information Models could be populated with the real time maintenance data captured by embedded systems it would be possible to attain an architectural component based (e.g. space, room, etc.) operations and performance monitoring platform.

This research project explains the initial thoughts on integrating various technologic tools that are used in the operational stage of buildings. Field data collection and management techniques e.g. Computer Aided Facilities Management (CAFM), Building Information Models (BIM) and Radio Frequency Identification (RFID) are reviewed and advantages / disadvantages of each system has been given shortly. Later, initial guidelines for a proposed IT system have been given in order to improve the presented drawbacks. Data, collected via embedded systems will be integrated with Building Information Models which would lead to an operation / maintenance platform. This platform will be used to monitor the performance of building services and building components.

Keywords

Building Information Models, Computer Aided Facilities Management (CAFM), Maintenance and Operation, Radio Frequency Identification (RFID)

1. Introduction

It has been well known that building and asset management is an important stage in construction project life cycle. Building management could be defined as the total management principles applied in order to manage the assets and the services of a constructed facility. According to the *International Facility*

Management Association (IFMA, 2008) this stage integrates work power, processes and technology in order to make various disciplines continue their operations effectively. Some of these principles are applied in order to make the building service elements (e.g. HVAC system) function well. Some others on the other hand, are related to the processes (e.g. cleaning). As a result of all of these activities, the service management contractors could be questioned about their performances.

In recent years we have seen a progress in the technology in order to support the building and asset management stages. There are tools to help the technical people who are on the operational field. Embedded systems such as barcode or Radio Frequency Identification (RFID), Personal Digital Assistant (PDA) help the people who are working in the field. On the other hand, Computer Aided Facilities Management (CAFM) tools help to record the history of the facility for the management staff at company headquarters. Usually the CAFM tools are recording the data in connection with two dimensional CAD files.

As could be seen more explicitly in the following sections, all of these tools facilitate the job of workers and managers. However, there is no effective integration between the operational field and management headquarters in order to manage the data more effectively and without any flaws. If field data collected by the embedded systems could populate the Building Information Model (BIM) at the same time, there would be a model dependent IT tool that could help managers make complex performance queries.

This paper aims to provide a review of the field automation technologies designed for the operations stage. Main advantages and disadvantages of these technologies will be presented and later generic guidelines of an IT system will be explained to improve the current situation.

2. Tools to Facilitate Building and Asset Management Stages

Information and communication technologies have been facilitating the building and asset management stages for a couple of decades. This paper examines these technologies in three main categories:

- Computer aided facilities management (CAFM) programs
- Building information models (BIM)
- Technologies that facilitate data collect at the operation stage

2.1 Computer Aided Facilities Management

Traditionally, data about building services have been recorded using CAD like computer programs. These computer programs are generally classified under the category of *Computer Aided Facilities Management (CAFM)* tools. These tools have appeared during 1980s in order to support the operation and management of the built environment. These programs are designed to manage the assets and data collected by these tools could later be queried and necessary interventions could be made. CAFM tools can monitor and record data related to the following points:

- Space / Asset Management
- Project Management
- Emergency Management
- Maintenance Management

CAFM programs have close relationship with the CAD programs; but they are generally integrated with databases. In fact, these programs act like an interface between the architectural drawings and a database and therefore data are recorded in connection to their places in storeys. For example, *FMDesktop* which

was bought by Autodesk in January 2006 works in connection with databases like Microsoft Access, SQL Server or Oracle.

The CAFM tools traditionally record two dimensional architectural drawings and record operations related data with this. One of the main disadvantages of CAFM tools are that they are not connected to the previous life cycle stages well enough. Model based -intelligent- information prepared in design and construction stages cannot be transferred into the operation stage well enough since there are not many CAFM tools that support the model based work processes and data.

2.2 Building Information Models

There has been lots of research projects carried out in the area of Building Information Models in the last decade. For example a recent project (Gallaher et al., 2004) carried out by the *National Institute of Standards and Technologies (NIST)* in 2004 has emphasized the necessity of BIM. According to this study, the inefficient communication between the computer programs in the USA cost the sector $15.4 billion. An important point identified in this research is that the building management and the operations stage undertake the 2/3 of this identified cost. This stage have been difficult to manage since routine activities like space usage reports, maintenance and operation of the service equipments are kept in computer programs that are not easily and intelligently communicating with each other. Therefore, CAFM programs need to be integrated with the previous life cycle stages intelligently in order to diminish this identified cost. BIM could play a vital role in this integration.

The CAFM tools have witnessed a fast progress since 1980s and their usage has increased considerably. However, the added value of these programs has been limited by some factors. Data produced in previous life cycle stages (design, construction, etc.) cannot be used by these programs in an intelligent way. One of the main reasons of this is that CAFM programs store data in proprietary file formats or databases. Secondly, the link between the building and the operations are done based on a two dimensional architectural plan. These plans are generally composed of simple lines as in first-generation CAD packages.

Many research projects have been carried out in order to enhance the explained problem and create a more integrated work between different life cycle stages. Neutral file formats such as Industry Foundation Classes is the main initiative created with the aim of enabling parties to communicate each other without losing data between life cycle stages.

Today many organizations are requesting that the data produced in the design and construction stages could be used in the operations stage as well. For example, the USA *General Services Administration (GSA), Public Buildings Service (PBS))* and *Office of Chief Architect (OCA)* have all started a national BIM program and decided to support innovative projects that use the concept of BIM. The new ICT tools -especially the BIM concept- offers new visualizations, coordination and simulation capabilities and therefore increases the satisfaction of the clients. Therefore, the GSA is proposing strategic importance to BIM and require BIM to be used in the projects.

2.3 Tools to Collect Data from the Field

Recent developments in the ICT field have made data collection for the operation stage possible. Building components could be tagged by the help of the *embedded systems* and data about them could be collected during the operation stage. These systems have been used in various sectors for a long time. Embedded technologies have been used to collect data from various locations of buildings. The operational data can be stored by these systems and accessed later. There are two main systems: Barcode and radio frequency identification systems (RFID).

Embedded systems can be used mainly in two of the important stages of construction project life cycle:

- The Use of the Embedded Technologies in Construction Management Stage
- The Use of the Embedded Technologies in Building Management Stage

The Use of the Embedded Technologies in Construction Management Stage

Recent studies have shown that this technology can be used in the construction management stage successfully. One of the main research projects was completed by Finch et al. (1996). They have examined the barcode technology and concluded that this would not be appropriate for the construction sites since it is not very durable for the exterior weather conditions.

Later efforts have concentrated in the RFID technology. In this technology the communication between a tag and a reader is carried out by radio waves. Today there are many varieties of the RFID technology according to the type of the tags, power supplies, operation frequencies and reading distance. Different from the barcode technology, the RFID technology is more resistant to weather conditions and most importantly usually there is no need to see the tag in order to read / write data.

The use of the RFID technology in the construction stage has generally been proposed in order to facilitate the material flow. In this respect, Jaselskis et al. (1995) produced one of the first research projects. In their paper, the authors provided a vision of the use of this new technology. They have also explained that the RFID technology could facilitate the material flow and provided an example in which the material carrying trucks could be automatically identified while they are entering from site gates.

Lake and Jaselskis (2000), Yabuki et al. (2002) and Goodrum et al. (2006) indicated that the RFID technology could potentially monitor tools, inventory and equipment. For example, Lake and Jaselskis (2000) have proposed the use of intelligent tags to monitor the stress levels of the steel building elements for future research projects. Jaselskis and El-Misalami (2003) have also proposed the use of this technology for material flow and later Song et al. (2006a) developed an IT system for this monitor process. According to Song the authors, their system has contributed project performance. Later Song et al. (2007) have proposed that RFID tagged materials could be monitored according to their proximity.

Wing (2006) proposed that material / personnel flow and inventory / equipment monitor could be carried out by this technology. Song et al. (2006b) suggested that prefabricated pipes could be better monitored and automated by this technology. His study indicated the advantages and disadvantages of the technology by some filed experiments. Finally, Ergen et al. (2007b) have done a similar study for the identification of prefabricated building components in factory filed. The authors have also integrated Global Positioning System (GPS) to identify tagged elements.

The Use of the Embedded Technologies in Building Management Stage

The main idea of using embedded technologies in the building management stage is to record the operational history of building / service elements into locally located RFID tags. There have been some research experiments and real life implementations of this idea. One of the earliest works has been carried out by Legner and Thiesse (2006). In this study, the authors explained how this technology is being used at the Frankfurt Airport. Frankfurt Airport is one of the busiest airports of Europe. As a result of this, the building complex requires complicated logistics, management and operation stages. For example, the correct operation of any fire fighting, ventilation, safety equipment is very important. Technical staff are required to control the equipment and building components regularly. They also need to prepare a report about what have been done and when. It is not very easy to manage this kind of complexity with traditional methods. Therefore, the managers of the building have decided to integrate building

components with RFID equipments and store the operation related information to locally located RFID tags. This approach has made the collection and the management of the field related data more efficient. The system was firstly applied for the fire extinguishers and facilitated the discovery of them at the airport. The operations and maintenance data was all recorded in digital environment. The advantages of the system are as follows:

- Easily identification of the service elements,
- Not centralized data storage,
- Planned recording system for the operation stage,
- Totally digitalized data storage,

Similar research projects have been carried out by Ergen et al (2007a, 2007c). In these studies, the authors proposed the use of the RFID tags in the operation stage and provided field experiments. The fire extinguishers were first tagged and it was experimented for 60 days whether these could be accessed. The results are successful enough. Sommerville and Craig (2005) have proposed to use this technology in order to organize the emergency escapes.

3. Evaluation of the Literature

The evaluation of the literature has shown that the technology now facilitates the life cycle of building operations and management. The CAD like computer programs, namely CAFM tools, record the operations data linked with the architectural plans. The data is generally stored in proprietary file formats or in Oracle, SQL, Access or Sybase databases. In most of the CAFM tools, the spaces to link FM data need to be digitally defined. For this, users are expected to draw poly lines around spaces. This is not an efficient way to link data into the CAFM tools. Some programs have automated this process but still extra effort is need to effectively use the programs in the FM process. The main reason of this is that the CAFM programs work in close connection with 2D CAD drawings. Therefore, it becomes very difficult to represent CAD entities in these programs since there is no data model to represent entities.

Another main critique is that these tools do not support the intelligent data transfer from earlier life cycle stages such as design or construction. As a result of this, there is now an intention to use BIM in connection with the CAFM tools. Some companies like Autodesk is trying to achieve the link between FMDesktop (CAFM package) and Revit (BIM package) by Drawing Web Format (dwf) files. This is also a temporary solution. It is therefore a need to successfully integrate the operational management data with the BIM model.

The field data collection technologies may help in this integration. The research projects presented in the previous section have demonstrated the use and the success of this technology in the various stages of the construction project life cycle. The use of the RFID technology in the construction stage has generally been proposed in order to facilitate the material / personnel flow and inventory / equipment monitor. For the building management stage researchers have tagged some of the service equipments (e.g. fire extinguishers) and monitored the history by the embedded systems. The RFID cards provide a local storage of the maintenance data. However, there is a need to back up the data on these cards in case there is a failure of the card. A Building Information Model or a database could be a modern solution to this. If data collected by the RFID tags could be integrated with the BIM, then managers at the company headquarters could have an IT platform which can be used for performance assessment in later stages.

4. Proposed System

The literature review presented above demonstrated the need to integrate different technologies used in the building management stage. The main result of the review is that there is a need to use the building information modeling approach for the operational stage more effectively. Therefore, this research aims to develop an IT system that will facilitate the operation and management stage of the built environment. In this project, it is aimed to transfer the data collected by the embedded systems from the field to Building Information Models. The system will firstly help technical people to record and search the history of the technical operations locally. This information will be recorded to RFID chips and be accesses by PDA type IT tools. Secondly, the managers at the company center will make complex performance queries based on Building Information Models. If RFID enabled field data collection could be integrated with BIM enabled operations management platform, it would be possible to provide data locally to the technicians who are working on site. This information would be about the operational history of the building components / equipments. It would also be possible to create an operations management platform for the managers who are working in company headquarters by querying the BIM database. These complex queries would reveal the performance of building elements. For example, it would be possible to make queries about which building elements or which building spaces provide problems more or it would be possible to understand the service history of building / building components.

The project will explore the following points to be researched:

- The operational data collected by embedded systems from the management stage will firstly be transferred to Building Information Model with this project. There is no research project that has created the link between these two concepts. The project will be innovative from this respect.
- The project will explore the performance concept which would be integrated in Building Information Models. This will be facilitated by creating a performance monitoring platform and querying the IFC models.

5. Conclusion

This paper has introduced a review of the technologies that facilitate the building operations management stage. Mainly the use of the CAFM tools, BIM and RFID systems in the operations stage has been explored and the advantages / disadvantages of each technology have been discussed. As one of the conclusions, the CAFM tools need to be integrated with intelligent information specifications. BIM will be a contemporary solution to it. On the other hand, there are field data collection facilities such as RFID cards. Embedded technologies are mostly used in the construction management field to track materials or equipment. For the operational stages, maintenance history could be recorded in these tags. If data recorded to the RFID tags could populate the BIM then it would be possible to create a performance monitoring platform for the managers who are working at company headquarters.

By developing this new IT platform, it would be possible to query Building Information Models and therefore take information about the performance of the building components – spaces. It would also be possible to make future performance estimations based on the facilities' history. The platform will be evaluated by field case studies and it will be explored how it contributes to the facilities management process. The future of this research project will include developing use cases, integration of embedded systems data to Building Information Models and developing an IT platform to query performance information.

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