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The challenges and potentials of utilizing building information modelling in facility management: the case of the Center for Properties and Facilities of the University of Helsinki

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Despite the promise of using building information modelling (BIM) during the whole life cycle of a building, there are only few studies of the actual uses of BIM and other information systems in facility management. We contribute to the discussion by analysing the Center for Properties and Facilities of the University of Helsinki. We ask (1) what kind of information tools for facility management the maintenance personnel use; (2) how the design data was handed over in the University's central library project; and (3) how designers and facility managers find the possibilities of integrating BIM models and maintenance information systems. In the library project, the data was handed over and archived for potential later use. The information for the maintenance manual, however, was collected separately by an outside consultant. The designers thought that models should be simplified to meet the needs of the maintenance. The representatives of the Center did not see that uses of BIM models would provide a significant added value in relation to the potential provided by the maintenance information systems already in use. They found as a possible next step the transfer of some information from BIM models to their facility management and maintenance systems. A partial, stepwise integration of the systems seems to be a realistic way forward.

Keywords: Building information modelling, facility management, integration, maintenance.

Introduction

The central goal for the development of a product model, and later building information modelling (BIM) in the 2000s, was that all the information of a building created during a design and construction process would be available during the whole life cycle of the building. For instance, a forerunner of building information modelling in Finland, the RATAS project, defined its goal in 1988 as follows (Enkovaara *et al.*, 1988, p. 15): 'The kernel of the RATAS systems is a product model for structuring all data on a specific building, for the use of design, production and maintenance.' This goal has included the promise that the owners and facility managers can use BIM as a tool for carrying out management operations more efficiently. BIM is also seen as a way of making it possible to share data between partners in the construction process (Succar, 2009). On the other hand, it is recognized that thus far, the industry has mainly used BIM in design and construction and that its use in facility management (FM) and operation is still in its infancy (Eastman *et al.*, 2011, p. 170).

It has been estimated that 85% of the life cycle costs of a facility occur after construction has been completed (Lewis *et al.*, 2010, p. 1). Moreover, approximately \$20 billion are annually lost in the US alone due to inadequate information access and interoperability issues during operation and maintenance phases (Newton, 2004). It is argued that the use of BIM in FM will significantly help to prevent these losses (Azhar *et al.*, 2012, p. 21). On the other hand, it has been

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argued that the construction industry will increasingly adopt business models based on integrated solutions and service-led projects that cover the whole life cycle of the building (Brady *et al.*, 2005; Leiringer *et al.*, 2009).

Paradoxically, however, it seems that owners and facility managers have not thus far been motivated to implement BIM, or invest in the creation of interoperability between design and construction models and maintenance software systems. An evident reason for this is that property owners and facility managers do not see sufficient benefits to be gained or positive return on investment of the BIM implementation (Kiviniemi, 2013). The BIM literature has reacted to this situation in three ways. First, it has been underlined that positive examples of the implementation have to be reported to enhance the implementation in FM and maintenance. Eastman *et al.* (2011) present two such cases in the *BIM Handbook*: Maryland General Hospital and a Coast Guard facility. In the Coast Guard facility planning case (Eastman *et al.*, 2011, p. 168) 'the team realized a 98 percent time savings by using building information models to populate and edit the facility management database'. Also other authors find the savings in the data handover in the establishment maintenance information systems as an argument for BIM implementation (Becerik-Gerber *et al.*, 2012). It can be doubted, however, whether the savings in the information handover are a sufficient reason to attract the interest of property owners in the implementation of BIM. Knowledge of more substantial and fundamental BIM-related benefits connected to the operation during the building life cycle may be needed for them to take the initiative.

The second approach dealing with the possible uses of BIM in FM and maintenance is to interview specialists and ask them to forecast what would be the forthcoming areas of BIM use in FM. This may be done by interviews, questionnaires and focus group discussions. This approach produces an expert view of possible or imagined uses of BIM. For example, Becerik-Gerber and her colleagues (2012, p. 434) found in their study 10 areas of application of BIM. The most frequently mentioned among them were: locating building components, maintaining real time data access, visualization and marketing, and checking maintainability. Arayici *et al.* (2012) found 18 possible benefits for BIM, including system maintenance and using BIM as an information source for managing and measuring maintenance work. Fox and Hietanen (2007) report in their study that two building owners had an idea of creating interphases based on as-built models that would allow janitors and cleaners to use the models. They add, however, 'Whether such views of the future prove to be technically feasible and economically viable remains to be seen' (Fox and Hietanen, 2007, p. 294). A recent review (Volk *et al.*, 2014, p. 122) concluded that owners, facility managers, deconstructers and related consultants are yet hardly involved in the BIM functionality development.

The third approach comprises attempts at defining the data structures, conceptual diagrams and technologies that would allow the integration of design and construction models with maintenance software systems (Vanlande *et al.*, 2008; Gu and London, 2010; Shen *et al.*, 2010). The suggested solutions by which to achieve this include defining the necessary information needed in FM models, creating BIM servers, and outlining FM object repositories, etc. These technologically oriented projects create technological conditions for the integration of the systems but do not as such provide an explanation of what motivates the maintenance management and personnel to implement BIM. Rapidly developing BIM technologies create challenges in interoperability (Volk *et al.*, 2014). Also, the difficulties of integration, such as unclear responsibilities in the creation of as-built models, issues in model ownership (Volk *et al.*, 2014), problems created by the variety of software used or insufficient supply of complementary tools in different phase of project, are mentioned.

The approaches described above all assume the point of view of extending BIM from design and construction to FM and maintenance. However, as a recent literary review shows (Volk *et al.*, 2014), the activities and needs of the owners and facility managers have not been extensively studied. Neither the uses nor the challenges of the FM software systems currently in use have been duly reported. We aim at contributing to the discussion by examining the development and uses of information and management tools used by the Center for Properties and Facilities of the University of Helsinki, which is in charge of over 700 000 m^2 of properties owned by the University of Helsinki. In addition, the Center constantly develops new University premises, for example in the extending campus of bio- and environmental sciences, as well as renovating and restoring old buildings.

In order to study the relationship between design modelling and the uses of maintenance software, we originally decided to follow a major project developed by the Center for Properties and Facilities of the University of Helsinki. The project was the construction of Kaisa Library, a new central library of Helsinki University (Figure 1). It turned out, however, that the modelling was mainly used in the preplanning of the building only, and modelling was not integrated into the maintenance information systems. We therefore shifted the focus of the study to the analysis of the maintenance information systems and to the stakeholders' views on the possibilities of integrating BIM

Figure 1 Main entrance and a view from entrance hall of Kaisa Library building (pictures Tuomas Uusheimo and Veikko Somerpuro)

with the prevailing maintenance information systems. The Center is rather a big facility owner and it has keenly followed the discussion on BIM implementation in Finland. We think that the knowledge on how the Center representatives view the conditions of the implementation of BIM reflects well the unripe transition phase in the extension of BIM into facility management and maintenance information systems. The aim of the paper is to provide knowledge on the practical conditions of the implementation of BIM in facility management and specifically to clarify the relationship between BIM and the existing facility management and maintenance information systems.

Theoretical framework, data, methods and analysis

Our theoretical framework for studying the activity and contribution of technology users is based on innovation and technology studies as well as design and cultural historical activity theory. One of the main findings of innovation studies is that in high technology the users (firms, professionals or consumers) constitute an increasingly important source of innovation (Kujala, 2003; von Hippel, 2005; Baldwin and von Hippel, 2011). Technology studies have shown that the technologies have developed by adopting the needs of specific user groups (Bijker *et al.*, 1987). In organizational studies it has been suggested that the future form of production will be co-configuration, in which constant development of a product or service as well as collaboration between users and clients play key roles (Victor and Boynton, 1998).

In analysing the user need and the conditions of implementation of BIM we rely on the concept activity system developed by cultural historical activity theory (Miettinen and Hasu, 2002; Engeström, 2007). The various elements of the user activity system, prevailing practices and information tools, usability of the new technology, division of labour, skills of the personnel and collaboration with service providers need to be considered. These diverse conditions will be taken up in the interviews of the designers, facility managers and maintenance persons. Activity theory underlines the systemic and historically changing relationship between mediational means or instrumentalities and the object and purpose of an activity. Following this concept, we pose two key questions: (1) Do the representatives of the Center find any such major changes or challenges in its activities that would require the implementation of BIM? (2) What added value and advantages do they see BIM would provide compared to the possibilities provided by the system of existing information tools?

Our three operational questions that guide the analysis are: (1) How is data from the design phase handed over and collected for maintenance? (2) What kind of information tools did the Center personnel use in the facility management and maintenance work? (3) How do the designers and representatives of facility management see the possibilities and challenges in utilizing BIM in maintenance and FM? The research questions and the related data are presented in Table 1.

We collected three types of data. First we interviewed the management, functionaries and maintainers of the Center for Properties and Facilities of the University of Helsinki as well as the designers that participated in the Kaisa Library project. The 11 interviewees can be grouped into three categories: (1) four representatives of the property management (property manager, property service manager, design archivist, and contact person of the library); (2) four designers involved in the Kaisa project (architect, HVAC engineer, BIM expert, HVAC design coordinator); (3) two representatives of operative maintenance (technical building manager, caretaker) and a coordinator of maintenance manual. The interviews covered four themes. First, the interviewees were asked to introduce and identify the information and management tools they use. Second, they were asked to describe the relationship between BIM used in design and the maintenance information systems. Third, they were asked to characterize the problems related to the relationship between the two sets of tools. Fourth, they were asked to foresee whether and how the integration of BIM and maintenance information systems could be achieved.

The interviews were transcribed. Thematic analysis (Braun and Clarke, 2006) was used in the analysis of the interviews. It soon turned out that many of the interviewees had difficulties in formulating well-founded opinions on the issues raised. For example, the representative of the end user did not have an opinion on information models that were unfamiliar to him. Also, the maintenance personnel's and designers' comments were limited by their particular position in the life cycle of the building. That is why a systematic analysis, labelling or comparison of the conceptions was not possible. For this reason, after reading carefully the transcripts we decided to present the analysis by explicating the points of view of the three groups separately and combine them in the introduction of the information tools they use.

In addition to the 11 interviews, we also used two interviews done during our previous study in BIM use. The first was an interview of a property manager of a life cycle project in schools and the second an interview of a software specialist who had been involved in developing the connection between BIM and maintenance tools as well as introducing the COBie standard in Finland.

As a second type of data, the interview data was complemented by the documents, demonstrations

Table 1 Research questions and data

Research questions	Interviews	Documents	Shadowing
1. How is data from the design phase of Kaisa Library handed over and collected for maintenance?	Coordinator of the maintenance manual	List of documents and information included in the maintenance manual, access to the maintenance manual	
2. What kinds of information tools do the Center personnel use in facility management and maintenance work?	Four representatives of the property management, four designers and two representatives of operative maintenance	Demonstrations of space management system, electronic archive, maintenance manual and building automation systems	Two-day shadowing of the caretaker
3. How do designers of Kaisa Library and the facility management see the possibilities and challenges in utilizing BIM in maintenance and FM?	Four designers, four representatives of the property management		

and access to the information tools the interviewees used. Interviewees showed (the researcher) how they use maintenance manuals, space management systems, building automation systems and design archive. The second type of data is used to give a broader idea of the contents of the tools or procedures of information acquisition.

Third, to gain a realistic view of the uses of the information tools and the possibilities of implementing BIM in maintenance, the work of the caretaker of the Kaisa Library was observed for two days by using shadowing technique (see e.g. McDonald, 2005; Czarniawska, 2007; Lee and Akin, 2009). Both the tasks involved in the workdays and the use of informational tools were analysed. This provides a realistic, although the only, viewpoint for the discussions of the possibilities of BIM use and implementation in maintenance.

In the following sections we discuss developing BIM and maintenance information tools in Finland, and modelling in our Kaisa Library case. After this, we discuss the data handover and information tools used in facility management and maintenance of Kaisa Library. Finally, we present the views of the designers and representatives of the Center on the possibilities and challenges in utilizing BIM in maintenance. Then to conclude, we suggest possible next steps in developing maintenance information tools.

BIM and maintenance information tools in Finland

Finland has been active in the development and implementation of BIM. The first projects to create a foundation for the use of product models in construction in Finland started in the late 1980s. In the 1990s, research on building information modelling mainly concentrated on creating suitable technology and standards for information exchange (Penttilä *et al.*, 2007). In 1997, the Finnish Funding Agency for Technology and Innovation launched Vera, a technology programme, the aim of which was to promote the use of information technology through a building's life cycle. During the programme, many Finnish software companies created and improved their model-based design software. However, the Vera programme did not reach one of its biggest targets: activating building owners. That is why the programme's results concentrated on new development, leaving existing building stock behind (Teknologian ja innovaatioiden kehittämiskeskus, 2002).

In the 2000s, the first pilot projects on building information modelling were carried out. The first projects, for example the so-called HUT600 project in 2002, concentrated on using modelling in design (Hänninen *et al.*, 2010). However, the idea of using models also in later maintenance activities was conceived (Penttilä *et al.*, 2007). In 2002, another national project was launched: the ProIT project. The ProIT project aimed at creating a common practice for modelling, improving information exchange and creating a common product library for simplifying design. As a result, a product library and common product modelling instructions were published (Kiviniemi, 2006). In 2007, Senate Properties published their own BIM requirements, which served as a basis for the Common BIM requirements 2012.

The Common BIM requirements 2012 (CoBIM 2012) present the requirements for modelling and using BIM in a construction process. The requirements were created by Finnish real estate owners, developers, construction companies and software vendors. Part 12 of the requirements entitled 'Use of models in facility management' (BuildingSMART Finland, 2012, p. 5) points out that 'Building Information Models (BIM) have been used in design and construction for many years; however, they are still a relatively new concept in facility management applications. Practices and even terms of model based information management are still under development. That being the case, this series, "Use of models in facility management", introduces more opportunities and alternatives than requirements.' The document presents operation areas of facility management with potential for utilizing models, lists potential uses of model-based applications and software, and tools used in design, construction and facility management. However, no examples or results of the actual uses of BIM in facility management are provided. The document also states that the COBie standard is being developed to facilitate the dissemination of information on the construction project from design and construction to the needs of maintenance. COBie is a performance-based specification for space and equipment information delivery, which helps to import data from design and construction into CMMS and asset management software (East, 2014). The COBie standard allows material and sustainability information to be included; however, it excludes information on some architectural parts that are essential for refurbishment, e.g. slabs, walls, ramps, stairs (Volk *et al.*, 2014). Since this new form of transmission is not yet in use in Finland, the requirements briefly suggest the potential ways it could be used.

On the other hand, there are several important tools used in maintenance and facility management. Our research group studied several life cycle projects carried out in central Finland in 2011. In an interview, a property manager in charge of a life cycle project explained that the Ryhti maintenance manual (since September

2013, called Granlund Manager) developed in Finland by Granlund Inc., is an essential tool in facility management and maintenance.

> It is an unbeatable tool for a property owner today … The maintenance manual is a tool for a maintenance company. It's a tool for the management of a maintenance company. It's a tool for a property manager. It's a supervisory tool for a property owner. He will be able to see what's going on all the time. For the users, in this regard it is a tool, because all service requests are made using it. (Property manager)

The property manager did not find substantial reasons for implementing BIM in maintenance. One reason for his hesitance was the risk of incorrect information related to using BIM in maintenance. An as-built model has to be done correctly and maintained through the life cycle of a building. The model has to be reliable and if it fails (even) once, its value is compromised and it's plausible that practitioners resort to using old tools. Reselling the idea of using BIM would take time.

> What we could do with it [BIM] has been envisioned. The problem is that when the modelling is done; it must correspond to the real product. If it doesn't, the point of modelling goes down the drain right away … If, even once, somebody would like to use the models but he notices that it's not correct, the models will then be forgotten and they say that let's do it like we have done before. And that is, in my opinion, the biggest fear in modelling: who will maintain, and who is capable of maintaining the models through the life cycle of a building. It has to be maintained all the time. (Property manager)

These statements justify making preliminary conclusions that will be developed further in this paper. First, workable information tools have been developed for facility management and maintenance largely independently of models used in design, and the maintenance personnel find the further development of these tools important. Second, the possibility of integrating the information from BIM models into maintenance systems requires that updating the models during the construction phases is organized.

Modelling in the Kaisa Library project

Kaisa Library is the new central library of the University of Helsinki into which several separate faculty and department libraries were fused. An 11-floor office building with 26 500 m^2 area in the centre of Helsinki was renovated for the purpose (see Figure 1). The library houses 1.5 million books, 150 employees work there and 5000 customers visit it daily. The design phase started in 2008; renovation and construction started in spring 2010. The building was completed two years later and opened in autumn 2012.

The design contract required that the architect and designers use modelling in their preliminary drawings. After that, modelling was optional. The goal of modelling was to get useful data for priced bills of quantities and to secure enough space for HVAC routings. The contractor also used IFC models for cross-checking the architect's and engineers' designs.

> We agreed in the Kaisa-building so, when we entered the project, that we want modelling to be utilized there, in the first stages of design, so that we get the models coordinated and confirmed … Everyone models until then, and it is done so that those models are IFC-compatible so that all the models can be combined. And it can be verified through that so that the work is feasible. For that reason we did it like this, because until that stage the amount of information is reasonable and after that the amount of information grows. And the amount of modelled information to maintain will grow exponentially from that point onward. (Property manager)

The architect made nearly 300 drawings and planning documents, of which most were 2D line drawings. However, the architect used the model for making floor plans, indoor wall drawings, and stair and elevator charts as well as a basis for the 2D line drawings. Electrical engineers modelled the preliminary drawings. They modelled the cable routings, but all installation solutions were not in the model. HVAC engineers modelled the main routings on the right height. HVAC engineers delivered 2D drawings that were from the model but all changes during the construction phase were made in those 2D drawings only (using drawing symbols and numeric information). The structural engineer used modelling. The main drawings for construction were from the model as such or with minor changes. Reinforcements were not modelled.

The data handover in the project

The data handover in the project was carried out in two ways. First, all design documents and drawings, including the models were handed over. The models were handed over both in native and in a combined IFC-format. The design archivist thought that the models may be used in future refurbishments. The 2D drawings were saved as dwg-format and pdf-format in the University's electronic archive. In addition, all project documents were archived in paper form.

Second, information was collected by a separate procedure for the Ryhti maintenance manual, a

Table 2 Providers and types of information gathered for the Ryhti maintenance manual by the outside consultant

Provider of information	Types of information	
Architect		
	• Basic information and description of the building • Location drawings: site plans and external areas to take care of	• Location drawings for other designers • List of rooms and their coating information • Window schedules
Structural engineer	• System description, location drawings: including bearing capacity, movement joints, fastenings, construction types of façade, escape routes	• Charts of used construction types
HVAC engineer	• Device list • Control charts • System description • Location drawings for HVAC devices • Catchment area drawings for AC	• User manuals • Target values for indoor conditions • Target consumption values for heating energy • HVAC electricity consumption • Cooling energy and energy consumption
Electrical engineer	• Rising main charts • Device list • Control charts • System description • Tele and security system charts • Location drawings	• Catchment area drawings for lighting and their control charts • User manuals, target values for lighting and list of luminaires • Target values for property's electricity consumption and lighting electricity consumption
Main contractor	• List of subcontractors • Material information	• Repair and care instructions for subfloors and floorings, partitions, wall substructures and finishing, internal and specific doors, specific fittings and equipment, roofing, external walls, floor slab fireproofs, bomb shelter equipment, mechanical smoke extraction systems and paving
Ventilation casing	• Device card information for ventilation system	• Repair and care instructions and user manual
Pipe contractor	• Device card information for fan convector, magnetic valves, fan coil units, heating and cooling valves	• Repair and care instructions • User manuals for devices
Ventilation contractor	• Device card information for air-conditioning units	• Repair and care instructions • User manuals

(*Continued*)

Table 2 *(Continued)*

Provider of information	Types of information	
Automation contractor	• Device card information for ventilation valves and frequency transformers	• Introduction records for frequency transformers • Repair and care instructions • User manuals
Electrical contractor	• Device card information for electricity, tele, security and HVAC devices' electricity information • Switchboard's device list	• Target values for lighting and list of luminaires • Repair and care instructions • User manuals
Sprinkler contractor	• Device card information for sprinkler systems • Sprinkler location drawings	• Repair and care instructions • User manuals
Reserve power contractor	• Device card information for reserve power system	• Care plan for warranty period and person in charge • User manuals
Elevator contractor	• Device card information elevators and escalators	• Repair and care instructions

product of a Finnish building services consulting firm, Granlund Inc. The main users of the maintenance manual are caretakers, technical building managers and in some cases, contracted service producers. The coordinator of the maintenance manual (an employee of Granlund Inc.) sent a comprehensive list of required information to 13 designers and contractors (see Table 2). In addition, the main contractor collected care and repair information from 35 other material and device suppliers. The providers of information and the types of information collected are depicted in Table 2. In addition, the architect and engineers delivered the list of documents and the contractors delivered the care plan for warranty period and person in charge and list of suppliers. Information in the maintenance manual is in pdf-format so it is easily opened and read. The maintenance manual does not include models.

The information handed over to the electronic archive guarantees that all possible information is stored and can be used for future refurbishments. The data collected for the maintenance manual is the information most needed in everyday maintenance work.

Information tools used by facility management and maintenance personnel of the Center for Properties and Facilities

In the interview with the property manager of the Center for Properties and Facilities, it turned out that the Center has been active in developing its own system of facility management and maintenance. There were five main information tools in use and one additional system was being developed. The systems used were:

(1) *An electronic archive*, where all drawings are saved as pdf-files, dwg-drawings and native models in the handover phase. All the functionaries have access to the drawings of all the houses in the care of the Center for Properties and Facilities. In future refurbishments, designers get their source information from the electronic archive.
(2) *Optimaze space management system*, developed by a Finnish firm Rapal Inc., was taken into use 10 years ago. Optimaze is a browser-based system for space management. It includes information about room types, square metres, owners and user units and it is used for managing space information. Optimaze is linked both to Ryhti

maintenance manual and ATOP cleaning measuring and management system so that Ryhti and ATOP get their space information from Optimaze. As for Optimaze, space information is based on dwg-drawings from the electronic archive. Optimaze is used mainly in facility services.

(3) *Ryhti maintenance manual* developed by the Finnish engineering company Granlund Inc. is used in planning maintenance, managing life cycle costs and renovations, monitoring energy consumption and delivering service requests. Ryhti includes six modules. The first module can be used in sending and managing service requests. The second module includes the history of maintenance work, described by maintenance personnel. The third module creates graphs about energy consumption metrics entered by maintenance personnel. Ryhti also contains contracts, a maintenance plan and long-term planning module. Ryhti is a browser-based system. The system provider feeds device information, e.g. manufacturer, model and location in the building into Ryhti. This information is collected with separate procedures from different suppliers (see Figure 2). Space information, which serves as a base for location drawings, is from Optimaze.

(4) *ATOP cleaning measuring and management system*, developed by a Finnish software firm ATOP-TIETO Inc., includes information about consumption of work, guidance about cleaning techniques and devices. It is used in scaling the cleaning work and creating documents about cleaning areas and density. ATOP uses area and space information, which originates from Optimaze as xml-format.

(5) *Timmi room reservation system*, developed together with Finnish Timmi Software Inc., is used in managing room reservations in University properties. University employees can use the system. Timmi also calculates the utilization rate of spaces, which allows a more efficient managing of space usage. The Timmi system is going to be linked into a system for planning teaching with the aim of enhancing space usage.

In addition to these tools, one system is under construction:

(6) Software for outdoor maintenance management ATOPkh developed by ATOP-TIETO Inc. The system includes consumption of work, information about work methods and possibilities to report about work.

The Center for Properties and Facilities has been active in developing and tailoring these tools for its

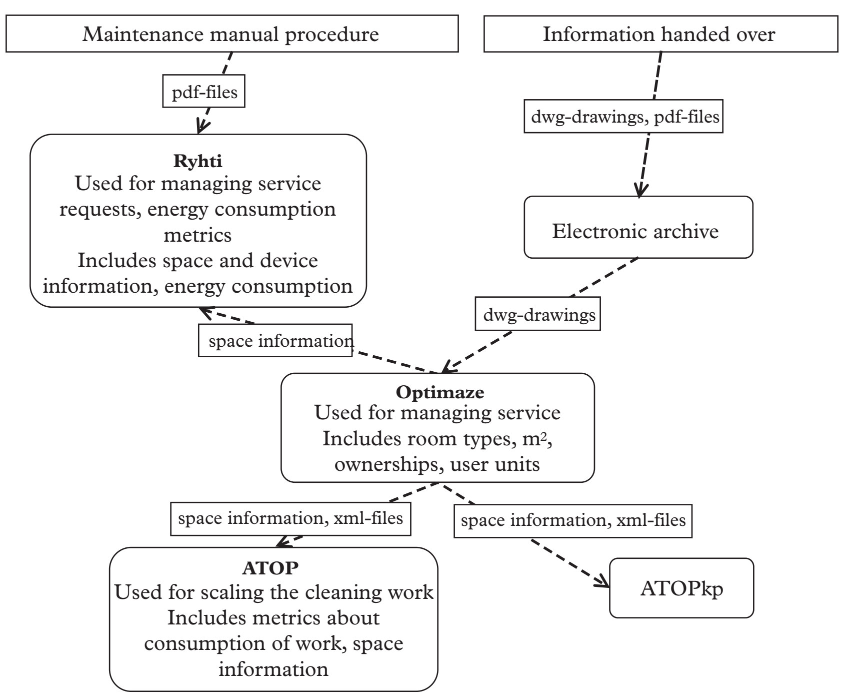

Figure 2 The system of informational tools in facility management of the Center for Properties and Facilities of the University of Helsinki

own purposes and in ensuring their compatibility. A link from Optimaze to both Ryhti and ATOP was constructed so that the space information in all three systems is similar. The property manager characterizes their strategy in the development of the systems as modular. Modularity is based on an idea by which systems and software function best for that certain purpose they are developed for. By keeping multiple systems, it is easier to change one system to a more suitable one.

> Like this background thought, with me at least is that every system is built on some basic philosophy … With the modularized system, the idea is that if we at the end of the day come to the conclusion that this (one) system is bad and expensive, we can put it away and take something else instead, something that can read the information from the model better and to move it there from the model. (Property manager)

The property manager presents the cleaning management system as an example: the system functions well, since 'we have been able to utilize the best software in the market which enabled us to use the space management drawings from Optimaze'. The Center for Properties and Facilities also attempts to collaborate with other stakeholders in developing the systems. It developed a project management system with three other organizations. However, it turned out quite soon that 'the needs, systems and way of acting in each of them were so different, that the system developer was unable to elaborate a system out of them'.

The property manager found that they had developed quite a functioning set of interactive tools, one that as a matter of fact can be understood as an information management model: 'It should be thought that Ryhti already is your information model. It is the model of the service and maintenance phase.' The property manager and design archivist agreed that the updating of the BIM models during the maintenance would be too expensive to organize especially since the advantages of their future uses were not clear.

Maintenance work and the uses of information tools

As part of the study, the work of the caretaker of Kaisa Library was shadowed for two days. The data consists of nine hours of audio and five hours of video material, and the field notes. In the analysis, the recordings were watched and listened to, and with help of them a data template was filled. The data collected included 61 events, the starting and finishing times of these events, conversations relating to these events, and the software used. The events were categorized into 10 main types of tasks. The tasks, the number of different events and the time spent on these tasks are listed in Table 3.

The analysis shows that the caretaker spent most of his time following, guiding and helping subcontractors and other workers. The caretaker followed the subcontractors' work, listened to them and collected tacit knowledge about the repairs. He led subcontractors to their posts. Kaisa Library is a complex building and the most of the routes contain locked doors, so the caretaker guided subcontractors along the routes and opened doors to subcontractors. In addition to working with subcontractors, he also delivered requested information, such as contracts, device card information and system diagrams. In those two days, he spent nearly half of his time interacting with subcontractors.

Then, the caretaker spent time doing work on his own, such as conducting regular inspections, repair and maintenance tasks and using automation and maintenance software. This personal maintenance work took 50% of his work time. He conducted monthly inspections in all ventilation plant rooms in two buildings to ensure everything worked correctly. He also carried out a big use test of the smoke detector system, including a test of fire venting installations and sprinkler systems. Maintenance work included also small repair and maintenance tasks such as changing fuses and putting up signs and fences to warn about falling snow. Similar to this category, the caretaker did some preliminary enquiring on site for reported faults and problems. The caretaker received information on faults and service requests by e-mail, through the service request part of the maintenance manual or in face-to-face conversation. He did some preliminary investigating on the problems, checked the situation but did not solve the problem. He ordered a subcontractor to solve the problem or decided to figure it out later.

As part of his work, the caretaker spent time on his computer checking the building automation system, checking and filling the maintenance manual and reading his e-mails for service requests.

In addition to these tasks, the caretaker also spent time discussing with users and co-workers. Discussions were informal based on conversing about problems and information was mutually exchanged. Users explained their problems to the caretaker and he told them what he had done to remedy them. With co-workers, the caretaker asked something or reported a fault that should be fixed.

The caretaker spent time in his office only when using automation software and maintenance manuals and looking for information. Most of his time (84%) he spent on the move in the building. We find it

Table 3 The number of events and time spent on caretaker's tasks on two-day shadowing period

	Task	Explanation	Number of tasks	Time spent (minutes)	Percentage of time
Interacting with subcontractors	Working with subcontractors	Following the work of subcontractors, commenting, opening doors, guiding routes	23	223	40
	Looking for and delivering requested information	Looking for information from papers and software, delivering it to subcontractors	4	41	7
Personal maintenance work	Regular inspections	Monthly inspections in ventilation plant rooms, regular test of smoke detector	6	117	21
	Repair and maintenance tasks	Repairing things, changing fuses, putting warnings of falling snow	7	64	12
	Preliminary enquiring reported faults and problems on site	Checking faults for further measures	7	45	8
Working on computer	Using automation and maintenance software	Checking automation system, maintenance manual, e-mail	7	48	9
Interacting with users	Conversation with users, feedback	Getting and giving feedback, changing information	7	17	3

unlikely that the personal presence of the caretaker in the building could be replaced or radically reduced with ICT systems. Table 4 presents the software used by the caretaker and the main uses. In two days, the caretaker sat by a computer on seven occasions (see Table 3). Each time, he used more than one kind of software. The number of times when each kind of software was used is presented in Table 4.

The caretaker had two buildings under his care, and there was different software used in the cases of those two buildings, which is why he used two kinds of automation systems and maintenance manuals. The caretaker used building automation software for keeping track and observing the general condition of the buildings. He checked alarms, read diagrams and meters to get an overall picture of the buildings. The caretaker used a maintenance manual in tagging tests and the regular inspections made. He also checked and commented on service requests and kept track of energy consumption. The other maintenance manual

Table 4 Software the caretaker used and for what purpose he used it

Software	No. of times software used	Use
Trend: building automation and energy management system	4	Watching data sent from control panel switchgears, keeping track of room temperatures and daily energy consumption, checking ventilation system diagrams and alarms
Atmostech: building automation system	5	Checking ventilation system diagrams, keeping track of daily energy consumption, checking a meter read-out, looking for information about devices for the maintenance manual
Ryhti: maintenance manual	2	Tagging tests and regular inspections done, checking, responding to and commenting on service requests, checking a use register
Tampuuri: maintenance manual	3	Keeping track of monthly energy consumption, looking for last year data for a new maintenance manual
E-mail	4	Getting service requests

was used only when he tried to find out information for a new maintenance manual on another building he took care of besides Kaisa Library.

The caretaker received service requests by maintenance manual, e-mail and phone. He preferred phone calls or face-to-face conversations because that way it was easier to ask specific questions about requests.

The maintenance personnel had little to say about modelling. The caretaker had not formed an opinion about models. The technical building manager was hesitant about the benefits of models and suspected it would be time-consuming and expensive to build a useful model. He imagined that models could be useful in getting a better picture of a room or space for renovation and in helping make contracts with service providers.

Views of the designers about the possibilities and challenges in utilizing BIM in maintenance and FM

In the Kaisa Library project, modelling was required only for making preliminary drawings. After that, each designer used modelling for their own purposes as it was suitable for them. That is why a proper as-built model was never created. Designers thought that modelling was helpful in their own work. However, the models used in the design phase would not be suitable for the maintenance phase. The purpose of use defines e.g. how specific a model should be and what kind of information it should contain. The architect thought that the orderer often does not know for what purpose the models are to be used and on what level he should demand modelling. That is why models may either be too specific or not include the needed information.

> I think that it depends on how much the client knows for what purpose the model is to be used and for what purpose it is really needed … I've noticed that [modelling] is such a new thing yet that parties don't have a clear picture of their possibilities and what is worth doing and what's not. (Architect)

The second problem in using models in maintenance is that models have to be updated also during the maintenance phase. The architect had doubts whether there was anyone capable of maintaining the model and its information content in maintenance. A model should be updated after refurbishments and big changes in the building and it is unclear who would be doing this work. Also, the HVAC engineer and the BIM expert thought that maintaining the model would require skills of the maintenance personnel, skills they don't have.

> In practice, it would require maintaining four models: structural model, HVAC model, electrical model, architect model. Maintaining all these in the maintenance phase would be quite a process. (HVAC engineer)

According to the designers, the third challenge in utilizing BIM in maintenance is that there is no software capable of using modelled information in maintenance. The main tool in the maintenance phase, maintenance manuals, is not yet ready to read information straight from the models. A possible solution could be a kind of link between the models and maintenance manuals.

The HVAC engineer and the BIM expert found many possible uses for models, such as space management and planning and scheduling maintenance tasks. A model could be a visualizing tool for maintenance companies for locating malfunction in systems. They also saw that in future modelled information should be used, not wasted.

> In my opinion, it [the model] would need to be useful. It is good just in the construction phase, but it seems senseless if its use ends there. It should be able to be used somehow for this sort of maintenance manual data, or that it would be directly obtainable to maintenance software. (BIM expert)

In the Center for Properties and Facilities, an HVAC design coordinator responded positively towards modelling. He thought that models should be used more in maintenance. However, similarly to the architect's view he pointed out that using models in maintenance would require that the designers' models were simplified.

> But if we want it [BIM] in use in maintenance, it should be able to be reduced so that all its elements are in a scale that is reasonable in maintenance … The use of this building information model should be increased the right way, the use of this heavy model as reduced, controlled, and allocated to different actions. (HVAC coordinator)

Different maintenance tasks and sectors, such as fire safety, electro-technical repairs, controlling dangerous situations, they all need different kinds of information and a model containing all that information would be too complex to use. The different maintenance models should be allocated to specific tasks so that they contain only the needed information.

The facility management's views on the possibilities and challenges of utilizing BIM in maintenance and FM

The representatives of the facility management were hesitant about using models in maintenance. The property manager pointed out that the information needed in the maintenance phase is not as detailed as in the design and construction phase. Also, specific information is needed so rarely that maintaining the model would not be sensible. The property manager summed up by saying that the amount of work required for maintaining that model is unreasonable compared to the advantages that can be gained from it.

> In a way, the need for information in maintenance work is different from what is (needed) in building work where you need to be told the screws and the details. Building work needs that more specified information … But the biggest problem is that the need for information is so rare in the maintenance phase, we don't find it sensible to develop the model further just for that. And especially to maintain the model information, the information model, product model information there. The amount of work required maintaining that model is unreasonable compared to the advantages that can be gained from it. (Property manager)

In addition, the design archivist found that organizing updating the model into an as-built model during the construction was a major challenge that needs to be resolved. In her view, to achieve this, somebody on the construction site should develop proper procedures for the task.

The vision of the property manager for the future was that the information from BIM models could be automatically or semi-automatically transferred to the maintenance systems. Nevertheless, he saw it as the duty of the client who also is in charge of the maintenance to require it. He pondered on the option of the Center for Properties and Facilities making experiments in which the building is modelled and information is taken from the models to Optimaze and Ryhti. 'As an exercise, we could take up a project small enough and tell that this time you will model it up to the end.' This was not the case in the Kaisa Library project.

The management, however, believed that the utilization of the models would proceed. They thought that the possible progress would be realized by requiring the designers to provide models from which the key information could be directly transferred to Optimaze and Ryhti. This solution would, however, require several organizational conditions. First, the designers must be required to do the modelling 'up to the end', which was not the case in the design of Kaisa Library. Second, updating the models during the construction phase into as-built models should be organized to avoid the problem of the model including information that does not correspond to the real situation. Third, the information from the BIM models should be automatically or easily transferable from the models to the maintenance systems. To what extent this is technically feasible and what measures should be taken to ensure it happens remain unresolved. In addition, a considerable part of the information included in Ryhti (see Table 2, repair instructions, etc.) is not available from the models. The transfer of space information from design models to Optimaze would not therefore replace the separate information acquisition procedure related to Ryhti (Table 2). Fourth, even from the space information it should be defined what information and on what level it should be included in the design and as-built models in order to meet the requirement of the maintenance systems.

Fifth, updating BIM models during the maintenance should be organized. In the case of the Center for Properties and Facilities of the University of Helsinki, this would be a new function requiring recruitment of new personnel. Since there is no experience of utilizing the models archived in renovations, and the immediate challenges of information management are in improving the use of existing maintenance tools (Optimaze, Ryhti, ATOP, Timmi), the investment in organizing the updating of the models is unlikely to take place in the near future.

Conclusions

The data handover in the University's library project was carried out in two ways. First, the models, 2D drawings and other documentation were archived in the archives of the Center. Only a minor part of this data was used in maintenance software: floor plans in the form of dwg-drawings were used as source information for the Optimaze space management system. Otherwise the models were stored in the archive to wait for the potential uses, such as future refurbishments. Second, an outside consultant, the coordinator of the maintenance manual, collected separately the information for the Ryhti maintenance manual from the designers, contractors and suppliers of the library project. The main bulk of the information used in the maintenance systems was not obtained from the design models.

In the designers' and the design coordinator's opinion, models as they are used in design are not suitable for maintenance. In the architect's view, the use of BIM in maintenance would require careful specification of the purpose and subsequent future uses in order to specify the level and contents of modelling. In the coordinator's view, BIM models should be simplified to make them meet the needs of maintenance and facility management. In addition, they both thought that the maintenance personnel did not have the expertise and skills required to update the models. The question of who should be responsible for updating and maintaining the models remained open. The maintenance personnel had little knowledge on BIM and did not have opinions about its implementation. For them, it was more important to utilize the maintenance manual and the building automation systems more effectively.

The case shows that the facility management of the Center for Properties and Facilities of the University of Helsinki had for years been active in developing and interconnecting FM and maintenance tools it had implemented (see Figure 2). To ensure information exchange between the systems, the property owner had asked the vendors of Optimaze and Ryhti systems to develop a function that enabled communication between the two systems.

This corresponds what has been found in the studies of the design and implementation of complex enterprise planning systems (Fleck, 1994; Pollock *et al.*, 2003). They are 'configurational technologies', created from selected existing component technologies and customized elements configured together. In the adaptation of these technologies design, implementation and organizational adjustments are closely coupled (Stewart and Williams, 2005, p. 205). Correspondingly, it has been shown that a prerequisite to adoption of BIM is its compatibility with existing methods and ways of working (Davies and Harty, 2013, p. 1123).

The facility management of the Center did not articulate any such essential challenge in their activity that would require the implementation of BIM. They did not see that uses of BIM models would provide a significant added value in relation to the potential provided by the maintenance information systems already in use.

The case shows that the integration of information from design models to maintenance systems requires measures related both to technical feasibility of the transfer of the information (e.g. implementing COBie), changes in contracts (agreement of what is modelled) as well as organizing the updating of the models during the construction and maintenance phases. It shows that instead of defining possible or imaginary uses for a BIM model, the starting point should be shifted to the needs of the owners, who will be in a key position in enhancing the utilization of BIM in facility management and maintenance.

What is potentially also needed is rethinking the concept of BIM. It has strongly been emphasized that the stakeholders should share all information during the life cycle (of a project). However, it might be more realistic to recognize that the FM and maintenance information systems are an essential part of building information management with their own functionalities and contents that differ from the models developed to be used in design and construction. A partial, stepwise integration based on selective communication between systems may be the way forward. Such steps of integration between multiple information tools will partly take place locally according to the needs of the owners.

The limitation of our paper is that we did not study the history of the collaboration between the Center and the system providers, neither did we interview the providers of the information systems. Therefore, a vital question of who could or should be in charge of the integration is not satisfactorily dealt with. The study, however, shows that the problem found in the integrated solution literature (Leiringer *et al.*, 2009), whether the asset management capabilities are developed in-house or outsourced, is a relevant strategic question also for the Center. At the same time, its modular and stepwise strategy suggests an alternative in which the capability may be developed through separate collaborative projects with different system providers. In future research these kinds of stepwise strategies and their implications for system providers should be studied.

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