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Research Report:

Exploration Towards the Development of a Concept and Requirements for FMBIM Information Management

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INTRODUCTION

Built environment plays an important role in the daily lives of humans and also organizations. Every organization, whether public, private or family unit, needs suitable and well maintained real estate in order to manage their main operations and activities. This means that facilities are designed and built for the particular purpose/function in mind.

However, beyond the traditional functions of delivering capital intense facilities is the Operations and Maintenance (O&M). Facility operations management is responsible for providing comfortable working and living environment; and maintenance encompasses a set of activities that Facilities Management (FM) services personnel perform to ensure that facility continues to fulfil its intended function(s) by providing the facility and equipment upkeep. There are many reasons why we need to manage, maintain and sometime also adjust the built environment. Most importantly, the need for FM is caused by the degradation of the facility because of its constant use for intended purpose, and adjustments and improvements are caused by the changing needs and requirements of the owner/users. In summary, it is only the well maintained and managed real estate object that can guarantee appropriate and safe environment for living and working purposes.

Typically, O&M makes up the longest period of the facility's life-cycle, meaning that the majority of the expenses occur during this stage. According to Teicholz (2013), more than 85% of the total costs spent over the lifecycle of a building are during the O&M. Corollary, it has become important to make the FM processes more efficient to avoid any added expenses and also to reduce the facilities downtime. The latter is particularly important as it can influence the user's returns from their daily either privet or public operations.

Traditional concepts, methods and tools in the real estate management have proven to work, but due to the increasing complexity of the facilities and changes in the environment, new approaches, methods and tools must be adopted. With the development of novel technologies, such as computerized maintenance management systems (CMMS), building automation systems (BAS), web-services, building information modelling/models/management (BIM), internet of things (IoT) etc., many functions and processes of FM have become automated, promising more efficient and effective ways of working.

This means that many novel technologies have been proposed to improve FM. In this research we are interested in the BIM, its related concepts, opportunities and challenges for FM purpose. BIM has become Business as Usual for procuring facilities in Estonia and abroad. Estonian Real Estate Agency AS (RKAS) has been one of the leading clients for implementing BIM based processes and technologies, however, mostly in the design and construction stages. Despite of the numerous opportunities, there is a peculiar lack of progress in the area of BIM based FM (FMBIM), which in addition to other topics will be the subject of this study.

For maximizing the utility from implementing BIM, RKAS has led the translation and development of numerous BIM guidelines and studies. Until now, the focus has been on increasing the quality of design processes and describing client's/owner's interests in using BIM. What is missing from this picture is the information requirements that the different suppliers need to hand over during the different stages of project delivery for the purpose of FM.

If to consider that RKAS has more than 1 million m^2 of property, and Elari Udam's presentation at the annual conference of Estonian Association of Facility Maintenance and Management in 2013, then RKAS has large potential in terms of increasing the efficiency of FM. Currently, relatively large amount of Facility Managers' time is spent on gathering, organizing and management of building information.

The purpose of this research is to develop good understanding of FMBIM and its related information management concepts. More particularly, the focus of this study is not on the usage of BIM applications for FM, but on what information, when, how and by whom need to be delivered to the facility's owner/manager. This problem is two-fold, first we need to understand the information content of BIMs handed over to the owner during the different stages of the project as well as processes for planning, organizing, leading and controlling the FM information management. Within this research we have posed the following research questions for achieving the expected objectives:

1. Why to use BIM for FM?
2. What is the current state of art for BIM based FM?
3. What are the main aspects to be considered when implementing BIM for FM?
4. What is the current state of the art in Estonian Facilities Management, including BIM?
5. What kind of information is needed for FMBIM, and what is the process for that?

In this research mixed-methods research approach together with different methods are used. Research itself is divided into several sections, including the literature review, research methods and materials, state of the art of the FM in Estonia, FMBIM information management concepts and finally, the development and evaluation of developed information requirements concept.

1 GENERAL CONCEPTS OF PROJECT DELIVERY AND FACILITIES MANAGEMENT/MAINTENANCE

Overall, the purpose of this chapter is to develop a general understanding of the state of the art of FMBIM and its related concepts. In following paragraphs, general concepts and principles of capital project delivery and operations are reviewed, including discussion about the opportunities, application areas and business cases for adopting BIM based FM. Finally, implications/challenges associated with FMBIM are summarized.

1.1 NATURE OF ARTEFACTS, PROCESSES AND STAGES

Every project must starts with the identification of client/user needs and requirements, followed by the design and engineering of structures for meeting expected functions and behaviors. Thus, the artefact (facility, built environment etc.) with its intended purpose is the object for design and engineering. The function of the design and engineering is to describe an artefact in terms of its organization (structure) and functioning (goal/purpose) in the context of its environment. Despite its roots in the Ancient Greek, Simon (1981) formalized and proposed the overall structure of 'science of the artificial' as illustrated in the Figure 1. It is describing the analytical framework and its components for studying artefacts, design and engineering aspects.

What is important to conclude from here is that it is the interplay between three components: every artefact is and must be contextualized to its environment (clients/users, use functions, flows of resources etc.), fulfil the intended goal/purpose (expected functions and behaviors), which is realized through the instantiation/embodiment of the artefact into the material/objective realm.

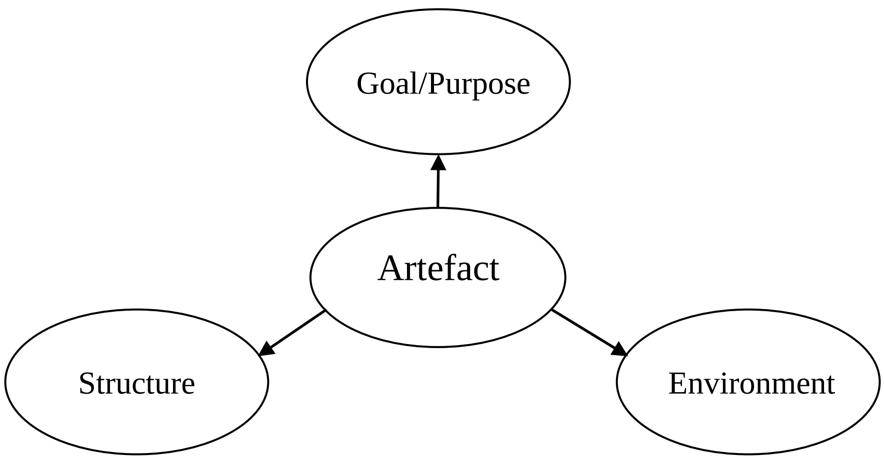


Figure 1. Definition of an artifact through its purpose, context, and characteristics (structure). (Simon, 1981).

Also in case of the built environment, facilities are designed and built for the particular purpose. Thus, the main function of a built environment is to provide well-functioning, aesthetic, healthy, safe, sustainable, efficient and effective spaces for accommodating human and business processes/activities (Reed, 2009, Teicholz, 2013), realized through the project delivery processes.

Planning identifies the needs and requirements; design specifies the requirements and provides descriptions for realization; and construction manages the flow of resources and materials for achieving the goals as shown in the Figure 2. Design/engineering has been described as a mapping process (Kroes, 2002, Suh, 2001), between client needs to functional and behavioral description and from there to structural description. The construction stage is the realization of design intention, structural description. Latter also requires the design of production systems, its implementation and improvement (Ballard and Howell, 1998, Ballard et al., 2001).

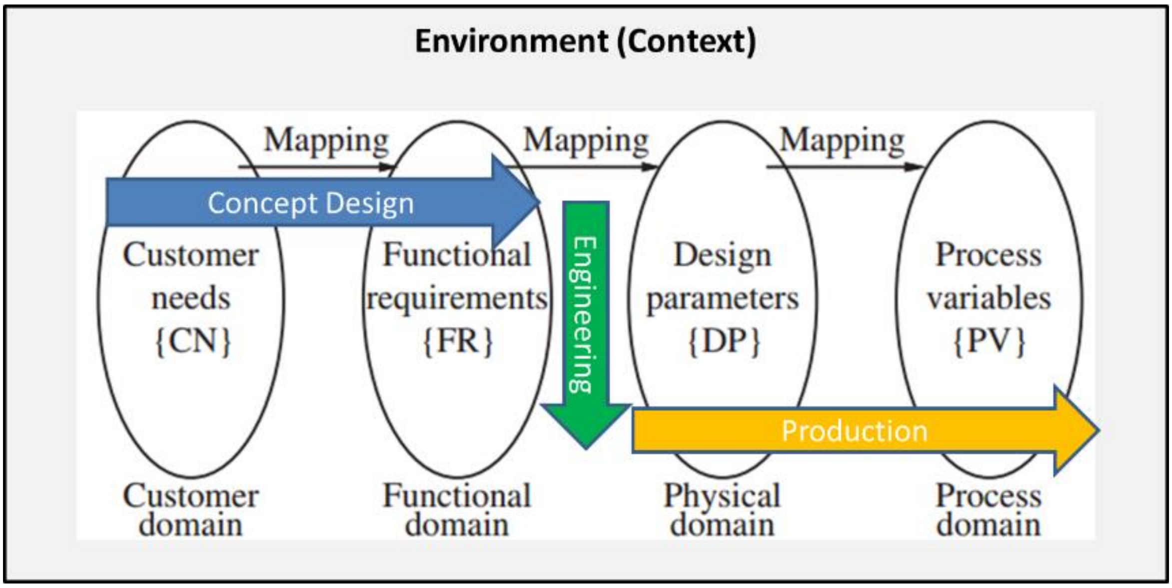


Figure 2. Two major stages of design and engineering prior production. (Suh, 2001).

1.2 DEFINITION AND NATURE OF FACILITY MAINTENANCE

It is clear from about that planning, design/engineering and construction are not the objectives in themselves rather it is the intended use of the facility, meaning the operations it is or will be used for. Therefore, beyond these traditional project delivery functions is the Operations and Maintenance (O&M): operations responsible for providing comfortable working and living environments; and maintenance providing equipment upkeep (Administration, 2011).

O&M is the longest period of building life-cycle, which means that the majority of expenses occur during this stage. According to Teicholz (2013), more than 85% of total costs spent over the lifecycle of a building accrue during O&M. Mossman et al. (2010) have illustrated this in Figure 3, indicating that design composes typically 1 unit, construction 10 units, building maintenance 30-50 units and user operating 150-300 units of the whole life cycle cost. D in a schema is the purpose why facilities are constructed, meaning it is the return from user's business processes.

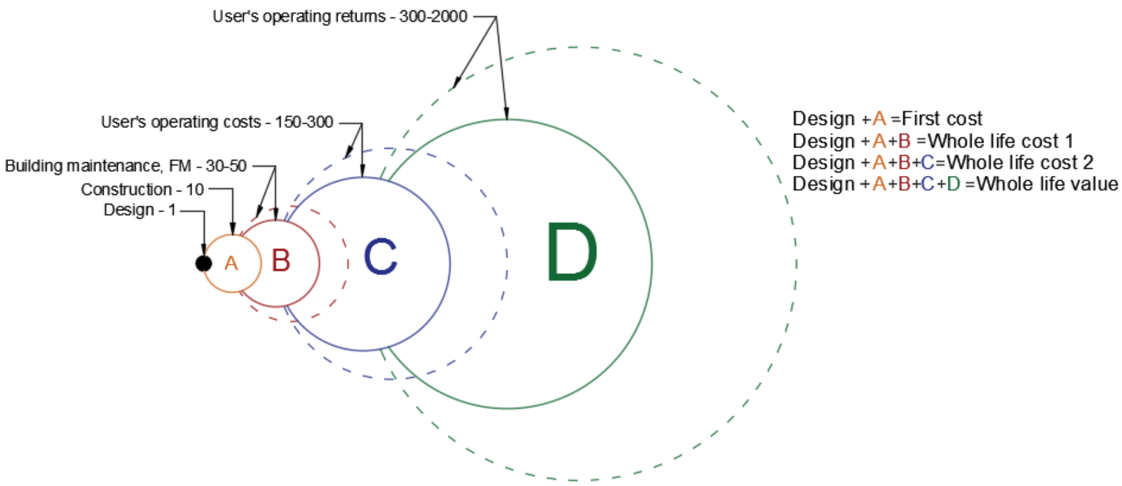


Figure 3. Whole life value of facility: output value (D) in relation to first cost (A+Design cost) and whole life cost (A+B or A+B+C). (Mossman et al., 2010)

Therefore, it has become important to make these processes more efficient to avoid any added expenses and reducing the facility's downtime. The latter is particularly important as it can influence the user's returns from its operations.

Definition of FM in Estonian Legislation, Standards and Documents

In Estonian legislations and standards, FM is defined similarly. However, according to the Estonian Construction Act paragraph '§19. Owners responsibilities', it is the owner who must ensure that facility, its construction and use comply with the requirements established within all related building acts. As specified within the 'Estonian Construction Act' and 'EVS 807:2010 – Maintenance of Facilities – Provision of Facilities Management Services', owner with his/her decisions and financing assures and ensures the safe maintenance and use of the facility for the society as a whole and specific users.

For that owners must undertake different activities, for which various kinds of information is needed (MKM, 2015).

The most basic document for FM is the facility maintenance guide, typically delivered either by engineers, contractors or other dedicated person with necessary skills. According to the paragraph '§17. Facility maintenance guide' in the Estonian Construction Act, in minimum facility maintenance guide must include information about installed materials, equipment and products, including operations or maintenance manuals supplied by the manufacturer. More specifically, the general requirements to the documentation of the facility itself and construction processes are detailed in ordinance of the "Requirements for the Preservation, Maintenance and Submission of Construction Documentation and Facility Maintenance Guide" (MKM, 2015). Now understanding the definition, function and purpose of FM, we can turn to studying the reasons, business cases and application areas of implementing FMBIM as well as related challenges.

1.3 WHY BIM FOR FM?

Each facility is a combination of numerous components providing primary or secondary function(s), making up the whole or in other words built environment. Maintaining and operating environment requires the ability to track components accurately, identify inefficiencies in building operations, and respond quickly to client requests (Teicholz, 2013). Components or assets have a cost associated with the installation, replacement and/or scheduled maintenance. An accurate equipment inventory is essential for budgeting repair/replacement and maintenance costs.

FMBIM, as a means for visualization, facilitates the access to the precise location, accurate existing condition attribute data, and relationships of building systems and equipment. Thus, BIM has several advantages over traditional 2D drawings by providing a data-rich, object-oriented, intelligent and parametric digital representation of the facility (Administration, 2011):

- BIM objects know what they are, (walls, doors, spaces, lights, plumbing fixtures, etc.) and where they are located;
- BIM provides a unique identifier (GUID – global unique identifier) that can be used to link the components in model with other facility management systems.

- BIM software tools support the creation of zones that can identify areas serviced by common components. For Example: Rooms 1, 2, and 3 are supplied by Air Handling Unit 21, or supplied electrical service from circuit panel L-1.
- BIMs capture building system relationships. For example: each electrical panel knows which transformer supplies its power.

BIM for facility management means a specification of the information needed to be passed from design and construction to operations and maintenance. BIM for FM can automate the creation of equipment inventory lists, populate facility management systems with information, and reduce redundancy in the maintenance of facility data for facility management activities. The potential benefits are twofold: a reduction in operating costs and quality gains in responding to tenants faster (Administration, 2011).

1.3.1 The Business Case for FMBIM

BIM for facilities maintenance brings many benefits and has a strong business case. General Service Administration (GSA) in US has listed several benefits according to roles of O&M (Administration, 2011).

For GSA Maintenance Workers:

- Removes the unnecessary movement or trips to the same location to carry out work orders by providing accurate field conditions and maintenance information before leaving the office;
- Increases completeness in preventive maintenance work orders through accurate equipment inventory;
- Reduces costs for repairs by providing faster response times to emergency work orders (e.g., a major leak in the wall and the water needs to be shut off immediately);
- Mobile access to BIM and other linked/integrated data in the field allows access to all documentation without making trips back to the office.

For GSA Building Operators:

- Reduces the O&M contract costs from incomplete equipment inventories. An accurate equipment inventory can reduce O&M contracting costs from 3% to 6% by identifying and tracking facility equipment and facility square footage;
- Reduces time creating equipment inventories from plans, specifications, and submittals. An accurate equipment inventory can generate a return on investment of 3% in energy savings by identifying all facility components that affect energy usage, require maintenance, and assist in safe operations;
- Reduces risk and uncertainty of performing work orders by identifying building components that are not easily identified;
- Maintains links to equipment histories facilitating equipment condition assessments. An accurate equipment inventory reduces the possibility of catastrophic costs for unforeseen repairs by identifying accurate equipment locations and components;
- Optimizes building performance by comparing actual to predicted energy performance. BIM can provide access to design and commissioning data for reference;
- Provides business analytics through integration of BIM, BAS, Electronic Maintenance Systems (EMS), and CMMS data, allowing better review and access to building controls, schedules, readings, and inventory. Cost and performance trending can be used to troubleshoot high tenant work order areas and identify customer satisfaction or building performance issues.

For GSA Design and Construction Teams:

- Reduces costs of re-documenting “as-built” conditions and field surveys for building renovation projects. Savings could occur from reduction in time to verify field conditions, change orders due to unforeseen conditions, reduction in destructive testing and repair costs to confirm existing conditions;
- Meets federally mandated energy targets through greater accuracy in model assumptions and better estimation of energy performance;
- Designs higher quality building systems from better equipment selection and specifications based on feedback from building operations;
- Better commissioning through understanding impacts of individual HVAC components on overall HVAC system. For example, a VAV box in Room 1 is

adjusted for a tenant. All other VAV boxes within the same HVAC system are affected because of the change in air flow. As adjustments are made to each individual box, the overall system performance can be analyzed and adjusted.

For GSA Spatial Data Managers:

- Increases precision in existing condition information, which is used for accuracy of rent bill management, reduction in costs for audits and re-walks;
- Reduces time to polyline spatial program drawings through automation process using BIM Guide Series 02.

For GSA Building Tenants:

- Increases satisfaction from quicker resolutions to unscheduled work orders;
- Reduces unscheduled work orders and increased communication between tenants and building maintenance workers regarding scheduled work orders.

1.4 FMBIM APPLICATION AREAS

Numerous applications areas of using BIM for FM have been reported, of which many are still supported rather partially by different software applications. Potential exists in most areas, from operative property management to maintenance, repairs and replacement of technical systems, end-user services, cleaning etc. Maintenance manual applications, utilizing models either on a restricted basis or more widely, are available for management of technical data, service requests, contracts, documents, various maintenance tasks and maintenance history. Building information models are also used to simulate energy consumption target and real–time monitoring of building performance (Jokela et al., 2010).

In "Finnish Common BIM Requirements", Jokela et al. (2010) have categorized the potential operation areas of property management based on the Finnish property services general quality requirements KiinteistöRYL 2009 as illustrated in Figure 4. The FM operation areas together with general processes are described in upper part of the figure and the ones colored black can be supported by BIM.

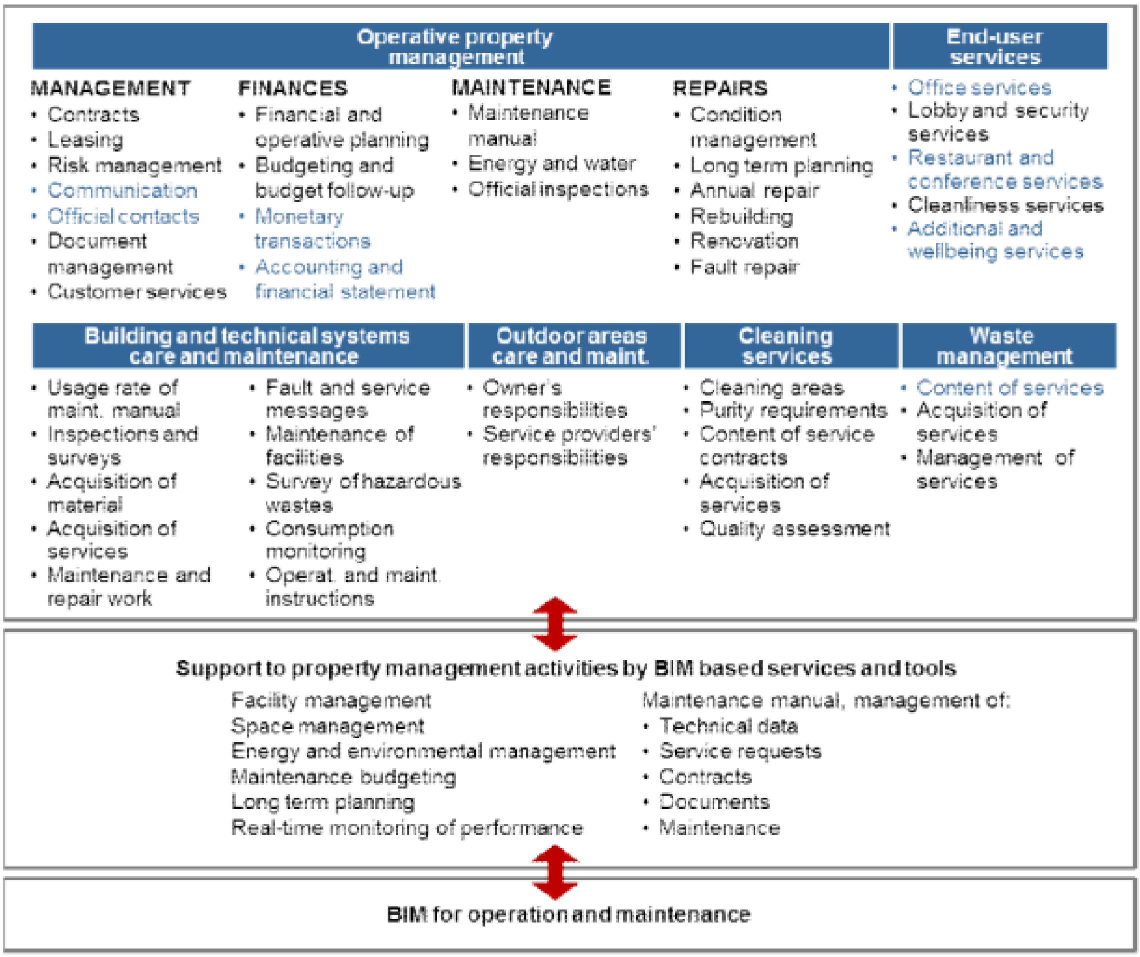


Figure 4. Property management operating areas supported by model based BIM applications (text in bold) (Jokela et al., 2010).

Similary, Becerik-Gerber et al. (2011) and GSA have listed largely the same use cases with few additions (see Figure 5). However, what is the most important aspect of 3D models is that it is the digital replica of the building physical and functional aspects. Digital assets and components could be referred to as nodes for accessing building related information from different sources, including its location, specifications, product information (assets), performance etc. Due to intuitiveness of 3D models, according to Becerik-Gerber et al. (2011) 'locating building components', 'facilitating real-time data access', 'visualizations and marketing' and 'checking maintainability' are obviously the most widely used application areas. Other application areas support the management of maintenance processes, spaces and building performance. Using FMBIM has also value in 'personnel training and development' as unnecessary trips to site and class can be avoided.

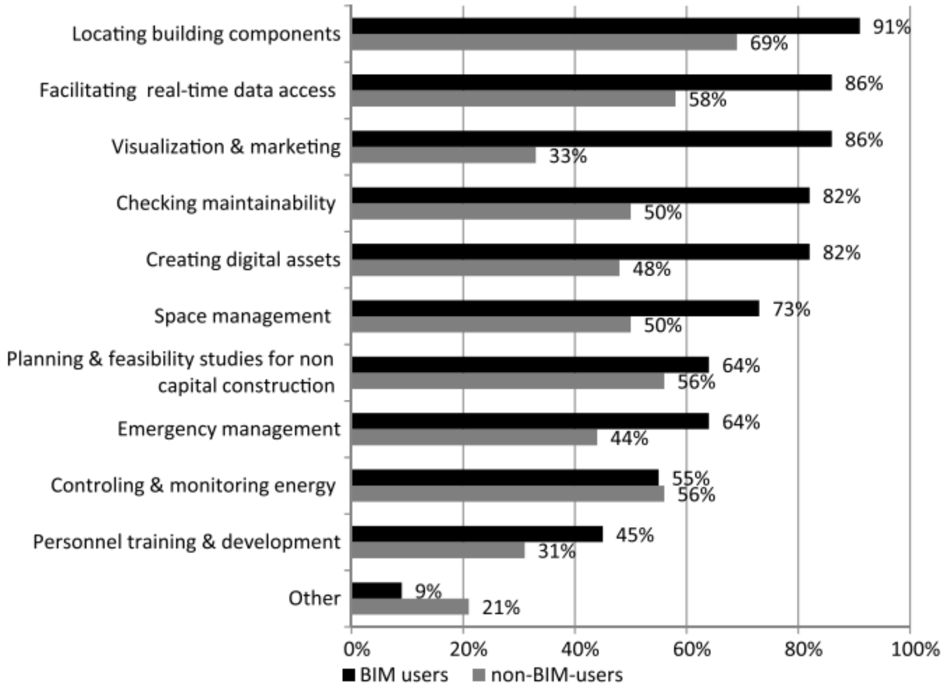


Figure 5. FMBIM application areas (Becerik-Gerber et al., 2011).

Many of these applications areas are already supported in BIM based applications for facility maintenance, for more detailed information see Appendix 1. In this study, facility management software refers to an application for facility and space management, maintenance budgeting, long-term planning, maintenance manual, monitoring of energy consumption and personnel training and development. Application areas are shortly described in the table below.

Table 2.1. Descriptions of FMBIM application areas (Administration, 2011, Becerik-Gerber et al., 2011).

No	Application area	Description
1	Locating building components	3D BIM models make it easier to see where the components are in a facility; enable the localization of the equipment on-site; and delivery/display of data relevant to the operational context.
2	Facilitating real-time data access	BIM together with its components provides unified graphical interface to access building data; even when data resides in different databases. Thus, interoperability between systems is a key issue.
3	Visualization and marketing	BIM provides improved visualization of different aspects of a facility during the different stages of life-cycle and it can support planning, decision-making, approval processes, training purposes etc. Moreover, the navigating, walkthrough, rendering etc. capabilities of BIM technology have the potential to be used for marketing purposes.
4	Checking maintainability	BIM facilitates maintainability studies that focus on desired performance at various stages of a facility's life cycle, which can address the following aspects: accessibility, sustainability of materials, preventive maintenance.
5	Creating and updating digital assets	Using BIM throughout the design and construction stages based on the owner's requirements could provide an opportunity for FM personnel to capture, digitalize, and transfer information related to assets as soon as the commissioning is completed. These assets include: equipment and systems; data; documents etc.

No	Application area	Description
6	Space management	BIM can visualize space and host space attributes for immediate access to facilitate identifying underutilized spaces, forecast space requirements, simplify space analysis, manage the move process, and compare actual with planned space utilization. This information could be used for efficient compilation and maintenance of office schedules, accurate identification of spaces' various purposes etc.
7	Planning and feasibility studies for non-capital construction	BIM can potentially assist in planning, designing, analyzing, and simulating remodel, renovation, or demolition work. The planned work could be modeled in BIM at such a level of detail that the visual characteristics of exteriors and interiors of the work are well presented, the dimensions of major components are scaled, quantities of required building materials can be estimated, and type and model of equipment are identified.
8	Emergency management	Utilizing BIM, and providing real-time access to data through BIM, spares emergency responders from having to make decisions without adequate information. BIM can assist emergency responders in locating and identifying potential emergency problems and pinpoint hazards through its graphical interface.
9	Controlling and monitoring energy	Converting floor plans to energy management system graphics is very time-consuming process, BIM's graphical interface could be a solution to that issue. BIM could also be linked with building sensors for real-time monitoring and automated control, and used for tracking the historical energy usage for each room/zone/occupant so that energy consumption behavior could be analyzed and predicted.
10	Personnel training and development	BIM could enable the trainees to virtually walk through facilities, investigate building spaces, components, and equipment, and review related semantic data. This would enable them to gain a better understanding of their assigned work zones and tasks, and therefore to perform their new responsibilities sooner.

1.5 IMPLICATIONS AND CHALLENGES

Despite the many benefits for using FMBIM, several technological and organizational challenges have been pointed out in the literature. Some of the technology and process-related challenges include the following (Administration, 2011, Becerik-Gerber et al., 2011):

- Unclear information management responsibilities.
- Diversity and lack of standardization in the BIM and FM software applications and processes.
- Interoperability issues.
- Lack of demand for BIM deliverables by the owner community due to the uncertainty about what BIM might be used for.
- Lack of clarity about responsibility in insurance and contracts.
- Facilities management personnel's limited experience with BIM technology.
- Lack of effective collaboration between project stakeholders for modeling and model utilization.
- Necessity yet difficulty in software vendor's involvement, including fragmentation among different vendors, competition, and lack of common interests.

Organizational-wide efforts are required to coordinate the collaborative effort between owners, FM groups, architects, engineers, contractors, and vendors. This requires establishing and updating roles and responsibilities for each BIM-based processes. The project data should be captured, recorded, shared and accessed by all BIM-based solutions throughout the building life cycle (Burcin Becerik-Gerber).

1.6 SUMMARY AND DISCUSSION

From the above, it is clear that project delivery is a complex process involving many different stages, stakeholders and aspects to be considered. Every project starts and must start with the end in mind, this means what are the needs and requirements of owner/clients/users for the particular facility. Typically, these needs and requirements are described qualitatively and quantitatively, including information about expected qualities, such as functions and behavior. These in turn became the basis for developing the design conceptualization and later embodiment into the physical realm, nowadays represented in the digital form.

After the completion of design and engineering comes the production of designed/engineered artefact/product, thus, producing physical assets for the intended occupancy purpose. Once completed, the facility will be handed over to the client for its intended use. Now it is the tasks of the FM to maintain the good working and living environment throughout the years of its use. For that, information including about requirements, digital and physical assets is required for efficient and effective management of facilities, including operations and maintenance as shown in Figure 6. Moreover, during FM it is important to maintain the information integrity between these three different domains; e.g. when requirements change due to the changing needs of the owner/user, then physical and digital assets must be changed as well; when a building element/component is replaced with the new one or type, this change must be reflected also within the digital model(s) etc.

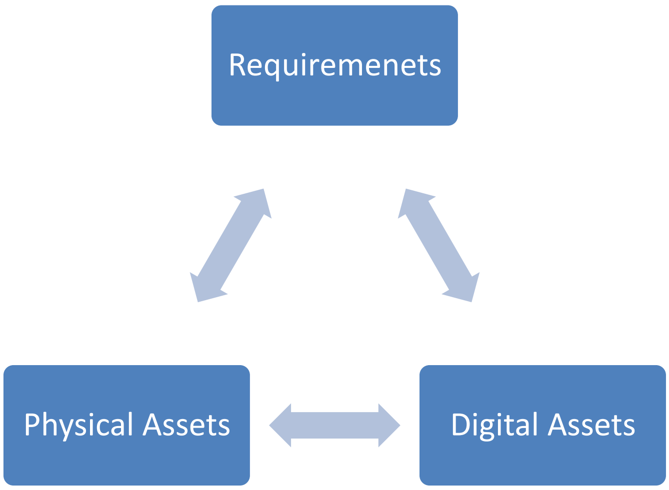


Figure 6. Relationship between requirements, digital assets and physical assets.

2 RESEARCH METHODOLOGY AND METHODS

The purpose of this research is to develop good understanding of FMBIM and its related information management concepts. This problem is two-fold, first we need to understand the information content of BIMs handed over to the owner during the different stages of the project as well as processes for planning, organizing, leading and controlling the FM information management. Considering the aims and the research questions, in this section the methods and research plan (with associated activities) are described.

Overall, mixed-methods research approach is used, including following methods for data collection, analysis and for drawing conclusions:

- **Secondary data collection –** compilation and analysis of data that was originally collected for other research purposes and by someone other than the author. Used within this research in the literature review and other introductory sections.
- **Questionnaire –** web-based questionnaire for FM related people to investigate the current state of the art and present state of FMBIM in Estonia.
- **Interviews –** with employees from FM organizations to validate the survey results and develop information requirement system.
- **Case study –** study formed to test the developed information requirement system on an existing project and validate its applicability.

These methods will be used within different stages of this study, which is divided into four main stages to find answers to the research questions listed in the introduction section:

- **First stage:** literature review about BIM in FM, with the purpose to understand the state of the art of BIM based FM. Including the review of existing BIM based FM software solutions (see Appendix 1) and information management concepts.
- **Second stage:** studying the state of the art of FM in Estonia:
    - Conducting web-based questionnaire among Estonian FM organizations in order to identify state of the art, problems with current practices and their expectations to BIM in FM;
    - Validation of the survey results through interviews with employees from FM organizations.
- **Third stage:** development of information requirements:
    - Development of the information requirements concept for FM;

    - Validation of the developed information requirements system within the context of the interviews;
    - Case study: implementation of information requirements on a test project.
- **Fourth stage:** based on the information from the first three stages conclusions are drawn.

Through these methods and stages, the study intends to make several contributions: to develop a good understanding of the current state of the art in the real estate management and maintenance; and to develop information requirements for BIM based FM. Research is divided into several sections, including the literature review, research methods and materials, state of the art of the FM in Estonia, FMBIM information management concepts and finally, the development and evaluation of developed information requirements concept.

3 STATE OF THE ART OF FACILITIES MANAGEMENT, MAINTENANCE AND BIM IN ESTONIA

In order to identify the current state of the art, practices, challenges and usage of technologies in FM, a questionnaire among specialists working within the Estonian FM organizations and interviews with five FM specialists were conducted. Firstly, the questionnaire and secondly, interview results are summarized, and finally, conclusions are drawn based on cross-case analysis between questionnaire and interviews.

3.1 WEB-BASED QUESTIONNAIRE RESULTS AND ANALYSIS

In order to find out about the current FM practices in Estonia, a web-based questionnaire (look at Appendix 2) was prepared. The main objective of this questionnaire was to identify the current state of practice within the FM industry, map the existing problems, and analyze the present state of FMBIM in Estonia.

This questionnaire was divided into 4 sections: **Part A –** Collection of information about respondents' general background and education; **Part B –** Questions about the current state in the FM, including the performance of information gathering and documentation; what FM applications are used; what are the main problems concerning the real estate management; and if the traditional methods are still adequate; **Part C -** similar to the second, but instead of management it concentrated on the current situation in maintenance of facilities, including the accessibility and quality of information, time expenditure for gathering relevant information, efficiency of preventive and corrective maintenance in current practice, the coordination and communication between different disciplines and the main problems concerning maintenance at the moment; **Part D -** of this questionnaire concentrated entirely on the possibilities for adopting FMBIM, including general knowledge about BIM, whether respondents believe it could be an effective step towards the future and if they are ready to implement it in their everyday work.

The questionnaire was compiled in the Google Forms and was forwarded to people working in the following companies or organizations: ISS Eesti AS, SOL Baltics OÜ, University of Tartu, Reminet OÜ, CityHaldus OÜ, Hooldusjuht OÜ, City Administration of Tartu, Tartu elamuhalduse AS, AS Saku Maja, Tallinn University of Technology, BRP Haldus OÜ, E.L.L. Kinnisvara AS, P. Dussmann Eesti OÜ, Riigi Kinnisvara AS, Ermeesia OÜ, DONE Haldus OÜ, Kvatro Kinnisvarahalduse OÜ and Majaabi OÜ. The final number of responses was 33. The final number of response is bit lower than expected, but large enough to show general trends to be validated through interviews.

3.1.1 Respondents Background

The first thing asked from the respondents was in which company they work. According to the responses received within the first question, we can predict that a large amount of answers might have come from RKAS, as 8 out of 13 (62%) respondents, who answered to this question. The remaining 5 respondents represented different companies.

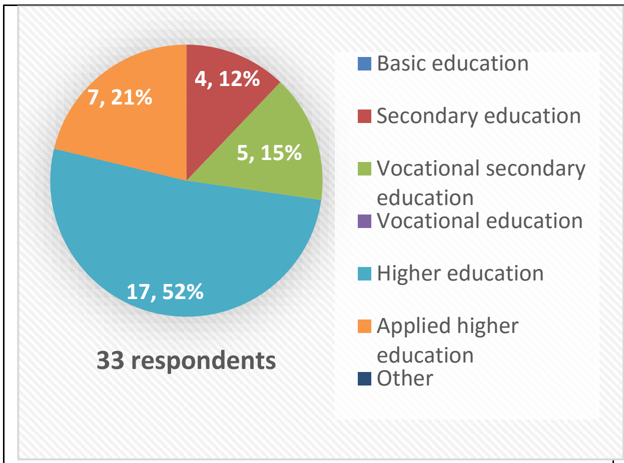
Secondly, the respondents were asked what their official job role was. Most of the respondents, 10 out of 32 (31% of the respondents) are working as a facility manager; 7 out of 32 (22% of all responses) are working as a head of administration; and 7 out of 32 (22% of all responses) claim to have different title than the ones provided within the list, which makes up in total circa 75%. The ones who chose „other" have following official titles: head of department, head of environment and energy, technical specialist, contract specialist, technical assistant, head of development, assistant/administrator. Four out of 32 respondents (13%) marked their official title as maintenance manager and the remaining 12% is equally divided between maintenance project manager and administration project manager (6%, 2 out of 32 respondents each).

As shown in the Figure 7a, all 33 respondents answered the question about the education level. As depicted, most of the respondents had either higher education (17 out of 33, making up 52% of the respondents) or applied higher education (7 out of 33, making up 21% of the respondents). Fewer had either vocational secondary education (5 respondents out of 33, 15%) or secondary education (4 respondents out of 33, 12%). Generally, specialists related to FM are highly educated with some exceptions.

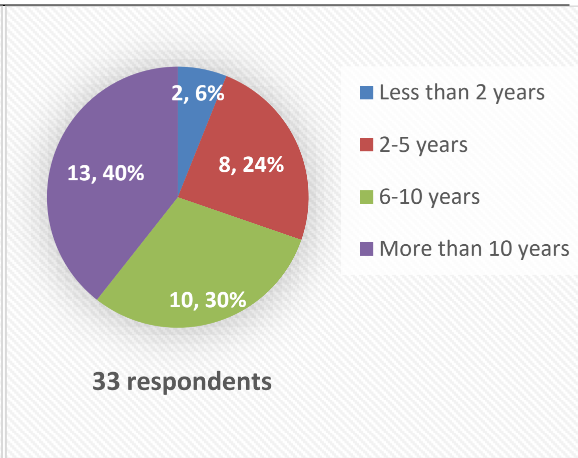
Figure 7b indicates the years of working experience in the field of facility maintenance and management. All 33 people answered to this question. The majority of them, 13 out 33 respondents (40%), have worked in the industry for more than 10 years; 10 people out of 33 (30%) have worked in the industry for 6 to 10 years, altogether making up 70% of all the answers. It can be concluded that most of the respondents are experienced in their field and have been actively working within the industry at least for 6 years.

Figure 7c summarizes the responses about professional certifications. Altogether this question received 28 answers from 33 possible: 46% (13 out of 28) marked their professional certificate as „Facility manager, level 4 or 5“;25% (7 out of 28) answered „Real estate maintenance foreman III or level 5”; the rest of the options were answered by 2 or less people. None of the respondents owned multiple certificates nor chose „Apartment building manager II” as their answer. Two people who marked their answer as „other” added a comment that they do not own any certification. It is safe to conclude that most of the respondents, 26 respondents out of 33 (almost 79%), own some kind of certificate in the field of FM.

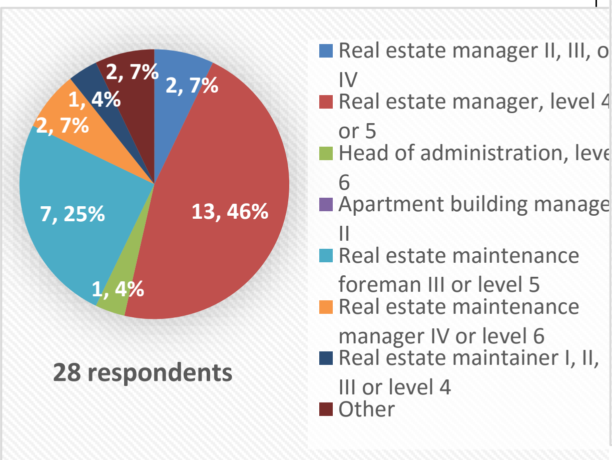
Finally, the respondents were asked how many different facilities they are involved with on average within one week. This question was answered by 32 respondents out of 33. As can be seen in the Figure 7d, 24 out of 32 (75% of the respondents) are related with the maintenance or management of more than 10 buildings on a weekly basis. 19% (6 out of 32 people) of the respondents said that they are involved with 7-10 buildings in one week. Finally, 2 people chose their answer from the remaining two options, one of them is involved with 3-6 facilities and the other with up to 3 facilities.



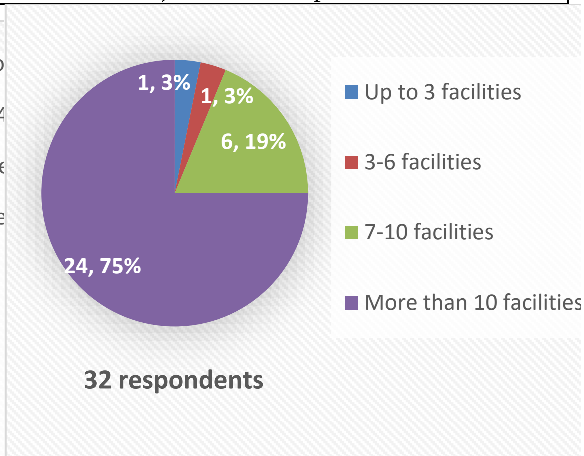
a) Respondents education



b) Years of experience



c) professional certificate



d) average number of facilities respondents are occupied with on weekly basis

Figure 7. Summary of all figures illustrating respondents' background information.

3.1.2 General practices and challenges

In the second part information about current practices and challenges were gathered. Questions related to the amount of information, quality, medium of information, tools being used etc.

The chart on the left in Figure 8 shows that 77% (23 out of 30) of the respondents believe that information for FM is insufficient. Problems brought out by the respondents, included: absence of user and maintenance manuals; owner's/client's lack of interest in the completeness of handover documentation; missing information and errors in the project documentation; and majority of information comes on paper making comprehension of received information without any help from the information source quite hard. Those who thought that the received information was insufficient, were asked to rate the completeness of the received information on a scale from 1 (not sufficient at all) to 5 (sufficient): 46% chose 3 (moderately sufficient), 25% of the respondents chose 2 (mostly not sufficient), 13% chose 4 (almost sufficient) and 8% chose either 1 (not sufficient at all) or 5 (sufficient) respectively. Although, generally the amount of information received after construction was considered to be incomplete, some respondents found that it actually depends on a certain project and context. There are ones that are just fine and others, which need much improvement.

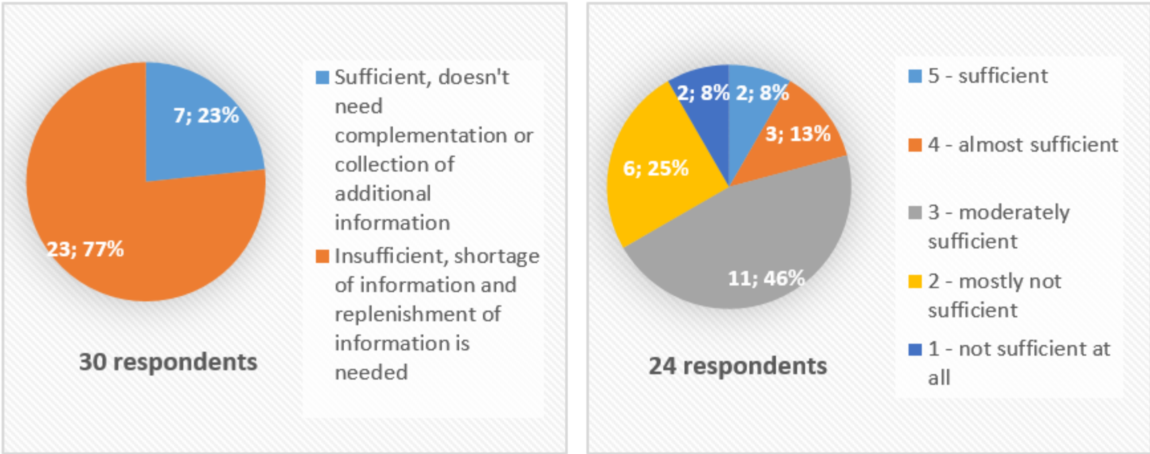


Figure 8. Respondents' opinion on information sufficiency (on the left) and information rate of completeness (on the right).

Related to the first question, respondents were also asked to rate the quality of the received information. Out of 30 respondents 16 (53%) believe that the information quality is not good enough and 14 respondents (47%) consider the received information to be decent. Similarly to the last question, most of the comments left by respondents say that there is a lack of quality in user and maintenance manuals. Also, it was brought out that documentation is often missing as-built data, which is unfortunate as the buildings' adequate management and maintenance depends heavily on the quality of as-built information.

In following, respondents were asked about the medium of the information received. Despite that most of the information is handed over to the owner/facility manager digitally (around 60%), much of information is still on the paper (43%). This in turn, and obviously also for another reasons, cause the double handling of information, meaning that facility managers must insert information manually, namely as shown in in the Figure 9, around 60% of the respondents believe that more than 40% of information must be re-inserted manually. It was also interesting to note that 4 respondents out of 8, who work for Riigi Kinnisvara AS, think that majority of the information comes on paper and needs to be inserted manually and other 4 think the opposite. The reason for this can be that information received at handover differs between projects, hence people's experiences are different.

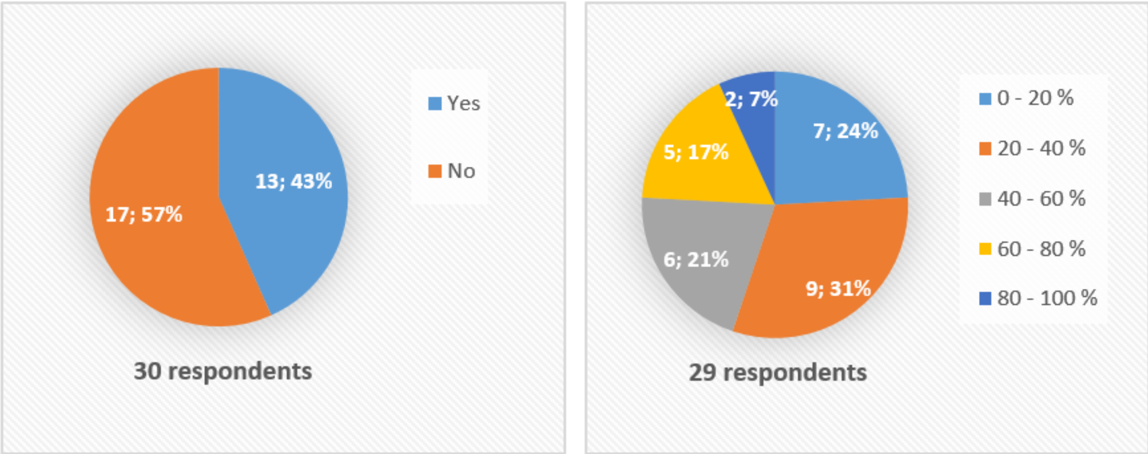


Figure 9. Respondents' estimation on the amount of information delivered on the paper or digitally (on the left) and percentage of how much information must be inserted again manually (on the right).

As most of the work in facility management is done in digital environment, different programs and technical capabilities form a huge part of the success. Respondents were asked what software is used mostly in current practice to perform facility management tasks. Respondents were provided with a list of different applications that could be used for FM, to choose from and an ability to add additional applications to the list if necessary. The results to this question can be seen on the bar chart in Figure 10. 90% use Microsoft Office products (most likely Excel and Word); 70% use different kinds of Autodesk products; and 63% use ARCHIBUS. Overall intelligent the level of using digital FM systems is relatively small. Some marked their answer as „other" and brought out 5 applications that were not provided in the initial list: ELKIS, SLX, Haldusnet.ee, BACnet, Korteriyhistu.net and application developed by the company itself. Responses are summarized in the Figure 10.

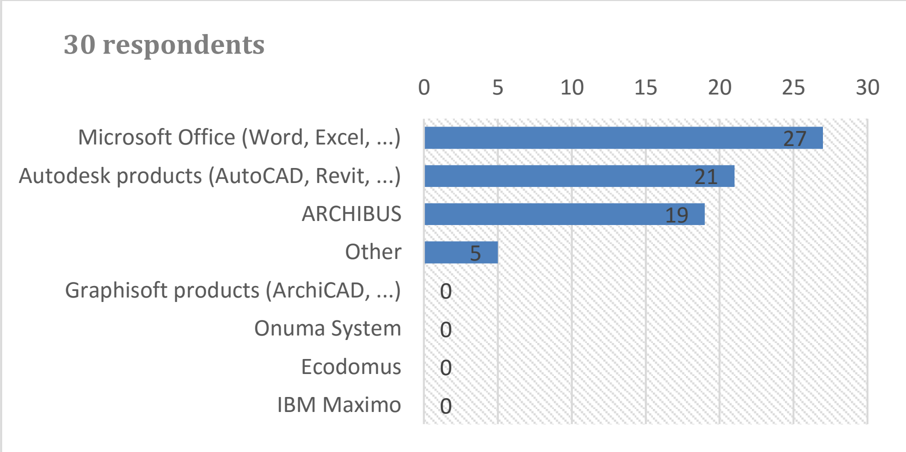


Figure 10. The number of respondents based on what kind of software do they use to perform FM tasks.

The fifth question in the second part was formed to identify what is missing in the current practice. Altogether this question received 27 responses as can be seen in the Figure 11. Out of three options suggested 59% of the respondents miss mostly the effective communication system, 56% of the respondents feel that there could be more decent FM application and only 30% of the respondents thought that there must be better local support system concerning FM software. 3 respondents brought out their personal opinions about what else is currently missing from the industry. One of them repeated that practical FM software is missed, where all the documentation could be stored, relevant management tasks could be executed and BIM in the FM. It was also stated that solutions for documentation and handover must be developed.

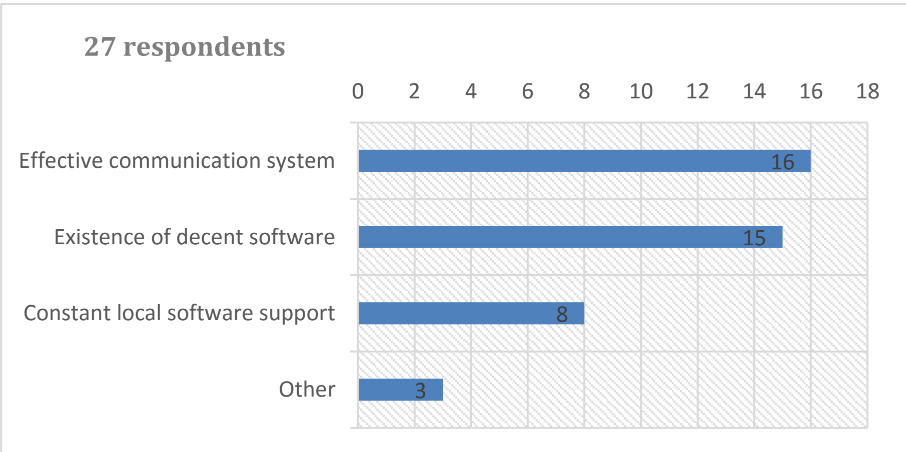


Figure 11. Responses on what solutions are missing in the current practice.

3.1.3 Maintanance operations

Overall, this sections is related to the second part, however the focus here is on the maintenance operations. The pie chart in the Figure 12 shows that all together this question received 32 responses rating the ease of access to the information on scale from 1 (very slow) to 5 (very fast). Most of the respondents, 12 out of 32 (38%) answered that the access speed to maintenance related information is satisfactory, but has room for improvement. 9 people out of 32 (28% of the respondents) believe that access speed is either very slow or slow. The remaining 34% of the respondents believe that maintenance information is easily accessible. Clear and understandable organization of documents and files was considered to be the key factor concerning the fast accessibility of maintenance information. It was brought out by the respondents in the comments section that accessibility of relevant information depends on the facility. Usually, the documentation for older buildings is rather more incomplete than in the new ones. In some cases, this information is kept in an archive in a completely different location, making accessing information even more problematic.

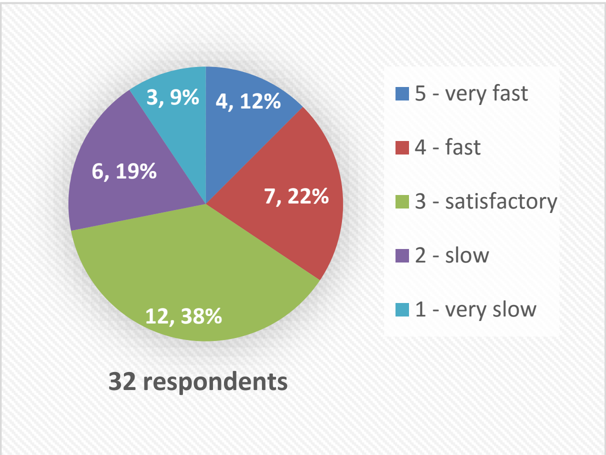


Figure 12. Ease of access to the information required for maintenance operations.

The second question studied about the major challenges, causing unnecessary time expenditure while gathering information for maintenance purposes. Respondents were provided with a list of activities to choose from and also had a chance to add activities if they felt it was necessary. The responses of this question are summarized in the Figure 13. The most time consuming activity was believed to be when information need to be found from paper documents. 58% of the respondents believed that communication inefficiencies between maintenance technicians and managers is another major issue.

Thirdly, 45% answered that acquiring necessary information is also an important issue. This means that when maintenance technicians perform their tasks onsite, but discover that they require additional information kept in their office (e.g. maintenance manuals), then they have to make wasteful journeys between the office and the site. Adding all these wasteful journeys together makes up a serious amount of wasted capacity and energy. Access to the relevant information digitally would save a lot of time and money.

Another issue is related to finding information about components' locations from 2D drawings, in total 8 people out of 31 related to this problem. Respondents were also given a chance to add their own thoughts and 4 people out of 31 used that opportunity. Three of them believed that poor documentation is one the main reason for wasteful time of gathering necessary information. Another respondent believed that currently used tools are inefficient as they are not easily accessible, such as an Excel tables. Additionally, it was brought out that the received drawings usually do not express reality as changes made during the construction are often missing from as-built documentation.

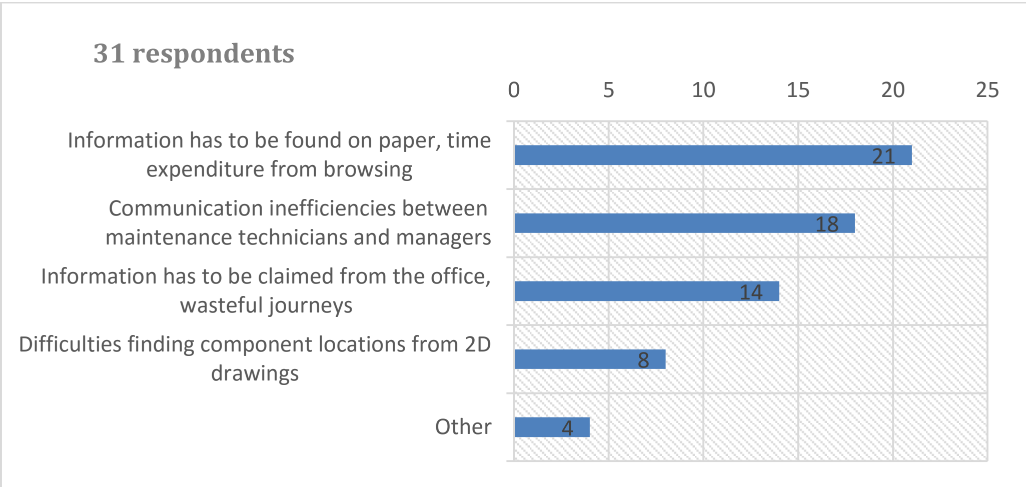


Figure 13. Main challenges causing unnecessary time expenditure while gathering information for maintenance task(s).

Moreover, respondents were asked if they thought that their company's work is coordinated well enough so that all the maintenance procedures could be executed with optimal efficiency. As depicted in the Figure 14, most, 20 people out of 30 (67%), believe that work in their organization is coordinated well enough and remaining 10 people (33%) think that there is something wrong with the current practice concerning work coordination. The respondents, who answered "no", brought out that more efficient software solutions are required the work inside the organization and staff has to be trained, how to communicate with each other. Also, respondents feel that feedback after performing maintenance tasks is incomplete or missing and there should be a way to rate the performance of the maintenance task(s).

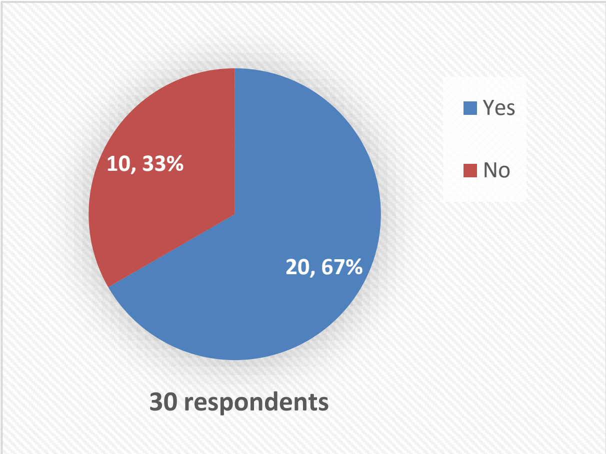


Figure 14. Respondents' evaluation on the efficiency of work organization in their companies.

In the following question it was asked if there is anything missing in the current practice. All together this question received 30 responses and the results can be seen in the Figure 15. Out of two options provided by the author, respondents miss digital access to the facility's documentation the most (67%). 16 respondents out of 30 (53%) believe that a decent software, which helps to coordinate and organize maintenance procedures, is missing and they would benefit out of its existence. In the comments section blow, authors brought out that all-encompassing cloud based FM application would be a major benefit. Two people out of 30 (7%) wanted to share their own opinion on what is missing in the current practice. One of them brought out that GIS (Geographic Information System) would be a nice addition to current practice and the other one claimed that competent maintenance personnel is missing.

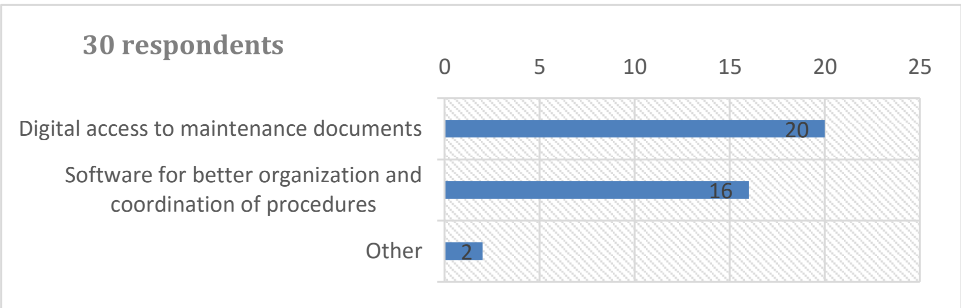


Figure 15. The number of respondents based on what they think is missing in current practice.

Finally, it was enquired whether respondents believe that current situation and traditional methods are still good and do not need improvement or they do. As shown in the Figure

16, 18 out of 31 (58%), believe that current methods are outdated and intelligent FM systems could be the way to improve state of the art. Still, 42% (13 people out of 31) think that traditional methods work fine and should not be changed. Respondents did add anything in the comments sections, why they believe so.

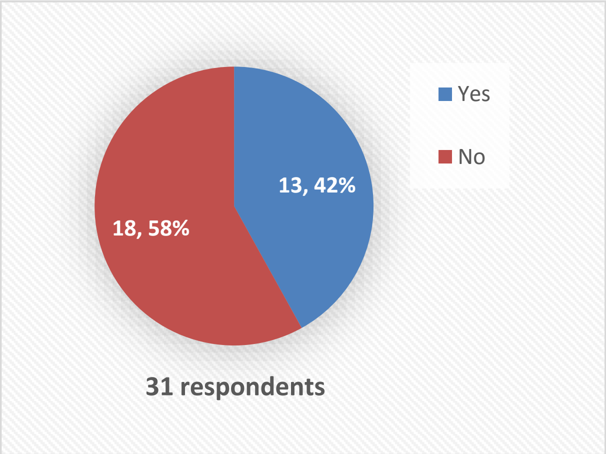
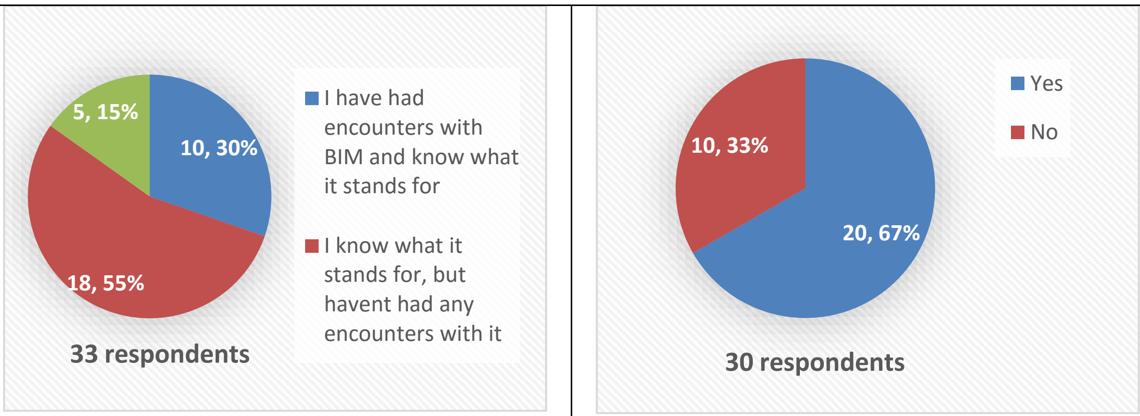


Figure 16. The number of responses about whether they believe that current situation and traditional methods are still good or not.

BIM in FM

The fourth and the final part of this questionnaire was formed to gather information about respondents' general knowledge and interest in BIM. The Figure 17a summarizes the results about common knowledge and encounters with BIM. All 33 respondents answered to this question and majority of them have heard of BIM. More particularly, 10 people out of 33 (30%) know what BIM stands for and have had some personal encounter with it. 18 people (55%) claim to know what BIM essentially stands for, but have never had any involvement with it and only 5 people out of 33 (15% of the respondents) have never heard of BIM nor come into contact with it. So in summary, 85% of the respondents are more or less familiar with the notion BIM, which indicates that something has been done to introduce BIM in the field of FM in Estonia.

However, the concept of BIM is rather new in the Estonian FM industry, meaning that traditional methods are still predominantly used. Therefore, respondents were asked whether they believe that transition from traditional methods to BIM would be wise. 30 people answered to this question and the results are summarized in the Figure 17b. Most believed that transition is necessary (20 out of 30) and remaining 10 people out of 30 believe it is not yet wise to transfer from traditional methods to BIM. Six respondents out of 10, who answered "no", explained why they think that BIM would not be the right direction at this point: even if the direction is right then the timing is wrong. Also, as the concept of BIM is relatively new in Estonia, they find it hard to see how the field of FM could benefit from BIM.



a) Knowledge of BIM and encounters with BIM | b) Is it necessary to switch to BIM

Figure 17. On the left if the summary of respondents knowledge and encounters with BIM and on the right their opinion about changing to BIM.

In following, respondents were asked whether the application of BIM seems scary because of all the new needed technological knowledge or interesting, because it creates new opportunities for more efficient work. 30 people answered this question and results can be seen in Figure 18. Majority (21 out of 30) of the respondents find application of the BIM to be interesting and are ready for change concerning their everyday work. 5 respondents out of 30 (17%) find the concept of BIM to be rather frightening and challenging, but they are willing to make necessary sacrifices in order to integrate BIM into their workflow. Remaining 4 people (13% of the respondents) are not ready to abandon traditional methods yet. However, 30 people out of 31 are willing to learn new software as stated in the response to following question: “would be open to learn new facility management software, which support BIM.”

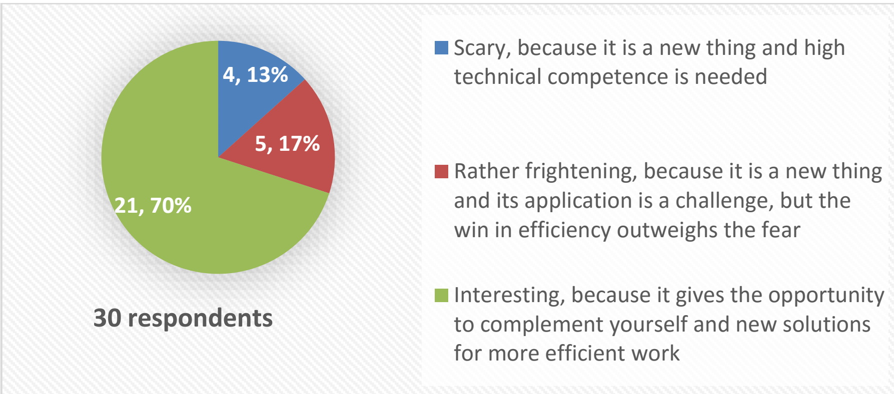


Figure 18. The number of responses if BIM seems scary or interesting.

The final question in the fourth part, as well as the final question in the whole questionnaire, examines whether the respondents think that the application of BIM is inevitable in the near future. 29 respondents answered this question and the results can be seen on the pie chart in Figure 19. Answers divided quite evenly in this questions. 15 out of 29 (52%) believe that BIM will become the state of the art in the field of FM and 14 respondents out of 29 (48%) believe that BIM is not necessarily going to be inevitable. It was brought out that application of BIM depends largely on legislation. If the use of BIM is not made mandatory by the law, then it is impossible to demand its use and no one will probably try to apply it independently.

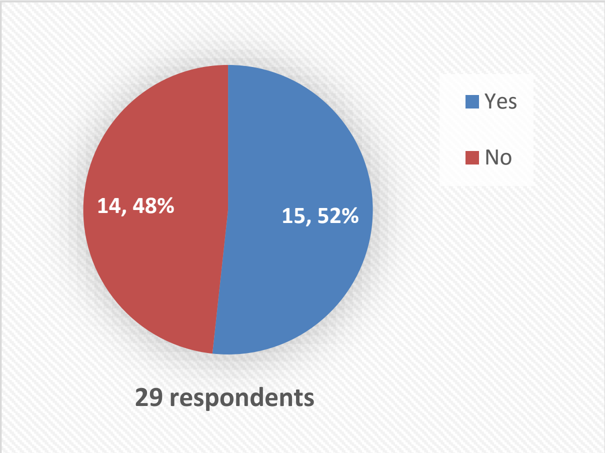


Figure 19. Whether respondents believe that the application of BIM is inevitable in the near future.

3.2 INTERVIEW RESULTS AND ANALYSIS

In order to validate the results of the questionnaire, 5 interviews were conducted (questions and structure of the interview can be seen in the Appendix 3). Specialists working in the field of FM were questioned. The general purpose remained the same as in the questionnaire, to investigate the current state of the art of FM. But unlike the questionnaire, interviews gave the opportunity to get more in-depth responses, which helped to examine current situation more deeply, possibly find reasons why the state of the art is seen in a certain way and to get opinions on the possible solutions for improvements. As a part of this interview, interviewees were also introduced to an information requirement system (introduced in depth in section 4), developed in the context of this thesis, in order to validate its applicability into the field of FM.

The interview consisted of 3 parts. The **Part A** was generally about understanding respondents' background and everyday challenges. The **Part B** was formed to examine the problems concerning current state of the art in Estonia, interviewees' standpoint on BIM and BIM compliant FM software. The **Part C** of this interview was formed to validate the information requirement system developed in the context of this research. As the information requirement system is yet to be described in Chapter 5.

Interviews were from the following companies or organizations: one from Ermeesia OÜ, one from EKHHL (Eesti Kinnisvara Haldajate ja Hooldajate Liit) and remaining three from Riigi Kinnisvara AS. Interviewees were chosen under a criteria that at least two would represent facility maintenance sector and two facility management sector, so that both sectors thoughts on this matter would be brought out.

3.2.1 General Information about the Interviewees

Interviews started off with a question about interviewees' official work title. Two people out of five are working as a facility manager, one as maintenance project manager and the other one as a CEO of a well-recognized facility maintenance company. The fifth person was the chairman of the board in EKHHL, having several decades of experience working in the different positions involved with O&M.

Secondly, interviewees were asked to describe their main responsibilities arising from their profession and what kind of problems they are facing while performing everyday tasks. The content of the facility managers' work was similarly as they work on the same position in the same organization. Main responsibilities were summed up as performing tasks concerning facility management and following detailed activities were listed: solving clients' problems; organizing maintenance of facilities and real estate; short and long term planning concerning managed facilities; communication with clients and making sure that they are satisfied with the service; fulfilling clients' wishes; communication with maintenance personnel etc.

As well as responsibilities, problems preventing them from performing their everyday tasks were overlapping almost entirely. The main issue regarding their work was the lack and quality of the relevant information. Quality is worse in the the old buildings and better in new facilities. Often, plans, drawings, user and maintenance manuals are also missing. Another issue mentioned was regarding the warranty issues concerning newly delivered or finished facilities as they had to constantly wait for someone.

Maintenance project manager’s main responsibilities included the procurement of facility maintenance services, consulting facility managers, updating procurement documents and solving urgent problems.

3.2.2 Problems Concerning Information Gathering and Accessibility

The first question in the second part was consisting of three questions. Firstly, interviewees were asked what the main problems with information handover are after construction and everyone agreed that there are several problems. These include missing or inadequate maintenance and user manuals, certificates and as-built drawings. Furthermore, some information is still on the paper documents, digital information is not well organized and facility managers are involved too late to the process. Due to these issues, in practice a lot of work is performed through observations. The information quality is not necessarily bad in every case, situation is better with new developments, because of the better supervision during the design and construction of the new facility.

One of the interviewees also brought out why problems with digital information might occur. He stated that when it comes to performing maintenance tasks, there is no good technical solution that would help to work with large files. Moreover, when one wants to work with several files at the same time, the problem is more serious. It has been recommended that some kind of a simple project bank is needed, to manage and organize information in easily accessible manner.

Interviewees were then asked to identify the reasons why these previously mentioned problems might be occuring:

1. Construction company only takes care of the minimum and if client is not persistent, then often quality of the documentation process will be very poor.
2. There is no proper procedure from the client side to verify the documentation at the handover, therefore, resulting in poor quality of as-built information.
3. Some companies tend to add irrelevant documents into the folders, creating a false illusion so that the owner/client would accept the documentation.
4. Poor organization and management issues on the site cause the disappearance of some information.
5. There is no person dedicated to the documentation of assets and construction processes.

6. Lack of interest from client/owner, who is more interested in making money as soon as possible.
7. Building Code of Laws (Ehitusseadustik) in not very clear concerning maintenance and user manuals, causing confusion. For example, there is a point that says „user and maintenance manual, hereafter maintenance manual“. These manuals are different things and must not be mixed up.
8. Money for documentation is paid up-front, making the construction organization lose interest in the quality of the documentation.

The second question in the Part B was also consisting of the three questions. These three questions examined whether these previously mentioned problems could be eliminated, what could be the possible solutions and has something been attempted by the interviewees in order to eliminate these problems.

Everybody agreed that information quality issues could indeed be eliminated. Some solutions provided by the interviewees were quite similar, yet others completely different. One of the solutions, which was brought out by 3 people out of 5, was strictly demanding complete set of documents from the beginning of the construction process. Facility managers must be involved already during the design to prevent problems. There are probably many ways to demand for the complete set of documents, but it was brought out by 2 interviewees that withholding money is probably the most influential. Money is a good sanctioning tool and all the payments should be postponed until all the necessary documentation is delivered and its content is verified. Another solution mentioned by an interviewee was to use custom agreements.

One of the interviewees believes that in the end everything comes down to people and their occupancy. If sufficient amount of human resource is existent, then it is possible to demand documentation that is complete, if sufficient amount of human resource is non-existent, then you can keep demanding, but you will not get any results. Everything that is necessary to be handed over by the law is probably being done, but as the information quantity is huge, no one really has the manpower to verify the quality.

The third question in the second part focused on what the interviewees think of intelligent BIM based FM systems as an opportunity to solve information gathering and availability issues. Generally, interviewees believed that BIM compliant FM systems are great and a step towards the future. Following benefits were listed: better visualization, easy access to information, all information in one place, easy communication to new workers and better communication opportunities. Joint access based on the appropriate role management to the system would make everything a lot easier, as everyone would have the possibility to obtain relevant information and even make changes to it if necessary. Interviewees also mentioned that manual facility management cannot be efficiently executed anymore, because of the large volumes of information. For example, if one organization has hundreds of sites in its portfolio and each site contains multiple buildings, then keeping paper records about all of it is near impossible.

Although generally BIM based FM systems were considered very welcome, then it was brought out that their necessity largely depends on organization's needs. Big organizations definitely benefit from it, but smaller organizations seek simplicity and speed. Main concern about these systems, brought out by most of the interviewees, was who inserts all the information and more importantly, who keeps it up-to-date. Behind every system are people and if no one manages it and inserts information into the system, then it does not fulfill its purpose. BIM can only be efficiently used when it consists of up-to-date information. Interviewees also had an important concern regarding models. What happens when some parts of the information model are updated and some not, then how does anyone know at end what is the latest version is and which parts are up-to-date.

Interviewees generally agree that introduction of BIM based FM applications is going to be hard in the near future and implementation process is going to be long in Estonia. Majority of the interviewees brought out that a big problem with these systems at the moment is the fact that they provide solutions for bigger organizations and seem less appealing to smaller ones. It was mentioned that small companies do not have enough money to invest in a software license and staff training. Also, smaller companies do not see where they could find the time for initial implementation and FM companies in general do not really understand how they could benefit from BIM. Additionally, if only few people independently have to cope with all the changes that BIM brings, implementation is going to be difficult. Content would become too huge for smaller companies to handle.

Other problems associated with BIM, brought out by the interviewees, were the need for additional human resource and low technical competence of personnel. A strong team and support system for BIM is essential in the implementation process. Companies would need to hire someone to manage BIM models. Whether it is an employee or a company providing that kind of service, they would have to do the work for very reasonable price at the beginning for the concept to be appealing.

Interviewees suggest that one way to smoothen the transition from traditional methods to BIM is if the government would help the smaller companies with it. BIM is believed to be the right path and is coming anyway, but the process has to be handled delicately. Applicants wishing to make the transition should be helped with finding the right technical solution, helped with the implementation process and helped with personnel training. Government should at least partially pay for these activities, so that everyone or at least most of the companies would like to make the transition to BIM. If that opportunity is not used by smaller organizations, then later they have to cope with the situation and the consequences on their own.

Most of the interviewees share the standpoint that some real steps have to be taken if the widespread implementation of BIM is really the desired result. It must be publicly apparent that BIM is actually coming, conclusive concept is actively being worked on and it becomes the standard in the field of FM on a certain date. Then everyone knows what to expect, everyone sees that BIM is not just an idea and everyone can use the remaining time to bring everything into accordance, indicatively with the assistance of the government.

3.3 SUMMARY OF QUESTIONNAIRE AND INTERVIEW RESULTS

Questionnaire and interview respondents believe that current practices are outdated and innovation is required. Most of the problems existing are related to poor information quality and its accessibility. It was often cited that the quality of the FM information at the handover is very poor, whether missing user instructions, maintenance manuals and/or as-built information of building units. It was generally agreed that something needs to change, otherwise the state of the art will not improve.

Furthermore, despite the 21th century, relatively large amount of real estate information management is still paper based. With all the technological capabilities existing today, archives should be replaced with databases, and project banks and information must be made easily accessible. As the world is constantly changing, methods and techniques also need to evolve. Excel together with AutoCAD is still applicable, but the development and implementation of new technologies must be encouraged.

In most cases it was admitted that considerable communication issues, logistical issues, documentation browsing related issues etc. are existent. Also, the need for a new FM software for better coordination and organization of workflow is required. The state of the art could be improved significantly with the introduction of FMBIM.

Most of the respondents had heard of the term BIM and at least partially know what it stands for. Respondents also agreed that BIM could be considered as a great innovative solution, however, it was stated in the interviews that transition to BIM in the next couple of years would be almost impossible. It is not yet appealing for the field of FM for the following reasons: benefits of BIM are not yet widely understood, software developers mostly provide solutions for big organizations, the issue of who manages the model and keeps information up-to-date etc. Most importantly, it was brought out that the owners of real estate lack the knowledge and understanding of BIM, which probably can be considered as one of the major impediments of implementing BIM technology.

4 FMBIM PROCESS AND INFORMATION REQUIREMENTS' CONCEPTS

In this section of the report, the focus is on studying and analyzing internationally recognized FMBIM information exchange concepts, requirements, and strategies and processes. Specifically, the focus is on the required information content of exchanging building information during the different project life-cycle stages. For that, we need to understand the FMBIM strategies; life-cycle facility related to the FM; geometric information requirements; non-geometric information requirements; LOD (Level of Development) and construction information classification systems.

4.1 FACILITY LIFE-CYCLE AND INFORMATION REQUIREMENTS' CONCEPTS

Gaining the maximum benefit of using BIM for the purpose of FM, facilities must be seen from the perspective of the whole lifecycle. Figure 20, proposed by Jokela et al. (2010), illustrates modeling and BIM management as a process that covers the building's life-cycle. It starts from setting the targets (red triangle) for life-cycle data management, progressing from design to construction and commissioning, handover of the as-built models to the property management, and further, managing and updating the models during operation and facility management. The greatest benefit and cost savings from modeling are obtained when the construction project data can be transferred to facility management's use with up-to-date and adequate content.

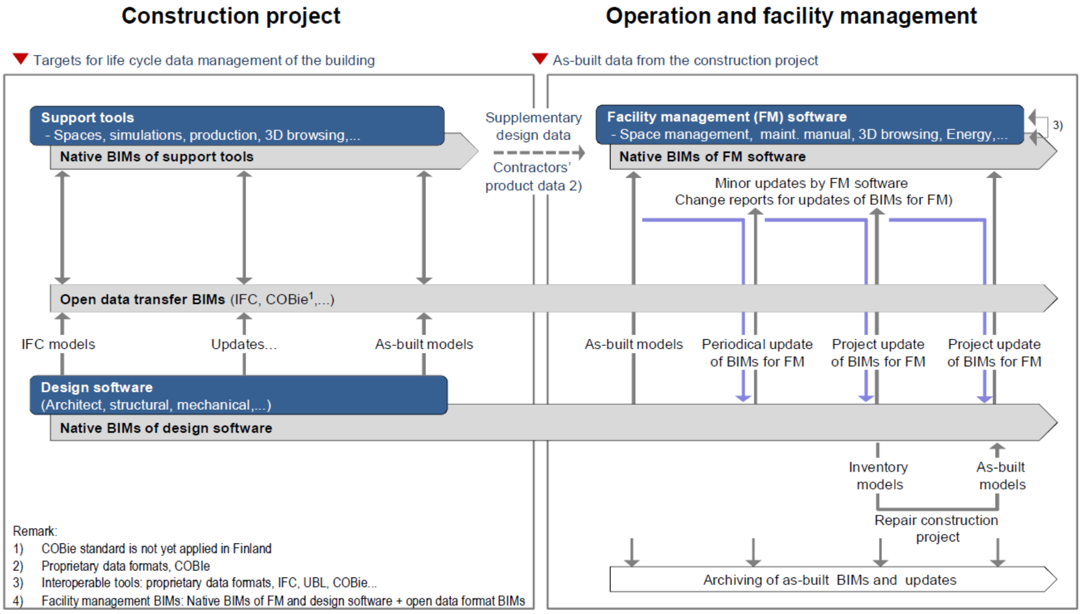


Figure 20. BIM management process during the building life-cycle. (Jokela et al., 2010)

An example of using AEC project data to support FM processes has been given in Finish Common BIM requirements by Jokela et al. (2010). Authors also state that it could be used to outline building information modeling objectives, planning software procurement, etc. On the large scale the information has been divided into three categories:

- Spaces and space groups (zones);
- Building systems, equipment and parts;
- Project documentation.

These categorize have been further divided into sub-categorize delivered by different disciplines (architects, engineers and contractors), see the Figure 21.

Construction project						Operation and facilities management		
Construction project data	Docs.	Native BIMs		Open data transfer BIMs		Facilities management data to FM BIMs	Technical visualization by FM BIMs	Support to property management processes
	PDF file	Design tools	FM tools	Req.	Design			
Spaces and space groups (zones)								
Base data of spaces (Arch.)		Min.		Min.	Min.	Work place data	Theme charts:	Rent management
Condition targets (MEP)	Min.			Option		Rent and service contract areas	- spaces	Tendering and service contracts
Technical services of spaces (MEP)	Min.			Option		Condition measurement data	- space groups	Planning of repair construction projects
Classification of special spaces (MEP)	Min.			Option		Cleaning areas and requirements	- attribute data	Maintenance planning and budgeting
Zones of technical systems (MEP)	Min.			Option		Repair needs		Security management
Zones of consumption measurem. (MEP)	Min.			Option		Access permissions and routes		Management of accesss rights and keys
Consumption targets	Option			Option		Keys		
Environmental classification	Option			Option		Official inspections		
Building parts, systems, equipment								
Building part model (Arch.)		Min.			Min.	Preventive maintenance plan	2D/3D graphics:	Tendering and service contracts
Structural model (Struct.)		Min.			Min.	Maintenance and repair history	- building parts	Planning of repair construction projects
System model (MEP)		Min.			Min.	Service requests	- systems	Maintenance planning and budgeting
Supplementary design data (All)	Min.		Option			Consumption data	- equipment	Management of repairs
Contractors' product data	Min.		Option					Management of service requests
Measurement and inspection data	Min.		Option					Monitoring of conditions
Operation and maintenance instructions	Min.							Monitoring of energy consumption
								Monitoring of environmental impacts
Construction project documents								
Design documents	Min.					Document archiving data		Guarantee inspections and repairs
Contract documents	Min.							Planning of repair construction projects
Construction and commissioning documents	Min.							

Remark:
1) to be agreed in each project:
- space model or building part model

Min. = required in all BIM projects
Option = to be agreed in each project

Figure 21. Examples of potential use of construction project data to support property management processes. (Jokela et al., 2010)

4.1.1 Construction Operations Building information exchange

COBie is a Model View Definition for exchanging information between suppliers (designers, engineers and contractors) with facility personnel (see also Appendix 4). Thus, in this sense, it is a tool to collect and transfer the data from the engineering systems to FM systems, preferably to FMBIM systems (East, 2013). In terms of the lifecycle, COBie divides the process into three stages: design, build and operate (East, 2007).

Designers can use their tools such as Autodesk Revit and its plugin for COBie and ArchiCAD to export the necessary information into COBie format (typically an Excel spreadsheet). According to COBie standard, this information must include data about layout (sections, floors, rooms and zones), spaces, and system and equipment type. Contractors must deliver product data and all the related documentation, and as-built models. Then, all this information becomes a basis for FM, as asset, space and FM process management systems can be populated with the required information.

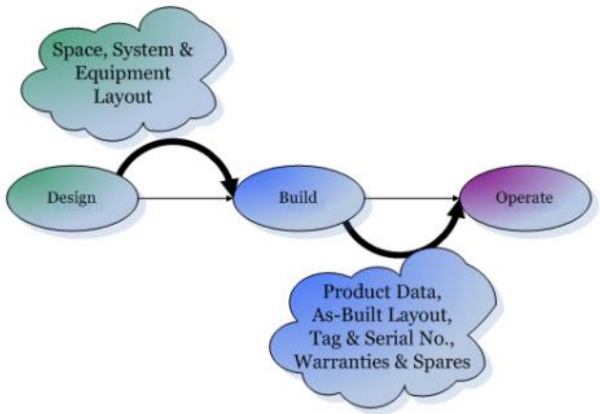


Figure 22. Generic COBie process of exchanging information (Nisbet, 2012).

However, each one of the FMBIM application areas shown in Figure 21 is data intensive and has specific process and personnel data requirements. Thus, it is a major challenges to define these data requirements, meaning who and when must provide the data of facility throughout the project lifecycle, which will be addressed in following sections**.**

4.1.2 Level of Development

The information collected throughout the project life-cycle varies significantly in terms of geometric precision, detail and information content. Several concepts for model specification progression have been proposed: level of development (Gerdano, 2013), model progression specification (VICO, 2013), level of detail (LOD) and data drops (Group, 2012).

Generally, the idea is the abstraction of an evolutionary aspect of the AEC project, from inception to utilization. LOD is a conceptual framework, describing the relative development of individual model elements in their journey from conception to realization. Classifying the elements on the LOD scale indicates how much it can be relied on for decision making purposes. The purpose of it is to simplify the communication between project members and standardize the model content, which elements and its related attributes must be in the model and who is responsible. All this means that BIM elements represent the accumulation of common project knowledge.

The intended use of a model directly affects how it is modelled and what data is included. Like any product, it is important that potential users of a model have a clear understanding of its intended purpose and any limitations associated with its use. For example, if models are used for simulating the energy efficiency during the conceptual design stage, then model should include elements/components and descriptions about following: geometry, occupancy, environment (whether and contextualization) and properties of the chosen components/elements/systems (e.g. windows, walls, roof, floors, building services etc.).

NATSPEC (2013) has indicated following key aspects of LOD:

- LOD scale represents the level of element maturation but not the model as a whole, from conception in the mind of the designer through to their construction and operation.
- Information associated with model elements is as important as the development of geometry, and is integral to its LOD.
- LOD is a valuable project management tool as shown in Figure 23, it can be used to define the roles, responsibilities of developing the model content. When documented in an LOD Table, it can serve the following purposes:
    - As a common reference for stakeholders planning model development.
    - For recording agreements made about model deliverables.
    - For planning and coordinating project resources.
    - For communicating project requirements to team members and organizing their workflows.
    - For monitoring progress against the project program.

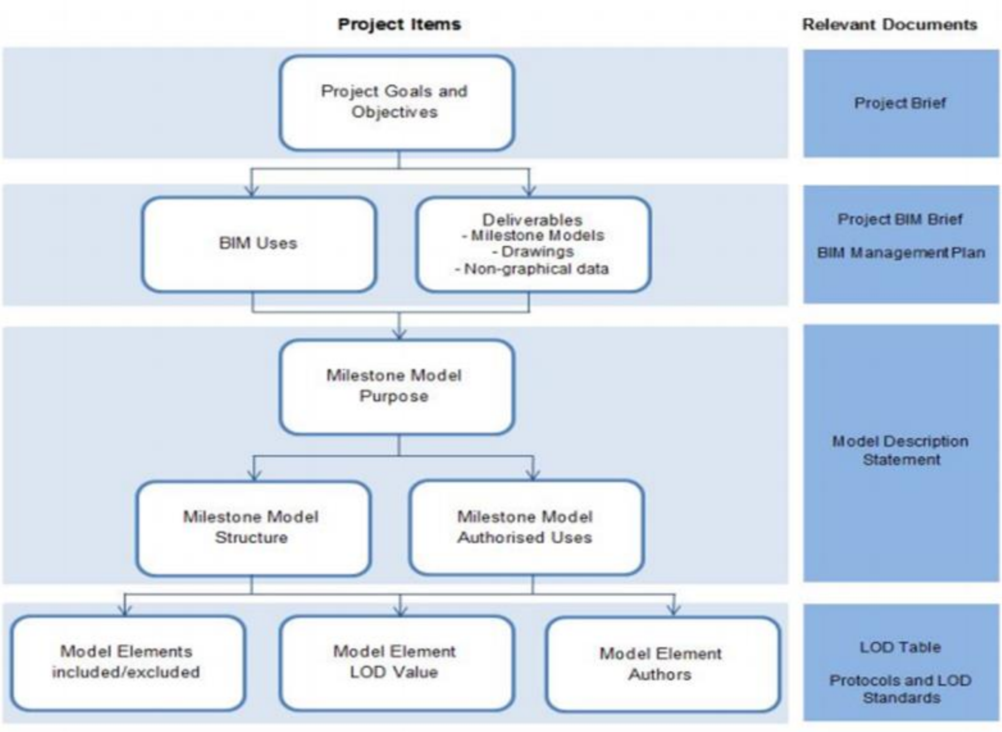


Figure 23. LOD tables as a project management tool (NATSPEC, 2013) .

- LOD is a means to an end. LOD is meaningless without clear definition of the model's purpose or intended uses, thus it is an ends-means relationship. In this case the main use is FMBIM.
- The resources devoted to developing and maintaining LOD Tables should be proportional to the degree that they assist management of the project.
- When implementing LOD on projects it is recommended that existing standards defining model element geometry and data content are referenced and an existing LOD Table format used to document the LOD values required for each element at nominated project milestones.

LOD is not a direct indication of a project stage, elements can have a different state of maturity at the different project stages. In following generic descriptions for each of the LOD levels are proposed:

- LOD 100 – Conceptual, generic representation of geometry;
- LOD 200 – Approximate geometry and general requirements;
- LOD 300 (350) – Precise geometry and requirements for products and parts;
- LOD 400 – Precision needed for fabrication;
- LOD 500 – As-Built geometrical representation, actual properties and documents of chosen products and parts.

When it comes to facilities' maintenance and management, provided model content must be level 500 in order to accurately represent the facility, so management can manage building and make decisions based on how they were actually built.

NATSPEC (2013) has indicated that it is better to use existing standards, unless there are any specific overriding project requirements. The rationale for this is that typically AEC projects go through similar life-cycle stages. An example of using BIMForum standard and NATSPEC BIM Element Matrixes for the description of element geometry resolution and content is given in Figure 24.

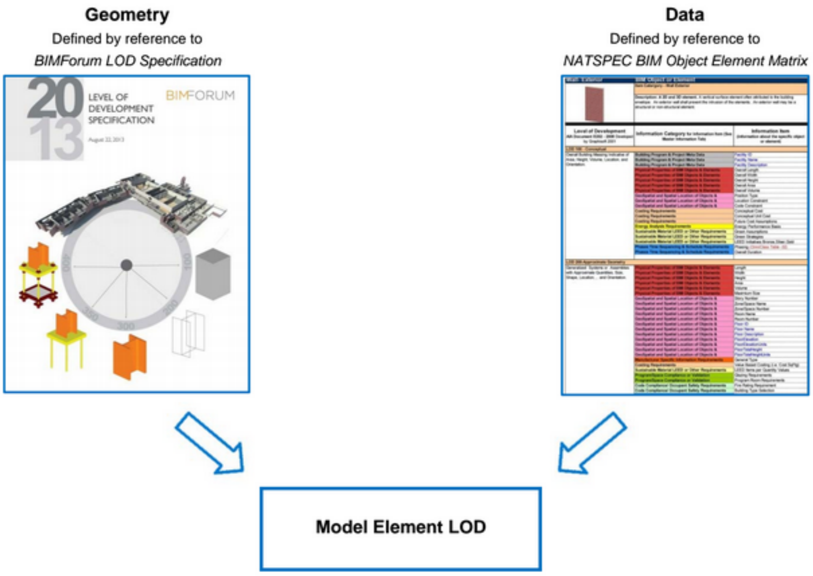


Figure 24. Defining the LOD by reference to standards. (NATSPEC, 2013)

They have also proposed the following specific recommendations:

1. Define the geometry of each model element for each nominated LOD by reference to a standard (e.g. The BIMForum LOD specification).
2. Define the data content of each model element for each nominated LOD by reference to a standard (e.g. NATSPEC BIM Object Element Matrix).
3. Use a standard LOD table to document the LOD of individual model elements at agreed times, preferably spread sheet-based, (e.g. USACE M3).
4. Use a standard for the protocols to be observed by team members when collaboratively managing model development on the project.
5. Document agreed standards and any variations to them in the BIM Management Plan.

In summary, no matter how it is called, LOD must be considered as a minimum requirements – i.e. an element has progressed to a given LOD only when all the requirements stated in the definition have been met – to be meaningful for its intended use, e.g. for energy simulations, quantity take-off etc. These requirements are cumulative representation of project knowledge – for a given element each LOD definition includes the requirements of all previous LODs. Thus for an element to qualify for LOD 300 it must meet all the requirements for 200 and 100 as well as those stated in the LOD 300 definition.

4.1.3 Construction Information Classification Systems

Construction information classification systems (CICS) must cover entire project life-cycle and built environment (Gelder, 2012), for utilizing and making information accessible for project stakeholders (Kang and Paulson, 2000) (see also Appendix 5). CICS is categorization of information and objects according to particular characteristics (Jørgensen, 2010). In NATSPEC report the following use have been summarized for CICS (NATSPEC, 2008):

- Organizing reference material on construction products, technical matters, costs etc.;
- Structuring the contents of individual documents in a consistent manner;
- Coordinating information between individual documents found in sets of documents;
- Facilitating communications between different members of a construction project team;
- Facilitating interoperability of digital systems.

Some of the globally well-known CICS are Uniformat, Masterformat and Omniclass in the US; Uniclass and Uniclass2 (unified classification) in the UK; BSAB 96 in Sweden; DBK 2006 in Denmark; NS 3451:2009 Table of building elements in Norway; and Talo 2000 in Finland (RAKENNUSTIETO, 2013, McGregor, 2001). Most of these CICS follow the framework proposed within the ISO 12006-2. In Estonia there is not specifically good standard for FMBIM but the best practice at the moment has been the mixed use of standard EVS 885 and TALO 2000.

4.1.4 BIM authoring applications

As IFC has become a standard in the AEC industry, project teams are often required to use BIM-authoring applications IFC compliant. For example, GSA in the US requires that the application at a minimum must be able to create IFCs in compliance with the coordination view, spatial program validation view, and COBie MVDs' (Administration, 2011). Moreover, in projects it is required to coordinate the usage of applications, its version and compliance to client's needs. For example, client's FMBIM system may only support certain version of Autodesk Revit.

4.1.5 Asset identification number

The lifecycle view of a BIM requires tracking what changes are made, when and by whom, over the life of the facility. Changes must be tracked at the element or component level, not at the file level. Thus, each object within a BIM needs to have a unique identity that can be referenced as changes occur.

Within the software community, this unique identifier is implemented as a Globally Unique Identifier, or GUID. The concept is that a GUID is a totally unique number – one that will never be generated twice by any computer in existence. While each generated GUID is not guaranteed to be unique, the total number of unique keys is so large that the probability of the same number being generated twice is very small. GUIDs are typically managed by the software and not under control of the user.

Some early BIM adopters discovered that certain BIM applications "recreated" the model and assigned all new GUIDs to the BIM objects. In order to ensure that client/owner and its consultants and contractors can manage each BIM object's unique identifier, each equipment object shall have an Asset Identification Number in addition to the GUID (Administration, 2011).

4.1.6 Geometric Information Requirements for FMBIM

Naturally, up until now, most discussions have focused on the geometric data requirements for BIMs to be implemented in FM. Some of these requirements include (Administration, 2011, Becerik-Gerber et al., 2011):

- Accurate as-built models of all building components, including architectural, structural, mechanical, electrical, plumbing, and fire protection systems, and site plan including safety accesses;
- Accurate as-built model for main utility lines to the buildings;
- Accurate telecommunication representations, including proper placing and annotation of outlets;
- Labeled, annotated, and colored spaces according to FM guidelines, which should include standards for space type, description, space usage, and so on;
- Built-in schedules in the model; and
- Logical object tree organization to manage the various components within the model;

- Accurate clearance requirements for mechanical, electrical, and plumbing (MEP) equipment to provide maintainability based on technical specifications.

Non-Geometric Information Requirements for FMBIM

Increasingly, non-geometric data is required to support successful implementations of BIM in FM. This section, specifically, focuses on building components (equipment, materials, and finishes). Although non-geometric data requirements for building components are by no means the only data requirement for BIMs to support FM practices, they are needed for the majority of the application areas outlined in the previous section 4.1.

Becerik-Gerber et al. (2011) have proposed the data classification in Figure 25, illustrating the data classification on the basis of the sequence in which the data should be captured throughout the project life cycle.

Figure 25. Data structure for non-geometric data requirements by Becerik-Gerber et al. (2011).

Data content increases substantially from top to bottom. This data should be identified and captured through a workflow at different stages of a project. At the beginning, service zone data such as site, building, floor, room, and zone for each building component should be determined and captured in BIM, at a minimum. The nomenclature and numbering usually follow standard naming conventions of the manufacturer’s and organization’s numbering systems. Therefore, component nomenclature and unique identification numbers should also be defined in BIM to interlink the equipment with FM systems (Becerik-Gerber et al., 2011).

Data related to a component's group and type should also be classified on the basis of industry standards (e.g., Talo, Uniformat, Masterformat, or Omniclass) or FM organization-specific standards. Classifying equipment, materials, and finishes into groups and types can facilitate the assignment of data for similar component instances (Becerik-Gerber et al., 2011).

Next, manufacturer and vendor data such as the model, serial number, acquisition source and date, warranty vendor, expiration date, and usage should be identified and assigned to the components in BIM. Upon determination of the service zone, group, type, and manufacturer/vendor data, component specifications and attributes should be added in BIM. In addition to operating conditions, specification and attribute data could be related to a wide range of activities from installation to operation and maintenance. Some examples of specification data are type, value and unit, and description. Some of the technical attributes of components include weight, power, energy consumption, and spare parts (Becerik-Gerber et al., 2011).

4.1.7 Information Requirements Based on the Estonian Ordinance

More detailed overview of information requirements based on the Estonian legislation is given in Appendix 6. In Estonia, the ordinance 'Requirements for the Preservation, Maintenance and Submission of Construction Documentation and Facility Maintenance Guide' establishes the general objectives and general requirements to the construction documentation (§ 3): the head contractor is responsible for the proper documentation of construction and assures that the other contractors (typically sub-contractors) follow the documentation and preservation requirements; and construction must be documented systematically in chronological order and in categorized manner. Documentation must enable to identify:

- Construction quality and proficiency;
- Installed materials and products;
- Covered construction elements, structures and details' location and compliance to Construction Project/Design Documentation;
- Person responsible for the facility construction or its element.

In addition to document content, each document meta-data must include information about document time, location, creator or creators participating in the documentation and signing of it. The information and documents about the assets built must be compiled right after the completion of construction task/activity. Document must be signed by responsible person at least three days after it is crated and made available to client/owner either physically or in real time over the web-application.

Instructions and installation manuals must include all the necessary information for installing, identifying, using, maintaining, cleaning and utilization of facility and its spaces, elements, materials, equipment and products. Also necessary information for emergency situations. Additionally, documents must include information about building elements' serviceable time, list of jobs for maintenance and cleaning, maintenance interval, energy need, instructions for energy saving, instructions for monitoring energy and water consumptions. Spaces must include also information about its basic parameters (temperature, humidity, lighting etc.) specified by designers and engineers.

4.2 STRATEGIES FOR IMPLEMENTING FMBIM

BIM for the FM requires making many strategic decisions (Administration, 2011), including the consideration of the context and the main driving expectations; i.e. the vehicle for taking the first step. Implementation of BIM in general and for the purpose of the FM requires the identification of project objectives and the involvement of all appropriate team members (e.g. project manager, facility manager, BIM manager etc.) to discuss potential opportunities and benefits. Following subjects must be covered as a part of strategic decisions related to FMBIM (Administration, 2011):

- Defining the uses cases and information required for these.
- Understanding the life-cycle information management (roles and responsibilities, and classification systems).
- Understand, which information, when and how is gather for FMBIM purposes.
- Choosing appropriate commercial project delivery model (Design-Bid-Build, Design/Build-Bridging, IPD, or other alternative project delivery methods).
- Develop contractual terms for information delivery.
- Establishing BIM execution plan together with monitoring information compliance and quality of deliverables.
- Choosing the infrastructure (software, versions, information exchange requirements, central information repository, etc.).

- Assuring that the information is maintained, secured and updated to reflect existing conditions.

4.2.1 BIM Execution Plan

It is important that clients who are either planning or procuring a new facility, prepare a BIM Execution Plan (BEP). It provides a master information/data management plan and assignment of roles and responsibilities for model creation and data integration at project initiation. The BEP shall align the project acquisition strategy needs and requirements with client technical standards, team member skills, construction industry capability, and technology maturity (Administration, 2011).

Through this process, the team members and client project management shall jointly agree on how, when, why, to what level, and for which project outcomes BIM will be used. The BEP brings together the modeling and attribute requirements with the format requirements (COBie, IFC, etc.), the current extent of BIM implementation for the facility, and the project-specific conditions and work processes to ensure that client receives the facility management information it requires dependably, timely, and cost-effectively (Administration, 2011).

4.2.2 Delivery Requirements to Architecture and Engineering

According to GSA, the following information delivery requirements are assigned to the Architecture and Engineering contracts (Administration, 2011):

- Spatial Program BIM, delivered at Final Concept Design in specified form, typically also including 2D drawings;
- Design Intent BIM: Building information model(s) created by and conformed to the bid addenda by the A/E. Elements are accurate in terms of quantity, size, shape, location and orientation. The Design Intent BIM includes the Spatial Program model. Elements also contain unique asset identification numbers that link them to the COBie data. The Design Intent BIM must be submitted in both .ifc and native format.
- MEP/FP BIM, created by and conformed to the bid addenda by the A/E that includes all GSA-required equipment. MEP/FP BIM must be submitted in both .ifc and native format. All GSA-required equipment shall include the following attributes:

  - Equipment GUID
  - Asset Identification Number
  - Space Primary Key
- Extract all major plans, sections and elevations from the BIM. The design, three-dimensional location, size and relationships of the building elements and equipment required by GSA in the BIMs shall be included in and derived from the BIMs only.
- Transition BIM to Contractor for the Construction phase. The BEP shall outline the transition process including changes in roles and responsibilities to ensure Design BIMs are appropriately used and leveraged during construction.

GSA also requires delivering COBie submittal during the design phase:

- Include the following COBie worksheets: Contact, Facility, Floor, Space, Zone, Type, Component, System, Document, and Attribute.
- Use the same coordinate system, model origin, and units used in the BIMs.
- Handover COBie submittal to the contractor for the Construction phase.
- Use unique asset identification numbers for COBie and corresponding BIM objects.
- GSA Project Managers shall contact their Regional BIM Champions for specific contract language.

4.2.3 Delivery Requirements to Contractor

The contractor must provide an updated project BIM Execution Plan, BIM, and COBie deliverables. These include in minimum the as-built model, product information and documentation, maintenance manuals and commissioning documentation. In COBie, contractor updates the Contact, Facility, Floor, Space, Zone, Type, Component, System, Document, and Attribute information and hands it over to client (Administration, 2011).

4.2.4 Monitoring Information Compliance and Submittals

One strategy is the monitoring of information compliance of submittals to BIM requirements. Quality control checks on BIM Models are performed at key project milestones across the project lifecycle, defined in the BEP. It is client’s responsibility to identify the means and methods to properly enforce contract BIM requirements throughout the project delivery and FM process. This includes the enforcement of standards and guidelines (e.g. attributes, naming conventions) and assurance that the virtual building is being maintained in conjunction with the constructed building at designated project checkpoints (Administration, 2011). Typically, it is the BIM Coordinator, identified in the BEP, who leads the validation effort and leverage other project resources as needed to assist. The output of the validation effort is a list of deficiencies and when they should be corrected, e.g. at current or next project milestone. The latter is important to ensuring that the accuracy of time sensitive information is addressed at the current milestone (Administration, 2011).

4.3 SUMMARY OF INFORMATION MANAGEMENT CONCEPTS

For maximizing the benefits from implementing BIM, facilities must be maintained and managed over their whole life-cycle. Essential life-cycle information (geometrical as well as non-geometrical information) must be gathered and transferred (for example using COBie) to the facility owner and maintainers in accordance to the purpose. Information must have a right level of detail (geometrical precision), model (what elements/components of the facility) and information content. This information must be correctly classified in order to maintain clarity and communication between different parties involved. Also, as changes tend to occur over the life of the facility, objects and components must have unique identifiers in order to track changes when they present themselves. For good interoperability between BIM-authoring applications, IFC compliance is the informal standard. Finally, it is the role of different stakeholders to supply owner and facility managers with the necessary information, for which different strategies could be used.

5 DEVELOPMENT OF THE INFORMATION REQUIREMENTS FOR BIM BASED FM

5.1 INFORMATION REQUIREMENTS FOR FMBIM MODELS

As already mentioned earlier in the chapter 2.5, the main concepts for FMBIM models concern life-cycle view of information management, geometric and non-geometric information management, level of development and construction information classification systems. All of these have been explained previously, therefore the main purpose of this chapter is to develop FMBIM information requirements system.

In terms of facilities life-cycle, the main purpose of the information requirements system is to provide guidance what kind of information needs to be added to the model during its creation, starting from setting the initial targets and ending with operations and facility management. It must be considered as a general concept of what needs to be delivered to the owner or manager of the facility during the delivery process, not only at the handover.

As the information requirement system contains information that needs to be added to BIM model at some point, it also has involvement with COBie in some sense. After the model has been created and the relevant FM information added, all this information can be transferred either to FM or FMBIM application via using COBie format.

Description of non-geometric information requirements is probably the largest contribution of this requirements system. These required attributes are not being inserted to the model at one point in time and not by the same person, but more likely as a process throughout the different stages of the project delivery and different stakeholders.

It is not clearly stated anywhere in the system at what LOD level the information becomes relevant, but as subject of this study is facility maintenance and management then most likely all relevant elements/components must be on the level of 500. LOD 500 corresponds to the as-built state of maturity and basically this should be the digital replica of the physical facility.

Use of a construction information classification system inside the information requirements system has been a central consideration, it has helped to link the different entities within different ontological domains. In Estonia, we still do not have an appropriate classification system for the purpose of using BIM, thus for this work EVS 807:2010 and TALO 2000 have been used.

5.2 FMBIM INFORMATION REQUIREMENTS SYSTEM

In the context of this study, the information requirements system was compiled with a purpose to function as a guideline for clients, designers, engineers, contractors and operators/maintainers for planning and controlling the content of the BIM models and documentation for the purpose of FM. It is not the aim of this system to describe which information from this as-built documentation will be kept in the models and which in the FM application. For developing a summary of information that needs to be collected throughout the project delivery stages, different materials from Estonia and around the world have been used for describing the data requirements, including NATSPEC BIM Object/Element Matrix (NATSPEC, 2013), COBie guidelines (East, 2013), Estonian Real Estate Management and Maintenance Standards, Estonian legislations and TALO 2000.

5.2.1 NATSPEC

NATSPEC is an Australian not-for-profit organization, whose objective is to improve the construction quality and productivity of the built environment through leadership of information. NATSPEC has been delivering construction specification systems for over forty years. For example, the National Building Specification for all building structures with specialist packages for different disciplines. NATSPEC is also responsible for the National BIM Guide and its associated documents: Project BIM Brief, BIM Reference Schedule and BIM Object/Element Matrix (NATSPEC, 2013). This BIM Object/Element Matrix and documents associated with it were used as a guide to compose the information requirement system for FM practices in Estonia. Both share similarities in terms of structure, but are very different in terms of the content. Instead of using Uniformat/OmniClass classification systems, here Finnish TALO 2000 classification system is being used, as it is more acknowledged in Estonia. Furthermore, relevant Estonian standards have been also used as a basis for developing this system. There are a many more differences between this and NATSPEC systems, but going into too much detail is irrelevant at this point.

5.2.2 EVS 807:2010 – Maintenance of Facilities – Provision of Facilities Management Services

In this standard, facilities management services are defined and primary operations for assuring facilities continues functioning are classified. These classifications also apply to financial and bookkeeping aspects of the facility. This standard is meant to be used as a guide for planning and organizing maintenance procedures for different real estate objects. This standard must be used together with other relevant standards (Estonian Centre for Standardisation, 2010).

The categories used for this research included '100 real estate management' and '200 technical maintenance of a building'. The most basic categories of complex activities are listed in the Table 1.

Table 1. Most basic categorize of complex facility's management activities.

	Name of the complex activity	Abbreviations
100	real estate management	management
200	technical maintenance of a building	maintenance
300	performing property maintenance tasks on the site/in the building	property maintenance
400	renovation tasks during life cycle	repair work
500	bearing the owners obligations of a real estate	owners obligations
600	provision of energy, water and communication services	consumption services
700	provision of support services	support services
800	construction and reconstruction between life cycles	development
900	payment sources of maintenance costs	income

After the instructions pages in the Excel, the primary content starts with the table of relevant main complex activities from EVS 807:2010. An example of the hierarchy is shown in Figure 4.1. On that page in Excel, all the necessary management and maintenance operations/activities are brought out and have been linked with a another table on the worksheet – TALO 2000 classification system (described in more detail in the next chapter). Starting from the activities table, first step can be taken in finding the desired component with its relevant information.

200	**200**			**Tehnohooldus**
210		**210**		**Krundi rajatiste TH**
211			211	Teekatete TH
212			212	Sildade, treppide, truupide TH
215			215	Piirdeaedade, tarade, väravate, tugimüüride, jalutusaedade TH
216			216	Väikehoonete (katusealused, jäätmehoidlad, abihooned) TH
217			217	Veekogude (basseinid, tiigid, purskkaevud) korrashoid
218			218	Eritarindite TH
219			219	Muude krundil alaliselt või ajutiselt paiknevate elementide TH

Figure 26. Example hierarchy of EVS 807:2010 activities in the information requirement system.

5.2.3 TALO 2000 classification system

The Finish Building („Talo" - building in English) 2000 Classification system is a system of organizing and grouping of building elements, services elements, project-related tasks, property management tasks, user tasks and project provisions. The classification system is meant to be suggestive and should be applied on case-by-case basis (RAKENNUSTIETO, 2013).

As already mentioned in the previous chapter, the third worksheet of the information requirements system contains the table of TALO 2000 classification system. Just like the activities table in the information requirements system, TALO 2000 table is also cropped and only relevant parts of it have been left. TALO 2000 table can be used independently to find desired building components from the file or in conjunction with previously described activities table, as they interactively link to each other.

An example of the hierarchy is shown in the Figure 4.2. These classifications interact with tables containing relevant attribute data of FM components. By finding the desired element from TALO 2000 table, a hyperlink to respective attribute table (described in more detail in the next chapter) can be found. Using TALO 2000 classification table can be thought as a second step in the process of finding relevant attribute information for FM about a certain component.

1	1				**EHITISEOSAD**
11		11			**MAA-ALA OSAD***
111			111		**Pinnaseosad**
112			112		**Toestused ja tugevdused**
113			113		**Katendid**
114			114		**Välisvarustus**
115			115		**Välisrajatised**
1151				1151	Õuehoidlad
1152				1152	Katusealused
1153				1153	Aiad ja tugimüürid
1154				1154	Trepid, pandused ja terrassid
1155				1155	Peatumisrajatised
1156				1156	Muud välisrajatised

Figure 27. Example hierarchy of TALO 2000 elements in the information requirement system.

5.2.4 Attribute Data Tables

As a first step, operations in EVS 807:2010 standard were mapped to elements in the TALO 2000 classification table, which in turn are related to the tables containing relevant attribute data of FM components. This means that all tables are interactively linked to see the relationship between Facility Management Activity, its related object(s) and tables with required attributes and handover documents. The attribute tables describe in detail what information must models contain for the purpose of BIM based FM.

All the remaining pages, starting from page 4, in the information requirements system consist of the attribute data tables. These attribute data tables should have the highest value for the creators of models for FM purpose. These tables clearly state which kind of attributes must be attached to different building components, so they could be adequately maintained during the building's life-cycle. The structure and most important information about using these tables are being covered in the following subchapters.

Color-coding

This information requirement system uses color-coding to distinguish different attribute data tables from one another as shown in the Figure 28. Same colors are used for similar building and services categorise. The purpose of color-coding is to make the whole system easily accessible.

Figure 28. Color-coding of building and services elements sheets in information requirements system.

5.2.5 General Information

Attribute data tables are located on the last 13 worksheets in Excel and all share a similar overall structure. On the top of the page there is a general information bar, which helps the reader to understand what kind of building element or building system they are investigating. In the case of a building system, one worksheet can contain more than one sub-elements and its attribute tables. Every table starts with the name of the system or the element and picture as a reference. General information bar also gives the reader the description of the element or system, its reference to TALO 2000 classification system and information about responsible parties. An example of the general information bar is shown in Figure 29.

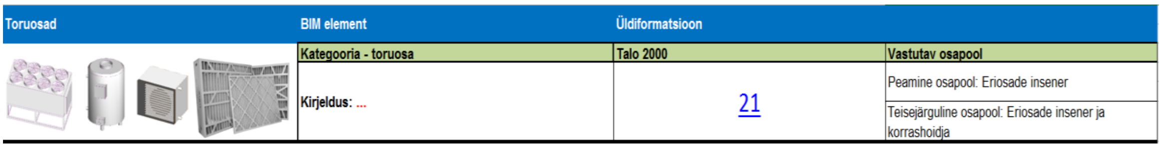


Figure 29. An example of a general information bar for HVAC system.

5.2.6 Attributes

Attributes about a specific building system or element come after the information bar and just like the information bars, there are two types of attributes: attributes that are more general in nature, describing every element in building or services system; and attributes that are specific to the particular system or element. As depicted in the Figure 30, every attribute (both first and second type) is bound with a number, information category, name, unit (if existent) and description.

Hooneosad		BIM element	Üldiformatsioon	
		Kategooria - hooneosa	Talo 2000	Vastutav osapool
		Kirjeldus: Hoone kandvad kui ka mittekandavad konstruktsioonid	12	Peamine osapool: Arhitekt Teisejärguline osapool: Konstruktsiooni insener, eriosade insener ja korrashoidja
Nr	Informatsiooni kategooria	Andmetüüp/andmeobjekt/attribuut	Ühik	Selgitus/Näide
1	Tuvastamine	Nimetus		Elemendile omistatud nimi
2		Kategooria		Talo 2000 kood või tellija ette antud identifikaator
3		Tüüp		Elemendi tüüp, näiteks sein või aken

Figure 30. Information bound with all the attributes.

In case of the building or service system, which contains many sub-elements, both types of attributes are used. The first type of attributes come right after the general information bar and are general in nature; for example the ID, category or type of the element. These are the main attributes that have to be attached to all of this building or services system's elements and are elementary when it comes to maintenance. The second type of attributes follow the information bars of specific elements under that building or services system and apply only to these specific elements alone. These second type of attributes only have to be attached to the specific sub-components as they do not affect rest of the elements in the same system/category. For example, there is a HVAC system sheet in the information requirements system (shown in the Figure 31).

12_Hooneosad	1242_Aknad	1243-1315_Uks	13_Ruumi_osad	21_Toruosad	23_Elektriosad	24_Andmeosad	2511_Liftid	133_Ruumivarustus

Figure 31. HVAC system sheet in the information requirement system.

This HVAC system sheet contains 13 first attributes: ID, category, type, measurements, location, material, key parameters of elements, manufacturer, manufacturer's code, warranty period, maintenance interval, cleaning interval and life-span. These are the attributes that have to be attached to each of HVAC systems sub-components to provide general information for maintenance.

Toruosad		BIM element	Üldiformatsioon	
		Kategooria - toruosa	Talo 2000	Vastutav osapool
		Kirjeldus: ...	21	Peamine osapool: Eriosade insener
				Teisejärguline osapool: Eriosade insener ja korrashoidja
Nr	Informatsiooni kategooria	Andmetüüp/andmeobjekt/attribuut	Ühik	Selgitus/Näide
1	Tuvastamine	Nimetus		Elemendile omistatud nimi
2		Kategooria		Talo 2000 kood või tellija ette antud identifikaator
3		Tüüp		Elemendi tüüp, näiteks sein või aken
4	Muu elemendiga seotud andmed	Mõõtmed		Tarkvara poolt omistatavad andmed, vastavalt projekti staadiumile kas projekteerimise või ehitatud täpsusega
5		Asukoht		Asetsemine ehitises ja selle osas
6		Materjal		Materjal(id), millest toode või element koosneb
7		Elementide põhinäitajad		Tulenevalt elemendi tüübist, esitatakse elemendiga vajalikud andmed
8	Toode/Tootja	Tootja		Materjali või ehitustoote tarnija
9		Tootekood		Kasutatud materjali või ehitustoote kood toimivusdeklaratsioonist
10		Garantii periood		Garantii lõpukuupäev
11	Korrashoid	Tehnohoolduse välp		Hooldusvälp (elemendile tervikuna ja koosteosadele eraldi)
12		Puhastustöödevälp		Puhastustöödevälp (elemendile tervikuna ja koosteosadele eraldi)
13		Eluiga		Eluiga (elemendile tervikuna ja koosteosadele eraldi)

Figure 32. HVAC system elements general attribute table with first type attributes.

There are 11 sub-components (chiller, boiler, filters, pumps etc.) described in the HVAC system sheet and each one of them has at least 5 second type attributes that apply only to them and may become necessary in the maintenance of these components only. The attribute table of chiller is shown in Figure 4.10 as an example.

Jahuti		BIM element	Üldiformatsioon	
		Kategooria - jahuti	Talo 2000	Vastutav osapool
		Kirjeldus: ...		Peamine osapool: Arhitekt
				Teisejärguline osapool: Eriosade insener ja korrashoidja
Nr	Informatsiooni kategooria	Andmetüüp/andmeobjekt/attribuut	Ühik	Selgitus/Näide
1	Toimivusnäitajad	Vool (Current)	Amper	
2		Pinge (Voltage)	Volt	
3		Sagedus (Frequency)	Herts	
4		Võimsus (Power)	kW	
5		Võimsus (Capacity)	kW	
6		Veevooluhulk (Water flow)	m3/h	
7		Ümbritsev Temperatuur (Ambient Temp)	C	
8		Survelang (Pressure Drop)	kPa	
9		Sissetuleva Vee Temperatuur (Entering Water Temp)	C	
10		Väljamineva Vee Temperatuur (Leaving Water Temp)	C	
11		Mootori Regulaator (Motor Controller)		
12		... (Unloading Steps)		
13		Jahuti Andmekandja (Chiller Media)		
14		Jahuti Tüüp (Chiller Type)		
15		Külmutusagensi Tüüp (Refrigerant Type)		
16		Energiatõhususarv (ETA) [Energy Efficiency Ratio (EER)]	Btu/h to kW	
17		... [Integrated Part-Load Value (IPLV)]		
18		Soojustagastus (Heat reclaim)		

Figure 33. Chiller’s attribute table consisting of second type attributes.

In the case of an independent building or services element in the information requirements system, first and second type attributes are mixed in one attribute table as there is no need for division. For example, doors and windows are treated independently in this system. They have their own sheets in the Excel environment dedicated for their information and attributes. Door’s attribute table is shown in Figure 34 as an example of an independent element in the system. It has the same first type attributes as previously mentioned chiller, but in this case first type general attributes and second type specific door attributes are grouped into one table, because there is only one component on that sheet.

Uks		BIM element	Üldiformatsioon	
		Kategooria - uks	Talo 2000	Vastutav osapool
		Kirjeldus: ...	1243, 1315	Peamine osapool: Arhitekt Teisejärguline osapool: Konstruktsiooni insener ja korrashoidja
Nr	Informatsiooni kategooria	Andmetüüp/andmeobjekt/attribuut	Ühik	Selgitus/Näide
1	Tuvastamine	Nimetus		Elemendile omistatud nimi
2		Kategooria		Talo 2000 kood või tellija ette antud
3		Tüüp		Elemendi tüüp, näiteks sein või aken
4	Muu elemendiga seotud andmed	Mõõtmed		Tarkvara poolt omistatavad andmed, vastavalt projekti staadiumile kas projekteerimise või ehitatud täpsusega
5		Asukoht		Asetsemine ehitises ja selle osas
6		Materjal		Materjal(id), millest toode või element
7		Elementide põhinäitajad		Tulenevalt elemendi tüübist, esitatakse elemendiga vajalikud andmed
8	Toode/Tootja	Tootja		Materjali või ehitustoote tarnija
9		Tootekood		Kasutatud materjali või ehitustoote kood toimivusdeklaratsioonist
10		Garantii periood		Garantii lõpukuupäev
11	Korrashoid	Tehnohoolduse välp		Hooldusvälp (elemendile tervikuna ja koosteosadele eraldi)
12		Puhastustöödevälp		Puhastustöödevälp (elemendile tervikuna ja koosteosadele eraldi)
13		Eluiga		Eluiga (elemendile tervikuna ja koosteosadele eraldi)
14	Toimivusnäitajad	Ukse Laius (Door Width)	mm	
15		Ukse Kõrgus (Door Height)	mm	
16		Ukse Paksus (Door Thickness)	mm	
17		Ukse Tüüp (Door Type)		
18		Ukse Materjal (Door Material)		
19		Ukse Viimistlus (Door Finish)		
20		Klaasimise Tüüp (Glazing Type)		
21		Turvakood (Security Code)		
22		Raami Tüüp (Frame Type)		
23		Raami Materjal (Frame Material)		
24		Raami Viimistlus (Frame Finish)		
25		Raami Päis (Frame Head)		
26		Raami Leng (Frame Jamb)		
27		Lävepakk (Frame Sill)		
28		Tuletõkkeklass (Fire Label Class)		
29		Riistvara Komplekt (Hardware Set)		
30		Survestamine (Pressurization)		
31		Väljapääsu uks (Egress Door)		
32		Õhuläbilaskvus		
33		Veepidavus		
34		Vastupanu tuulekoormusele		
35		Soojusjuhtivus	W/m^2K	

Figure 34. Door's attribute table as an example of an independent building element.

The same way, all the 13 attribute data table sheets in Excel describe different building/services systems or independent building elements. The first three attribute tables are more general in nature and consist of information about the building, the property and the rooms/zones of the building. The other 10 consist of information about the following: building's architectural systems; building structural systems; windows; doors; inner surfaces and finishes; HVAC system assets; electrical system assets; control system assets; elevators; room furnishing and equipment.

5.2.7 Building and Construction Process Documentation

Each worksheet also contains information about the type and categories of building documents (e.g. including materials, products manuals, installation instructions etc.) that is needed for these kinds of elements. This way it is possible to plan and later control the building documentation process. As an example, a segment from a table of necessary building documents for windows can be seen in Figure 4.12.

Täitedokumentatsioon				
Nr	Kategooria	Tüüp	Tüüp	Selgitus
FASSAADID ja AVATÄITED				
1	Fassaadid	Kergpaneel-fassaad	Paigaldusjuhendid	
2			Tootejoonised, tööjoonised, sõlmed	
3			Materjalide dokumentatsioon	
4			Kaetud tööde aktid	
5			Hooldus- ja kasutusjuhend	

Figure 35. Segment from a table of necessary building documentation for windows.

5.3 VALIDATION OF INFORMATION REQUIREMENT SYSTEM BASED ON THE INTERVIEWS

In order to validate the developed system, it was introduced to the target group, who will most likely benefit the most from its application. Therefore, during the 5 interviews summarized in chapter 3, interviewees were also asked five questions about the developed information requirements system discussed below.

The first question was to investigate whether the developed information requirements system seems practical and could be implemented. All the interviewees agree that the system is indeed practical and could find use in the future. It was brought out that information content seems relevant and this kind of system is definitely missing from the current practice in Estonia. Interviewees also mentioned that enforcing this system on the designer would make jobs for FM personnel a lot easier. If someone actually inserts all this information into the model and there is a way to enforce it, then this system would have a great value. Additionally, interviewees brought out that if this system would become a part of procurement documentation, then from FM point of view this would help to assure a good quality of delivered information.

Although it was believed that main beneficiaries would be facility maintainers/managers, it could be valuable to the designers and engineers as well. As designers generally are not familiar with maintenance and management classifications, which also should be added to the model elements, this system could be the solution as it is associated with two classification systems mostly used in Estonia. One of the interviewees pointed out that the great visualization of tables, together with pictures, provide complementary value to the system as well. Generally, this system was thought to be moving in the right direction, but does not seem to be in its final form.

Secondly, interviewees were asked if they see the need for some other information requirement systems, similar to the one developed in the context of this thesis. This question can be considered relatively hard to answer without prior thinking, therefore 2 interviewees out of 5 were not able to come up with any new system that could be helpful in the field of FM. However, the remaining three were able to suggest at least one possibility and all of them proposed one similar thing – long-term cost monitoring system.

Thirdly, interviewees were asked what they would additionally add to this information requirements system. Almost all the interviewees agreed that tying it with costs somehow would be a good idea. Also, it was brought out that if the information that is required in this system would eventually return into Excel format, possibly into these same spreadsheets, then this system would have additional value.

Another thing suggested by an interviewee was to emphasize the fact that all the information that is inserted in the models, based on this system, must be as-built information. It is not technically an addition, but an important note concerning information adequacy. Interviewees also believe that at some point this system has to be released in some form, so the actual shortfalls and potential needs would emerge. As much feedback as possible has to be obtained in order to perfect it.

The last question in the third part asked the interviewees whether they see any potential obstacles concerning the implementation of this system. Interviewees brought out following possible obstacles:

1. Designing process may get a little more expensive and cause negative feedback;
2. This system requires a lot of feedback from target groups, so it would consider all the needs of different stakeholders;
3. Difficulties in understanding the structure of the system might make it unappealing to users;
4. Issues with human resource, because implementing this system would probably mean tight cooperation between the field of FM and field of IT.

Generally, this system was considered to be necessary addition for the practice. The field of FM just needs to evolve a little bit before this system could be fully implemented. Eventually, the information requirements system would probably have a positive effect in connecting real estate to construction to engineering to design to planning of the new facilities and its different stakeholders involved during these stages.

5.4 SUMMARY OF THE INFORMATION REQUIREMENTS' SYSTEM

Composed information requirements system defines the scope of the information while modelling guarantees sufficient data exchange for FM at the information handover either from the designer/engineer or contractor to the owner of the facility. This system could become a relevant guide to designers, engineers and contractors to consider the needs of the facility management and maintenance field. The developed system got positive feedback when were shown to the people working in the field of FM and although different improvement possibilities were pointed out, the system in general is believed to be useful.

However, in its current form the content of this system is currently too exhaustive for FM practices in Estonia and different modifications during any new project are needed, depending on the project and the needs of the user. All the provided content does not have to be necessarily inserted and in most cases about one third of the required information is already enough for current practices. In the end, this system is developed to help designer meet the needs of FM specialists.

5.5 CASE STUDY: IMPLEMENTATION OF FMBIM INFORMATION REQUIREMENTS

In collaboration with Gravicon OÜ, a case study, to test the applicability of the developed information requirements system was conducted on an office building that is currently being built in Tallinn, Estonia. In the following sections we first describe the project, continue with introducing client's information requirements and conclude with the case study results and lessons that were learned during the process.

5.5.1 Project Description

The research object was chosen according to the following criteria: organization, who is the owner of the research object, should be familiar with BIM (possibly using it in work execution) and be interested in its further implementation. In that case fruitful cooperation is possible and information requirement system could be tested in real working environment.

Figure 36 illustrates the office building chosen for the case study. Site is located in Downtown area, Tallinn, on Kai 1 between Sadama and Poordi streets. The office building, currently under construction, is going to be six stories high with net area of 6048 m^2. The net area of underground floors is approximately 1405 m^2. The first floor of the office building is planned as commercial area for restaurants, cafeteria or retail businesses and remaining upper floors are planned as office premises. There is presumably 5836 m^2 of rentable space in the building together with functional terraces on the first floor and patios on the sixth floor, offering stunning views of the city skyline and the Gulf of Finland. The frame of the building is designed from monolithic reinforced concrete and facade is covered with different types of glass. Facility is going to be surrounded by a green area with different paths and squares.

Figure 36. 3D rendering of the selected case study building.

5.5.2 Client Information Requirements

The client Capital Mill Ltd was interested to collaborate in order to test the assembled information requirements system. As they were already implementing BIM to some extent in their Kai 1 project, the concept of BIM was familiar to them. Client's wish was to get some sort of information bank, where realization information could be held and retrieved when planning, managing, monitoring and performing of FM activities.

Initially, client was thoroughly acquainted with the developed information requirement system and given some time to get familiar with the content. Then the client was asked to highlight the attributes they need for the FM. During this process, some external assistance was given to the client in the highlighting process, because they were having trouble comprehending all the information provided within the system. With the help of modelers, relevant building elements were chosen and after a while the initial task was completed. Client also brought out the documents they would like to see attached to the BIM elements.

The categories for building elements in the client's initial task were following: architecture and structures; electricity systems; low current systems; automation systems; ventilation systems; smoke removal ventilation systems; heating systems; cooling systems; water, canal and rain water systems. Under each of these categories about 5-10 elements were determined by the client to be included within the as-built model. For each of these elements, client specific in average 2-3 attributes and in addition, some documents. The amount of attributes chosen can be considered pretty low, as for example only one attribute out of 23 possible was considered relevant when it comes to lighting fixtures. A segment from the client's initial task for the test model can be seen in the Figure 37.

Nr	Element	Geomeetria	Attribuudid				Andmeaalikas
	Arhitektuur ja konstruktsioon						
1	Lamell	Y (koos ledlampidega)	LEDlambid				
2	Klaasfassaad	Y	Klaasi tüüp	U-arv	g-väärtus	raami värv	Joonise pealt ja vaata, kas saab linkida kohe elemendi külge umbosast ja klaasosast tüüpjoonised
3	Välissein	Y	Kihttide nimetused				
4	Siseseinad kandvad	Y	Nimetus	Viimistlus (värv)			
5	Siseseinad mittekandvad	Y	Materjal	Viimistlus			
6	Põrandad	Y (koos järeltrossidega)	Kattematerjal	Pindala			
7	Ripplagi	Y	Tüüp				
8	Elekter						
9	Seina sees kaablid	Y	Tüüp				
10	Kaabliredelid	Y	Tüüp				
11	Kilbid	Y	Kilbi number				Kas saame siduda kilbiskeemi või joonist sellega, et klikkad peale ja näed seda
12	Põrandaküte	Y	Tüüp	Võimsus			Spets lingina juurde
13	Pistikud	Y	Tüüp				
14	Valgustid	Y	Tüüp				Valgusti spets juurde ehk eraldi faili ja lingina
15	Inverter	Y	Tüüp	Võimsus			Spets lingina juurde
16	Päikesepaneelid	Y	Tüüp	Võimsus			Spets lingina juurde

Figure 37. Segment from the client's initial task, describing the needs for architectural and constructional elements and electrical elements.

5.5.3 Results

Based on the initial task provided by the client, the test project was executed. At first, only the third floor of the Kai 1 office building was modelled as a prototyped, so that the general idea of the potential end result can be seen in reduced time. If the results of this part are acceptable for both parties, then the rest of the building is going to be modelled in the similar fashion.

All the elements with their respective attributes from the client's initial task (formed on the basis of information requirement system) were entered into the model. As a result, a model that expressed client's information requirements was created. Two pictures of the third floor model can be seen in the Figure 38.

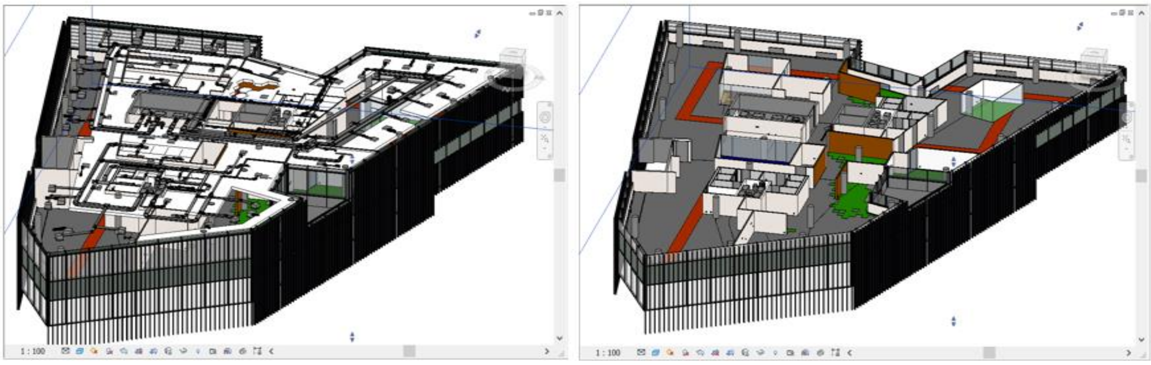


Figure 38. Pictures of the third floor model.

As the construction was already at a late stage when the as-built model creation began and as-built documentation compiled at that point was inadequate, then finding the correct attribute information for the installed elements was not an easy task. 30-40% of the time was spent on collecting information from the incomplete documentation. Second aspect that took relatively long time was related to the creation of custom made BIM objects. Currently, in Estonia we do not have BIM product catalogues/dictionaries from were BIM elements could downloaded and inserted into the model. An example of a building element's (floor finish) properties box with its relevant attributes is depicted in Figure 39.

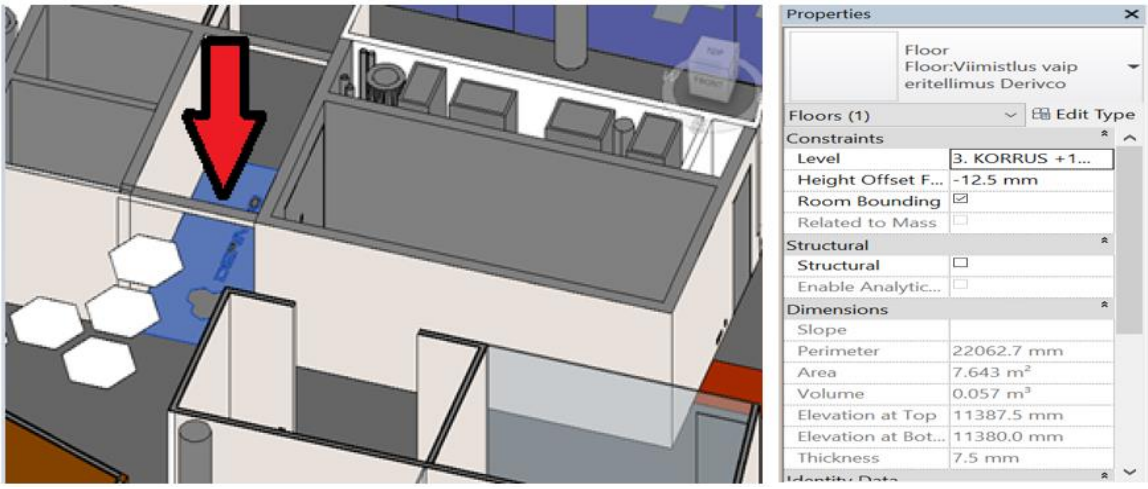


Figure 39. Floor finish location in the model and its properties.

Besides the attribute information, client also wanted relevant documents to be added to the BIM elements. For that project/building Dropbox account was crated and all the relevant documents were linked to BIM elements via hyperlinks (URL-s). A picture of the ventilation unit properties with a link to Dropbox folder and the respective document, where the link leads to, can be seen in the Figure 40.

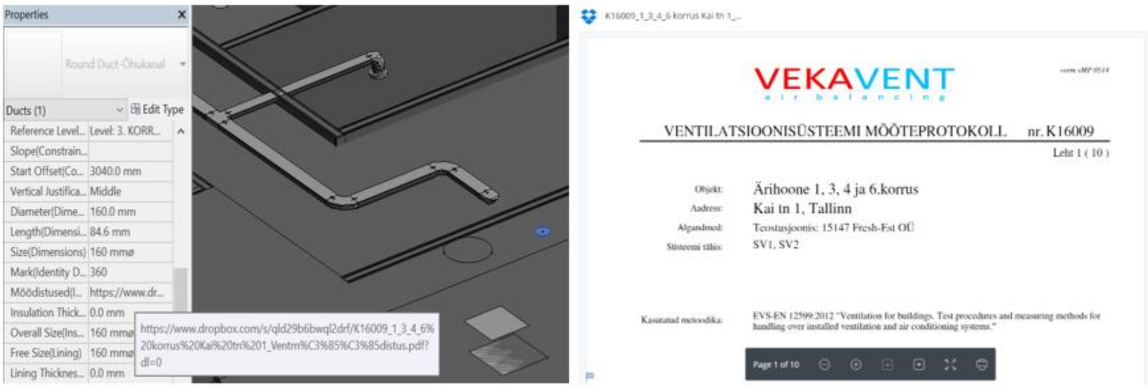


Figure 40. Ventilation unit's properties box with a link to Dropbox folder (on the left) and the respective document where the link leads to (on the right).

5.5.4 Lessons Learned

Although, the information requirement system can be considered useful and the test project limited success, there still are many shortfalls in the current practice that prevent using this system adequately and using BIM efficiently in general. Several lessons were learned from this experience:

Poor documentation causes inefficiencies in modelling 6D models: the biggest problem concerning this test project was with as-built documentation. As-built drawings were incomplete and product information was frequently missing, which made the modelling process difficult and modelers often had to fill the gaps arbitrarily. Often in current practices as-built documentation is just a copy of the detailed design and the documentation file is structured in a manner that finding relevant information is troublesome and time consuming. Also, requesting additional information causes unnecessary delays in the work process as response time is usually couple of days. Therefore, the quality level of as-built documentation must increase considerably in the future.

Documentation process and construction are not synchronized: as construction of the building was partially still going during the modelling process, then new information was constantly received from the site and there was never a moment when all the necessary information was present at the right time. Drawings were defective, a lot of crossing of different elements appeared and that raised a question, should the real solution to these problems from the site be determined or should the faulty parts be modelled the way drawings show. Height information in the as-built drawings was generally insufficient as well. Also, frequent minor changes (changes of finishing materials for example) were spontaneously made during the construction and not documented, making it impossible for modelers to express complete reality. It became evident that as-built model and documentation must be done in parallel with the construction process.

Lack of clear needs and requirements by the client: it was also learned that clients must have a good understanding of what they need to better describe their requirements. Only then could the modeler focus on the actual work and avoid a lot of needless effort. For example, if the plan is to use the model for visualization, then modeler could only focus on the geometry of the as-built. If the plan is to use the model for FM, then modeler would know that attributes of the building units are also important. Client could also bring out in the initial task what detail level they are expecting from the model elements. If element LOD-s and LOI-s could be associated with the client's initial task and information requirement system, then the job of modeler would become much easier.

Involvement of facility managers into documentation and 6D modelling process: the capabilities and general awareness of the client is also very important in BIM related projects. Client should have a BIM expert or/and facility management related personnel to assist them, who potentially could consult the client on specifying the requirements and help to clarify the possible application areas. Otherwise client most likely would make some questionable decisions and potential possibilities of the model are used minimally.

The complexity, content, level of detail and information must be modelled according to the needs: model should meet the needs of the client and meaningless information complexity should be avoided. Otherwise model sizes will get too huge and viewer software cannot handle them efficiently anymore. Client's computers also usually are not powerful enough to cope with large model files. For example, elements, found from the Internet, often contain a lot of unnecessary parameters making model files very data extensive. These kinds of elements have to be adjusted in a manner that only the parameters relevant to the client remain.

Usage of technologies, such as laser scanning or photogrammetry can help to simplify the modelling process: laser scanning and/or photogrammetry could be used to simplify and accelerate the modelling process. By using laser scanning it is possible to get very detailed and accurate 3D model about the current situation and collect resourceful information. When to apply laser scanning on different projects might be the most difficult issue, because at different phases of the construction some relevant parts might not be visible anymore and other parts might not even be installed yet.

Difference between current state of the art and compiled information system requirements: it was evident from the test project that developed information requirement system is currently too ambitious for the introduction phase of BIM in client organizations. Using it at full extent in the beginning is not practical, but this should reflect the direction that 6D modelling needs to go. If in the context of this test project all of the content from the system would have been used, then the workload would have gotten enormous. The information requirement system could be applied at full extent only if it's in parallel use with modelling from the beginning of designing stage. Then it is possible to insert data continuously and workload would be moderate.

Prototyping helps to reduce misunderstandings and uncertainty as clients still lack the understanding of how to implement BIM in FM: the style used in this test project, where only one floor was modelled at first, is definitely worth using again in future projects. If the entire building is being modelled all at once, without any breaks in the process, and in the end the result is not acceptable for the client, then all the work would have been for nothing. If only one floor is being modelled for testing purposes, then it is possible for client to see in less time what the model is all about and designers could get the general idea what is the quality of the information provided by the client and what would modelling this building mean in the long run.

CONCLUSION

The purpose of this research was to develop a good understanding of FMBIM and its related information management concepts. More particularly, the focus of this study was not on the usage of BIM applications for FM, but on what information, how and by whom need to be delivered to the facility's owner/manager.

Based on the literature review the definition and nature of FM in relation to project delivery concepts was explained and reasons for implementing BIM in FM were introduced. Overall, it was recognized that the efficiency of facility's management depends heavily on the quality and accessibility of as-built information, and keeping the information up-to-date. For these reasons, using BIM for FM has numerous application areas, thus, it has a strong business case. In this study, it was found out that FMBIM has several advantages over traditional methods, but the most advantageous is the organization of information into one central database, which helps to reduce information fragmentation.

In order to identify the current state of the art and present state of FMBIM in Estonia, a web-based questionnaire was conducted among people working within the field of FM. The questionnaire was forwarded to the 18 FM related organizations. 33 respondents believed that current state of the FM industry needs improvement. Respondents believed that most of the problems are associated with poor information quality and accessibility. They also indicated a need for more efficient FM software that would help to better coordinate and organization the FM workflows, and better manage the building and construction documentation. Overall, most of the respondents saw value in BIM, but also acknowledged the difficulty of the transitioning from contemporary practices to new BIM based processes.

As only 33 responses were received from questionnaire, five interviews were conducted to validate the survey results. Just like the answers from the questionnaire, interviews revealed that current state of the art is not satisfying. Construction as-built documentation quality is lacking, methods are inefficient and information technologies are outdated. BIM was considered to be a practical solution and although complete transition to BIM is going to take some time, steps towards widespread implementation must be considered.

Within this research, information requirements were developed for FMBIM. While gathering essential facility information, aspects such as information content, level of detail and level of information need to be taken into account. Furthermore, information must be classified in order to maintain clarity and facilitate effective communication between participants and information systems. Also, objects and components within the model must have unique identifiers to track changes made over the lifecycle of the facility. All these factors were essential for developing FMBIM information requirements.

As a part of the conducted interviews, interviewees were also introduced to the developed information requirement system, to validate its applicability into the field of FM. Positive feedback from the interviewees was received and the system was believed to be beneficial.

As the last part of this research, a case study was developed to test the developed information requirements. It was recognized that using the developed system to the fullest extent is not yet practical, but should reflect on the direction of the future of 6D modelling. Overall, systems helped modelers to understand and meet the client needs and requirements for FM.

REFERENCES

ADMINISTRATION, U. S. G. S. 2011. BIM Guide For Facility Management.

BALLARD, G. & HOWELL, G. What kind of production is construction. Proc. 6 th Annual Conf. Int'l. Group for Lean Construction, 1998. 13-15.

BALLARD, G., KOSKELA, L., HOWELL, G. & ZABELLE, T. Production system design in construction. Proceedings of the 9th annual conference of the International Group for Lean Construction, 2001.

BECERIK-GERBER, B., JAZIZADEH, F., LI, N. & CALIS, G. 2011. Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management,* 138**,** 431-442.

BURCIN BECERIK-GERBER, A. M. A., FARROKH JAZIZADEH, NAN LI, GULBEN CALIS Application areas and data requirements for BIM-enabled facilities management.

DELANY, S. 2015. *CLASSIFICATION* [Online]. National Building Specification. [Accessed 07.10 2015].

EAST, D. B. 2013. The COBie Guide.

EAST, E. W. 2007. Construction Operation Building Information Exchange (COBie): Requirements Definition and Pilot Implementation Standard.

GELDER, J. 2012. Revising ISO 12006-2:2001. *Articles on Classification* [Online]. Available: http://www.thenbs.com/topics/practiceManagement/articles/revisingISO12006-2_2001.asp.

GERDANO, M. 2013. Draft 2013: Level of Detail Specification. BIMForum.

GROUP, B. T. 2012. COBie Data Drops: Structure, uses & examples. England, URL: http://www.bimtaskgroup.org/cobie-data-drops/.

JOKELA, M., LAINE, T. & HÄNNINEN, R. 2010. Common BIM Requirements. *Use of Models in Facility Management.* Finland: Olof Granlund Oy.

JØRGENSEN, K. A. Classification of Building Element Functions. The 26th International Conference on IT in Construction & 1st International Conference on Managing Construction for Tomorrow, 2009. 301-307.

KANG, L. S. & PAULSON, B. C. 2000. Information classification for civil engineering projects by Uniclass. *Journal of Construction Engineering and Management,* 126**,** 158-167.

KROES, P. 2002. Design methodology and the nature of technical artefacts. *Design Studies,* 23**,** 287-302.

MCGREGOR, C. D. 2001. A Description and Comparison of National Specification Systems,. *A report for the International Construction Information Society.* International Construction Information Society.

MKM 2015. Ehitamise dokumenteerimisele, ehitusdokumentide säilitamisele ja üleandmisele esitatavad nõuded ning hooldusjuhendile, selle hoidmisele ja esitamisele esitatavad nõuded. *In:* INFRASTRUCTURE, M. O. E. A. A. (ed.). Tallinn.

MOSSMAN, A., BALLARD, G. & PASQUIRE, C. 2010. Lean project delivery–innovation in integrated design & delivery. *Draft for Architectural Engineering and Design Management Special Issue on Integrated Design & Development Systems (IDDS)[available at http://independent. academia. edu/documents/0095/5229/Mossman]*.

NATSPEC 2008. Information classification systems and the Australian construction industry.

NATSPEC. 2013. *NATSPEC BIM Documents* [Online]. Available: http://bim.natspec.org/index.php/natspec-bim-documents/national-bim-guide.

NISBET, N. 2012. COBie-UK-2012.

RAKENNUSTIETO. 2013. *Finnish Building Classification System* [Online]. Available: https://www.rakennustieto.fi/index/english/productsandservices/finnishbuildingclassificationsystem.html.

REED, B. 2009. *The integrative design guide to green building: Redefining the practice of sustainability*, John Wiley & Sons.

SCIENCES, N. I. O. B. 2012. National BIM Standard - United States Version 2.

SIMON, H. A. 1981. The sciences of the Artificial. 1969. *Massachusetts Institute of Technology*.

STANDARDIZATION, I. O. F. 2001. Building construction -- Organization of information about construction works -- Part 2 *Framework for classification of information.* Geneva, Switzerland: ISO.

SUH, N. P. 2001. *Axiomatic Design: Advances and Applications* New York, US, Oxford University Press.

TEICHOLZ, P. 2013. *BIM for facility managers*, John Wiley & Sons.

TRENDAFILOVA, A. K. 2010. *Link Between a Structural Building Information Model and Classification Systems in Construction.* Masters of Science, Aalto University.

VICO. 2013. *Virtual Construction 2013* [Online]. Vico Software, Inc. Available: http://www.vicosoftware.com/ [Accessed Aprill 2013.

APPENDIX 1. OVERVIEW AND COMPARISON OF EXISTING MAINTENANCE SOFTWARE APPLICATIONS

Selected Applications

This section gives an overview of the maintenance applications selected for this study to describe the functionality of these. The applications chosen are listed in the table below along with some general information. Applications were not chosen randomly. The main criteria for these facility management applications were their compatibility/interoperability with BIM technology. Another very important consideration was their global availability. Taking these criteria under consideration, 10 applications were chosen as shown in Table 1.

Table 1. Overview of selected applications.

No	- Application	Country	Website	Business model
1	ArchiFM	Hungary	www.archifm.net www.vintocon.com	Tool to serve facility management profession and it is being used by small, medium sized and large companies.
2	Granlund Manager	Finland	www.granlundmanager.fi	Application for managing facilities in all sizes. Scalable from an individual building to a large number of properties.
3	IBM Maximo	USA	www.ibm.com	Application for managing physical assets in asset-intensive industries. It helps manage all types of assets – including plant, production, infrastructure, facilities, transportation and communications.

No	- Application	Country	Website	Business model
4	Archibus	USA	www.archibus.com	Application is used in financial services, education, government, healthcare, energy, real estate, infrastructure and facilities management. Users can be found in the both the largest and more modestly-sized organizations worldwide.
5	Onuma System	USA	www.onuma.com	Onuma is created for wide range of users from owners, planners, facility managers, architects etc. It can be used on different sized facilities and there are different products depending whether it is used by an individual, a small group or a large group.
6	FM:Interact	USA	www.fmsystems.com	Target group is facilities and real estate professionals who manage either small or large real estate or facilities portfolios.
7	Cannistraro	USA	www.cannistraro.com	Target markets are healthcare, biotech/ pharma, education, office/multifamily constructions, mission critical/utility.
8	EcoDomus FM/PM	USA	www.ecodomus.com	Mainly used by firms providing facilities management services and is used on larger establishments, like government agencies, campuses etc.
9	Artra	UK	www.artra.co.uk	Mostly used on highly complex or bespoke plants and equipment requiring frequent test and inspection.
10	Bentley facilities	USA	www.bentley.com	Professions: facility managers, real estate managers, logistics department, maintenance managers, security managers, human resources. Mostly used by large, global or multi-national firms that offer facilities management services or facilities management departments in government agencies etc.

In conclusion, most facility management applications are applicable from small to very large facility management businesses, but mostly for handling big real estate or facilities portfolios with a few exceptions. Some applications focus mostly on facilities where the crucial issue is asset management, like plants etc.

Integration with BIM

As mentioned earlier, integration with BIM was one of the main criteria of choosing FM applications as a subject for this study. Therefore, following section will briefly explain how integration with BIM is achieved in a few selected cases. All this information was gathered from software websites.

ArchiFM is a BIM-based operation and maintenance system. It uses BIM model as a basis for FM. All the information is accessible from the database, and all the changes made in the data are synchronized with the BIM model. BIM model is always kept up to date through synchronization. ArchiFM can import and export a BIM model as an IFC file. IFC files can also be imported and exported in all BIM programs, including ArchiCAD, Revit, MicroStation, AutoCAD, VectorWorks etc. This guarantees that files can be imported or exported regardless of which software consultants are using.

Onuma System is web-based Building Information Modeling (BIM) tool and is rather a Model Server storing the data than a file based storage system. Cloud based computing platform allows users to connect to other systems on the web in real time. It also links to GIS, such as ESRI and uses open standards such as XML, BIM IFC, OGC, OSCRE, COBIE. Import and export in many formats. Links to BIM tools such as Revit, ArchiCad etc. and to other tools like SketchUp, Ecotect, IES, Google Earth, Excel etc. Project requirements can be defined in Onuma and then exported to other BIM applications. Data and graphics can be exported from Onuma to IFC. It is possible to open in IFC Compatible Tools: Archicad, Revit, Vector Works, Solibri Model Checker, DDS CAD, SketchUp etc.

Artra works with BIM/CAD applications (architectural, structural and building services models) produced by Autodesk, Bentley, Graphisoft, Tekla, etc. Through its support of IFC and COBie standards, Artra is fully interoperable. Models can be read in the NWD file format and it includes an Active-X version of Navisworks. ArtrA can be linked with current systems and also historical electronic documents. Import/export possibility to/from MS Excel. Opens/imports/merges all major file formats including IFC, RVT, DWG, DGN etc. Possible integration with all kinds of external systems.

Modules Provided

Almost every chosen application provides some kind of modules, which purpose and structure are usually also provided on their homepage. All the information about modules is strictly from respective websites and therefore might not be completely covered. Applications have their own unique names for their modules and provide slightly different functions under these modules, therefore it is quite challenging to compare different applications to each other considering modules.

Although there are many differences between different applications modules, there are also a few common and more general modules, which almost each application provides:

Asset management module – for effectively tracking organizations assets by linking them with models, so it is possible to easily locate them and get necessary product information such as warranties etc.;

Move management module – for reducing moving costs and making it more efficient;

Maintenance management module – for improving equipment performance and reducing its downtime by more effectively using corrective and preventative maintenance programs, which serve all the buildings in the portfolio. Also, reduce costs by managing technicians more effectively;

Space management module – for managing spaces in every building in the portfolio, giving visibility over space and occupancy.

Despite these general modules, which are similar in most applications, each application tries to be special by providing something more than their competitors. To get even better overview of the typical modules IBM Maximo was chosen as a object of study, which all together includes six management modules:

1. Asset management;
2. Work management;
3. Service management;
4. Contract management;
5. Inventory management;
6. Procurement management.

Asset management can be used to more efficiently track and manage asset and location data throughout its lifecycle. **Work management** can be used to manage both planned and unplanned work activities, from beginning to their completion, while recording all of the documentation. **Service management** can be used to define service offerings, establish service level agreements, monitor service level delivery and implement escalation procedures. **Contract management** can be used to gain complete support for purchase, rental, lease, warranty etc. contracts. **Inventory management** – can be used to keep track of the details of asset-related inventory and its usage including what, where, when, how many and how valuable. **Procurement management** can be used to support all the phases of enterprise-wide procurement such as direct purchasing and inventory replenishment.

FMBIM Functionality

Facility management applications provide many different modules and even more functions and covering them all is not possible. All the information about the applications and their functionality was gather from the representative of the respective software company or from their website. Following application representatives contributed in the composition of the table: ArchiFM, Granlund Manager, Ecodomus and ARCHIBUS. Information about the remaining applications was gathered from their respective websites and may not be completely representative. “X” in the table below indicates that the application supports particular feature/functionality or not.

Table 2. Overview of functionalities provided by different applications.

Feature	**ArchiFM**	**Granlund Manager**	**IBM Maximo**	**Archibus**	**Onuma System**	**FM:Interact**	**Cannistraro**	**Ecodomus**	**Artra**	**Bentley Facilities**
BIM link	X		X	X	X	X	X	X	X	X
Mobile, tablet application	X	X	X	X	X	X	X	X	X	
Using color to show status	X	X		X		X		X	X	
Link documents to objects	X	X	X	X	X		X	X	X	
Barcodes and scanning for equipment	X			X				X	X	
Field access to system	X	X	X	X	X	X	X	X	X	
Laser scanning								X	X	
Cloud possibilities	X	X	X	X	X	X		X	X	
Graphisoft integration	X			X	X			X	X	
Autodesk integration			X	X	X	X	X	X	X	
3-dimensional visualization	X		X	X	X	X	X	X	X	X

Feature	**ArchiFM**	**Granlund Manager**	**IBM Maximo**	**Archibus**	**Onuma System**	**FM:Interact**	**Cannistraro**	**Ecodomus**	**Artra**	**Bentley Facilities**
Reporting (fault report, work report etc.)	X	X	X	X	X	X		X	X	X
Browser based	X	X	X	X	X	X		X		X
Component/module integration	X	X		X		X		X		
Spreadsheet upload	X	X		X	X	X		X	X	X
Real-time data from sensors	X			X				X		
Offline working capability	X			X				X	X	
Available in several languages	X	X	X	X				X		X
COBie		X	X	X	X	X		X		X
Geographic data and geospatial extensions				X	X			X		

As mentioned earlier, the functions shown in Table 2 are general and in reality different FM application provide a lot more functions. As an example we look how many main functions Artra really provides according to its website, to prove that there are endless possibilities that a FM application could provide. All the features are shown in Figure 1.

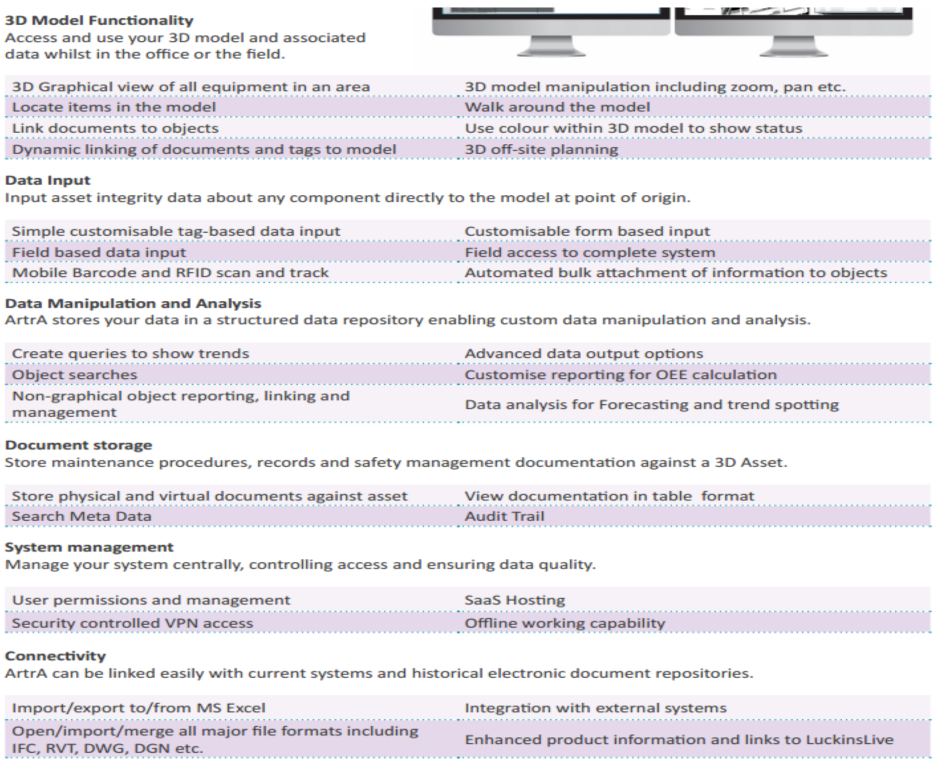


Figure 1. An example of Artra functionality.

Short Overview of Selected Applications

In this section, a short overview of three applications is given. Firstly, Granlund Manager is selected, as it is a Finish product; secondly ARCHIBUS, as this is currently already used by RKAS and thirdly Artra, as it has 3D interface for BIM based FM. All the information originates from their websites.

Granlund Manager

Granlund Manager (GM) is Finnish browser-based maintenance management application, which offers user the possibility to view relevant data that relates to their property according to their role. All the components of GM form an individual unit and those units can be easily integrated with each other. **Granlund manager is** suitable for mobile devices, scalable from a small portfolio to a large number of properties, provides up-to-date information through effective reporting, provides different information and views according to users roles, available in several languages (FI, SWE, ENG, RUS), turns building data into information and indicators to support decision-making, easy to integrate with other information systems, available as a SaaS solution or can be installed in a separate server environment etc.

Some of the practical examples of GM offerings are: energy management based on hourly data; the controlling of the whole real estate portfolio's capital expenditure. The new mobile device application supports field operations, making them more effective and enabling users to receive work tasks and to report regardless of their location. GM allows user to efficiently manage and control maintenance costs, reduce risks and ensure energy efficiency.

ARCHIBUS (Web-based)

ARCHIBUS is according to their website #1 provider of real estate, infrastructure and facilities management solutions in the world at the moment. ARCHIBUS is applicable to organizations of all sizes to help manage relevant facilities information. It covers following sectors: finance, education, healthcare, government, manufacturing etc. ARCHIBUS is available in over 190 countries and more than 30 languages. ARCHIBUS has over 1,700 Solution Centers and Business Partners around the globe to support deployment.

ARCHIBUS, Inc. offers different product options to satisfy organizations' needs, depending on organizations size. When scope of activities expands, then ARCHIBUS deployment can be scaled. There are following product options to choose from:

ARCHIBUS Enterprise

Facilities management solution for managing space totaling thousands to millions of square meters.

- Modular structure;
- Unlimited number of concurrent users and sites are supported;
- Unlimited number of unique records;
- Microsoft SQL Server, Oracle, and Sybase are supported;
- Web-enabled if ARCHIBUS Web Central is added.

ARCHIBUS Facil-o-tor™

Facilities management solution for managing facilities less than 500,000 SF (46,000 m^2)

- Complete with a full suite of applications for fast deployment;
- Up to six concurrent users at a single site are supported;
- Limited number of unique records;
- Microsoft SQL Server, Oracle, and Sybase are supported;
- Web-enabled if ARCHIBUS Web Central is added.

ARCHIBUS Express™

Facilities management solution for small offices and single-users for managing facilities measuring less than 250,000 SF (24,000 m^2).

- Most important applications (for critical tasks) included;
- Only a single user is supported;
- Limited number of unique records;
- Microsoft® SQL Express and Sybase® RunTime are supported.

ARCHIBUS Web Central®

The Web engine for sharing information to an entire global organization.

- Access to centralized information using a simple Web browser;

- Different applications and personalized dashboards to choose from;
- Only relevant applications can be chosen from the structure;
- Unlimited number of unique records;
- Web functionality provided for ARCHIBUS Enterprise and Facil-o-tor.

Artra

ArtrA is a solution for asset and plant lifecycle management, construction management and FM. ArtrA is a database management application with a graphical front end. It is built around SQL database that can easily be integrated with other database applications and uses client server technology. ArtrA provides the possibility to put the entire project information and documentation into a single manageable resource. ArtrA provides the functionality to search, link, tag and report on information, which is stored in 3D models or BIMs. ArtrA also provides the ability to add new construction and maintenance data captured from site. ArtrA can be used for QA/QC, progress monitoring, commissioning, inspection and maintenance.

Any Type of Project

ArtrA can be used on any type of multi-discipline AEC, civil engineering or infrastructure project (hospitals, tunnels, plants etc.), example shown in Figure 2. ArtrA can also be used for conditioned surveys of existing buildings, infrastructure etc.; plant lifecycle management, corrosion monitoring, inspection and decommissioning.

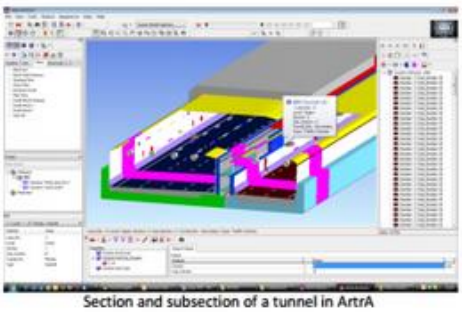


Figure 2. Section and subsection of a tunnel in ArtrA.

ArtrA is designed to be used on intelligent models or unintelligent models that have to be converted into BIMs. ArtrA links design models, construction and fit-out, and building lifecycle management.

Database and CAD Attribute Link

All the objects found in intelligent models (by Revit, Bentley, Tekla, ArchiCAD, CADDUCT, etc.) have attributed data describing:

- Architectural: slabs, rooms, spaces, doors, etc.;
- Structural: beams, columns, plate, piles, etc.;
- Mechanical: pumps, fan-coils, diffusers, etc.;
- M&E: service systems, pipes and fittings, valves, etc.

These attributes are used as a link between project database and model. One attribute identifier for every object is required to create the link, for example room number. Once a link has been established, it is possible to create new information in the database or capture new information from the site.

ArtrA Tags

ArtrA tags are created by BIM manager. Single model attribute can be linked to an unlimited number of tags and each tag can have an unlimited number of properties, which contains options that are selected by field users (see Figure 3).

Figure 3. Multiple tags linked to a single slab attribute.

ArtrA Tags can contain a mixture of new database information and design attributes from models. The information is presented as tag input forms that are used to view/capture info from the site (see Figure 4).

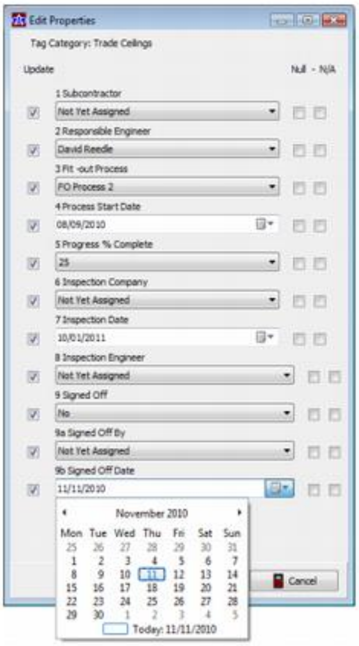


Figure 4. Tag input form.

Data Capture

New information is added in the database or captured through TAG input forms. Tag input forms can be accessed using tablets on the field. High level of data consistency is ensured when several engineers are working on the same project together. When the tablet PCs are docked at the end of the day the captured information is uploaded to the server and merged with the main database.

Bill of Materials – From Site

ArtrA allows the possibility to run material reports from site. ArtrA will collect data across multiple disciplines and generate accurate and flexible reports. Considerable cost savings and reductions in waste can be achieved by using ArtrA.

When new information becomes available during fit out, it is added to ArtrA's database (added as tags and properties). ArtrA will produce reports using information from the design model (areas, lengths, etc.), manufacturer information (material descriptions, part numbers, etc.), labor values and progress information from the site.

Thematic Reports

Any information from the database can be shown thematically in color in the model. An example of a thematic report is shown in Figure 5. This function can be used for progress monitoring, to identify items scheduled for maintenance or highlighting critical test results.

Figure 5. Thematic report of LNB Hospital.

Progress Monitoring (4D)

ArtrA Field-BIM provides thematic 4D reports to monitor/record progress during fit out. When tablet is docked at the end of the day, all the progress information captured from the site is automatically updated. ArtrA generates room based thematic management reports using the latest information.

Laser Scanning – From Point Cloud to BIM

Laser scanning technology is becoming more cost effective and accessible because of the need for new software applications that can handle "point cloud" data. Illustrative picture of laser scan can be seen in Figure 6.

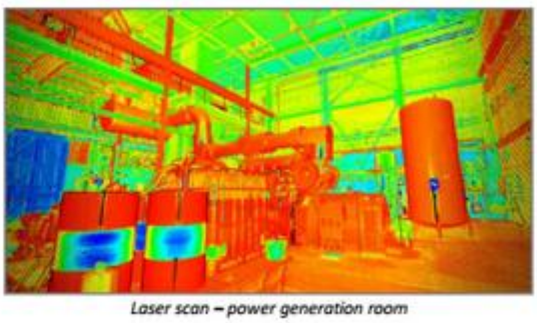


Figure 6. Laser scan of a power generation room.

More accurate and faster surveys of existing buildings can be produced using 3D scans, which also provide greater detail comparing to traditional methods. Point cloud is offered to vector conversions allowing the results to be opened in standard CAD applications (see Figure 7).

Figure 7. Laser scan point cloud converted to BIM in ArtrA.

ArtrA uses vectorised point cloud data for the BIM database, where lifecycle or decommissioning information and documentation can be added.

Bar Codes and RFID

Bar codes are mapped to objects in the model such as rooms, doors, main equipment items, etc. The items bar code has to be scanned into an ArtrA tag form and once this is done, the bar code and object will be linked. Tablets are equipped with bar code readers and RFID scanners, so it would be possible to use them in identifying the objects (see Figure 8).

Figure 8. Identifying rooms using bar codes.

ArtrA will find the object in the model, including its documentation and latest maintenance data, so the field engineer can work with that information. More than 14,000 servers have been mapped to ArtrA’s database to help with maintenance processes and information retrieval.

APPENDIX 2. WEB-BASED QUESTIONNAIRE FOR FM SPECIALISTS

Küsitlus hoone halduse ja hoolduse valdkonnas tegutsevale inimesele

Küsitlus on koostatud TTÜ Tsiviilehituse eriala viienda aasta tudengi poolt seoses magistritööga. Küsitlusele vastamine ei tohiks võtta aega rohkem kui 10 minutit ning iga esitatud küsimustik on suureks abiks magistritöö kirjutajale, kes üritab seoses oma lõputööga leida lahendusi teie töö lihtsustamiseks. Küsitluse eesmärgiks on välja selgitada haldus- ja hooldus valdkonnas tegutsevate inimeste üldine teadlikkus BIM-i olemusest ning selle rakendusvõimalustest hoone halduses ja hoolduses. Samuti uurida, mismoodi hetkel praktikas tööd teostatakse, millised on hetkel kasutatavad tarkvarad ja meetodid, kuidas toimub informatsiooni kogumine ja dokumenteerimine ning kui vastutulelikud ollakse BIM-i rakendamisele.

Küsitlus on suuremas mahus ülesehitatud valikvariantidega küsimustena, kuid ideaalis sooviks ka Teiepoolseid selgitusi/märkusi küsimustes küsitu kohta, mis võiksid autorile täiendavaks abiks olla. Küsitluse plokid A, B ja D on mõeldud vastamiseks haldusele spetsialiseerunud töötajatele ning A, C, D vastamiseks hooldusele spetsialiseerunud töötajatele. Vastata tuleks kõigile küsimustele, kui ei ole jäetud valikuvõimalust küsimuse püstituses.

A. Teie taust ja haridus

1. Mis asutuses te töötate?

Valikuline, võimalus jääda selle koha pealt anonüümseks

Lühike vastuse tekst

2. Milline on Teie ametinimetus?

- ○ Halduse projektijuht
- ○ Haldusjuht
- ○ Haldur
- ○ Tehnohoolduse projektijuht
- ○ Hooldusjuht
- ○ Hooldustehnik
- ○ Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

3. Milline on teie haridustase?

Selgituste all võiks välja tuua ka konkreetse eriala ning õppeasutuse

- ○ Põhiharidus
- ○ Keskharidus
- ○ Kutsekeskharidus
- ○ Kutseharidus
- ○ Kõrgharidus
- ○ Rakenduskõrgharidus
- ○ Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

4. Kui pikk on teie tööstaaž ehitise halduse/hoolduse valdkonnas?

- ○ Kuni 2 aastat
- ○ 2-5 aastat
- ○ 6-10 aastat
- ○ Rohkem kui 10 aastat

Täiendavad selgitused/märkused

Pikk vastuse tekst

5. Milline on teie kutsetunnistus/-ed?

Selgitusse kirjutada täpne nimetus

- ◯ Kinnisvara haldur II, III või IV
- ◯ Kinnisvara haldur, tase 4 või tase 5
- ◯ Kinnisvara haldusjuht, tase 6
- ◯ Korterelamuhaldur II
- ◯ Kinnisvara hooldusmeister III või tase 5
- ◯ Kinnisvara hooldusjuht IV või tase 6
- ◯ Kinnisvara hooldaja I, II, III või tase 4
- ◯ Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

6. Mitme erineva hoone halduse/hooldusega olete seotud keskmiselt ühe nädala jooksul?

- ◯ Kuni 3 hoonet
- ◯ 3-6 hoonet
- ◯ 7-10 hoonet
- ◯ Rohkem kui 10 hoonet

Täiendavad selgitused/märkused

Pikk vastuse tekst

B. Hetke olukord halduses

See küsimuste plokk on mõeldud vastamiseks haldusele spetsialiseerunud töötajatele

7. Kas pärast hoone valmimist saadav informatsiooni hulk on üldiselt piisav hoone halduseks ning reeglina ei vaja palju täiendamist?

- ○ Piisav, ei vaja täiendamist ega lisainformatsiooni kogumist
- ○ Ebapiisav, esineb puudujääke ning vajalik on info täiendamine

Kui vastasite ebapiisav, siis hinnake informatsiooni terviklikkust 5 palli süsteemis

5 – vajab vähe täiendamist; 1 – vajab palju täiendamist

- ○ 5
- ○ 4
- ○ 3
- ○ 2
- ○ 1

Täiendavad selgitused/märkused

Pikk vastuse tekst

8. Kas saadav informatsioon on kvaliteetne?

- ○ Jah
- ○ Ei

Kui vastasite Ei, siis hinnake ebakvaliteetsust 5 palli süsteemis

5 – peaaegu võiks lugeda kvaliteetseks; 1 – täiesti ebakvaliteetne

- ◯ 5
- ◯ 4
- ◯ 3
- ◯ 2
- ◯ 1

Täiendavad selgitused/märkused

Pikk vastuse tekst

9. Kas suurem osa sissetulevast informatsioonist on esitatud paberkandjatel ning tuleb andmebaasi sisestada manuaalselt?

- ◯ Jah
- ◯ Ei

Hinnake manuaalse informatsiooni sisestamise osakaalu ühe hoone/objekti suhtes

Manuaalse informatsiooni sisestamise ligikaudne % kogumahust

- ◯ 0 - 20 %
- ◯ 20 - 40 %
- ◯ 40 - 60%
- ◯ 60 - 80%
- ◯ 80 - 100%

Täiendavad selgitused/märkused

Pikk vastuse tekst

10. Milliseid tarkvarasid kasutate halduse teostamiseks?

Märkida ära kõik ette antud valikus teie poolt kasutusel olevad tarkvarad ning vastava(te) tarkvara(de) nimekirjast puudumisel see (need) juurde lisada

- [ ] Microsoft Office (Word, Excel, ...)
- [ ] Autodeski tooted (AutoCAD, Revit, ...)
- [ ] Graphisofti tooted (ArchiCAD, ...)
- [ ] IBM Maximo
- [ ] ARCHIBUS
- [ ] Onuma System
- [ ] Ecodomus FM
- [ ] Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

11. Millest tuntakse hetke praktikas puudust?

Siinkohal sooviksin teie aktiivset osalust puuduste määratlemisel nende lisamise teel

- [ ] Korraliku tarkvara olemasolu
- [ ] Pidev kohalik tarkvara tugi
- [ ] Efektiivne kommunikatsioonisüsteem
- [ ] Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

12. Kas hetke olukord ning traditsioonilised meetodid tunduvad siiani head ja ei vajaks mugandamist või arvate, et tööd saaks oluliselt lihtsustada minnes üle intelligentsematele süsteemidele?

Vastake Jah, kui arvate, et hetke olukorda ei oleks vaja muuta ning Ei, kui arvate, et oleks aeg muutusteks ning arenguks.

- ◯ Jah
- ◯ Ei

Täiendavad selgitused/märkused

Pikk vastuse tekst

C. Hetke olukord hoolduses

See küsimuste plokk on mõeldud vastamiseks hooldusele spetsialiseerunud töötajatele

13. Kas ligipääs hoolduseks vajalikule informatsioonile on reeglina kiire ning tõrgeteta?

Hinnake olukorda 5 palli süsteemis (5 – Informatsioonile ligipääs on kerge ning kiire; 1 – Vajalik informatsioon on raskesti kättesaadav ning võtab palju aega)

- ◯ 5
- ◯ 4
- ◯ 3
- ◯ 2
- ◯ 1

Täiendavad selgitused/märkused

Pikk vastuse tekst

14. Millised on põhilised tõrked, mis põhjustavad üleliigset ajakulu info kogumisel?

Märkige ära kõik variandid, mille mõjust tunnete ennast puudutatuna ning vajadusel lisage omaltpoolt asjakohaseid põhjuseid

- [ ] Informatsioon tuleb leida paberkandjatelt, sirvimisest tingitud ajakulu
- [ ] Informatsioon saadakse kätte kontorist, mis põhjustab tühisõite
- [ ] Kommunikatsiooni ebaefektiivsus hooldustehnikute ning –juhtide vahel
- [ ] Joonistelt raskesti välja loetavad hooldatavate süsteemide asukohad
- [ ] Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

15. Kas pärast hoone valmimist saadav informatsiooni (seadmete tehnilised spetsifikatsioonid, kasutus- ja hooldusjuhendid jne) hulk on üldiselt piisav hoone hoolduseks ning ei vaja erilist täiendamist?

- ○ Jah, saadav informatsioon on piisav
- ○ Ei, saadavat informatsiooni tuleb täiendada

Kui vastasite Ei, siis hinnake informatsiooni terviklikkust 5 palli süsteemis

5 – vajab vähe täiendamist; 1 – vajab palju täiendamist

- ○ 5
- ○ 4
- ○ 3
- ○ 2
- ○ 1

Täiendavad selgitused/märkused

Pikk vastuse tekst

16. Kas hoone hoolduse korraldamisel keskendutakse piisaval määral nii preventatiivsele kui ka avariilisele tehnohooldusele?

- Jah
- Ei

Kui vastasite Ei, siis mis võiksid olla teie arvates selle põhjused

Pikk vastuse tekst

Täiendavad selgitused/märkused

Pikk vastuse tekst

17. Kas ettevõtte/allüksuse töö on teie arvates piisavalt hästi koordineeritud, et kõik hooldustööd saaksid optimaalse aja jooksul teostatud?

- Jah
- Ei

Kui vastasite Ei, siis mida võiks teie arvates olukorra parandamiseks teha

Pikk vastuse tekst

Täiendavad selgitused/märkused

Pikk vastuse tekst

18. Millest tuntakse hetke praktikas puudust?

Siinkohal sooviksin teie aktiivset osalust puuduste määratlemisel nende lisamise teel

- [ ] Digitaalne ligipääs hoolduseks vajalikele dokumentidele
- [ ] Tarkvara kollektiivi töö paremaks koordineerimiseks ja korraldamiseks
- [ ] Muu...

Täiendavad selgitused/märkused

Pikk vastuse tekst

19. Kas hetke olukord ning traditsioonilised meetodid tunduvad siiani head ja ei vajaks mugandamist või arvate, et tööd saaks oluliselt lihtsustada minnes üle intelligentsematele süsteemidele?

Vastake Jah, kui arvate, et hetke olukorda ei oleks vaja muuta ning Ei, kui arvate, et oleks aeg muutusteks ning arenguks

- ○ Jah
- ○ Ei

Täiendavad selgitused/märkused

Pikk vastuse tekst

D. BIM hoone halduses/hoolduses

20. Kas teil on olnud kokkupuuteid BIM-ga (Building Information Model) ning kas te teate, mida see sisuliselt tähendab?

- Olen puutunud kokku ning tean mida see endast kujutab
- Tean sisuliselt, mida see tähendab aga kokkupuudet pole olnud
- Ei tea mis on BIM ning pole sellega kokku puutunud

Täiendavad selgitused/märkused

Pikk vastuse tekst

21. Kas teie arvates oleks mõistlik minna üle traditsioonilistelt meetoditelt BIM-ile?

- Jah
- Ei

Kui vastasite Jah, siis mis oleksid teie arvates need head omadused, mida BIM-i rakendamine halduses endaga kaasa võib tuua

Pikk vastuse tekst

Kui vastasite Ei, siis miks ei ole BIM teie arvates õige suund

Pikk vastuse tekst

Täiendavad selgitused/märkused

Pikk vastuse tekst

22. Kas teie oleksite valmis tegema enda töös vajalikud korretkuurid selleks, et integreerida tööprotsessi BIM?

- Jah
- Ei

Kui vastasite Ei, siis mis võiks(id) olla põhjus(ed)

Pikk vastuse tekst

Täiendavad selgitused/märkused

Pikk vastuse tekst

23. Kas BIM-i rakendamine tundub uute vajalike tehniliste teadmistega seoses hirmutav, kuna erineb senisest praktikast või pigem huvitav, kuna loob uued võimalused efektiivsemaks tööks?

- ○ Hirmutav, kuna on uus asi ning nõuab suuremat tehnilist pädevust ning teadmisi
- ○ Pigem hirmutav, kuna on uus ning rakendamine väljakutse, kuid võit efektiivsuselt kaalub selle üle
- ○ Huvitav, kuna on võimalus ennast arendada ning avada uued võimalused efektiivsemaks tööks

Täiendavad selgitused/märkused

Pikk vastuse tekst

24. Kas oleksite avatud uute haldustarkvarade õppimisele, mis toetavad BIM-i ja seeläbi tulevikus muudaksid teie töö lihtsamaks?

- ○ Jah
- ○ Ei

Kui vastasite Ei, siis mis võiks(id) olla põhjus(ed)

Pikk vastuse tekst

Täiendavad selgitused/märkused

Pikk vastuse tekst

25. Kas kaugemas tulevikus on teie arvates BIM-i kasutuselevõtt möödapääsmatu?

- ◯ Jah
- ◯ Ei

Täiendavad selgitused/märkused

Pikk vastuse tekst

Lõpp

Suured tänud leidmaks aega küsitlusele vastamiseks, Teie panus on väga suureks abiks minu magistritöö kirjutamisel, millest loodetavasti on tulevikus abi Teie töö lihtsamaks ning tõhusamaks muutmisel.

Kui soovite, et lõputöö ja uurimistöö tulemusi jagatakse ka Teiega, siis palun kirjutage siia enda email aadress:

Pikk vastuse tekst

APPENDIX 3. STRUCTURE OF THE INTERVIEWS

A. Taust

1. Millisel ametikohal Te töötate?
2. Teie ametikohast tulenevad põhilised tööülesanded? Milliste probleemidega seisate igapäevaselt silmitsi tööülesandeid lahendades?

B. Probleemid seoses informatsiooni kogumise ja selle kättesaadavusega

1. Mis on Teie arvates peamine või peamised probleemid ehitamise lõpus informatsiooni üleandmise juures? Informatsiooni kogumise ja kasutamise juures ekspluatatsioonis? Kas oskate välja tuua ka nende võimalikke tekkepõhjuseid?
2. Kas need probleemid saaks kõrvaldada? Mis võiksid olla lahendused? Kas olete üritanud midagi nende kõrvaldamiseks teha?
3. Kuidas suhtute intelligentsetesse haldussüsteemidesse kui võimalusse lahendada probleemid informatsiooni kogumise ja kättesaadavuse osas? Kas näete neis lahendust lähema paari aasta jooksul ja oleksite valmis kergeteks muudatusteks või usute traditsiooniliste meetodite jätkusuutlikkusse seniks kuni seadus teilt vastupidist ei nõua?

C. Informatsiooninõuete süsteem

1. Kas vastav süsteem tundub asjalik ning võiks leida rakendust?
2. Kas Teie näeksite vajadust ka muude taoliste infonõuete süsteemide järgi?
3. Mida lisaksite omalt poolt veel sellesse süsteemi juurde?
4. Kas sellel süsteemil leidub mingeid puuduseid? Millised?
5. Mis võiksid olla takistuseks sellise süsteemi rakendamisel?

APPENDIX 4. OVERVIEV OF THE COBIE

The Construction Operations Building information exchange (COBie) is a life-cycle information exchange format describing the spaces and equipment within a facility. The primary COBie exchange occurs at construction handover; however, efficiencies will be gained by using COBie throughout the life-cycle whenever information about spaces and equipment need to be exchanged (Sciences, 2012).

COBie is not a specific product or software solution. COBie is implemented in commercial software to allow the users of that software to transfer the information from one phase of a project to another without having to repeatedly recapture that same information, as is the case in the capital facilities industry today. As a buildingSMART alliance project, COBie is based upon the Industry Foundation Class (IFC) model. Although COBie data can be viewed in commonly used spreadsheet software, the focus of COBie is not a software product or program, but a common method for moving building information through the project life-cycle (Nisbet, 2012).

COBie eliminates duplication of information about facility spaces and equipment throughout the facility life-cycle. A fully populated COBie data set contains the minimum requirements for the transfer of construction project information at beneficial occupancy to the facility manager. Subsets of the COBie model capture COBie data during planning, design, construction, and commissioning stages to streamline the delivery of spatial and equipment-related building information (Sciences, 2012).

COBie Elements and Information Content (Data Drops)

Initially only the Facility need be defined, but as the design stabilizes, the Floors (Sectors) and Zones can be registered. These can then be populated with Spaces. Following on, Types and Systems are specified and the manageable asset Components assigned. During construction specific products can be identified and Jobs, Spares and other Resources for their maintenance and operations catalogued (Nisbet, 2012).

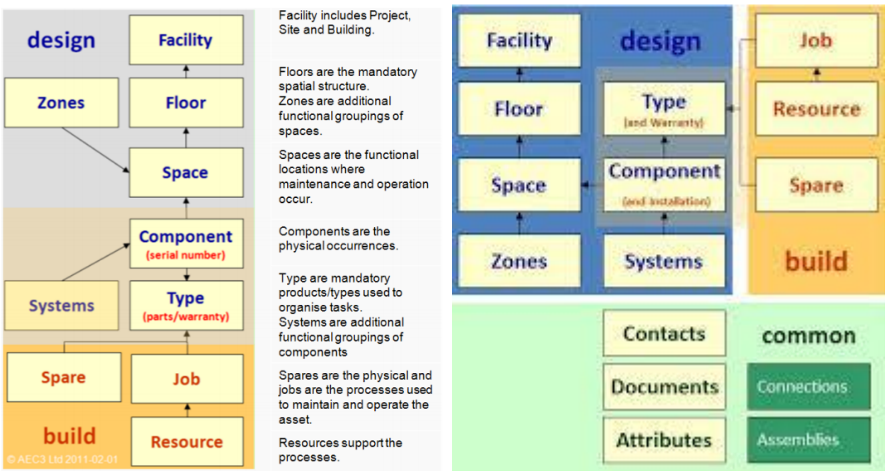


Figure 28. COBie represents the facility as a simple spatial and physical hierarchy (image: AEC3 Ltd).

For buildings, the assets include the Facility as a whole and its constituent Spaces and Components. These are managed through groupings into Zones, Floors, Types and Systems.

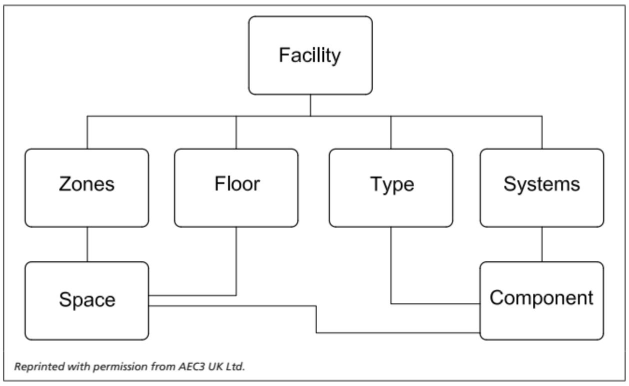


Figure 29. Building View of COBie, using standard terms.

Assets - includes the overall Facility and the constituent aspects Space (location), Floor (region), Zone, Component, Type and System.

Component - named and individually scheduled physical items and features that might require management, such as inspection, maintenance, servicing or replacement, during the in-use phase.

Facility - named distinct operational built or geographic asset, typically a building or section of infrastructure along with details and extent of the geographic site and of the temporal project.

Floor (region) - named intermediate spatial subdivision, including distinct vertical levels and horizontal areas and sections with Spaces allocated.

Space (location) - named location for activities such as use, inspection or maintenance, including un-occupied or un-inhabitable Spaces, but not necessarily inaccessible voids.

System - named set of manageable Components providing a common function.

Type - named specification for Components including equipment, products and materials.

Zone - named set of Spaces (locations) sharing a specific Attribute, such as activity, access, management or conditioning.

Job - named task or activity during the in-use phase associated to Types.

Resource - named material or skill required to execute Jobs.

Spare - named replaceable part associated to Types (Institution, 2014).

Additional information relevant to specific kinds of objects can be associated. This additional data can include **Documents**, **Attributes**, **Coordinates**, economic and environmental **Impacts** and **Issues**. Additional relationships such as **Connections** and **Assemblies** can also be documented (Nisbet, 2012).

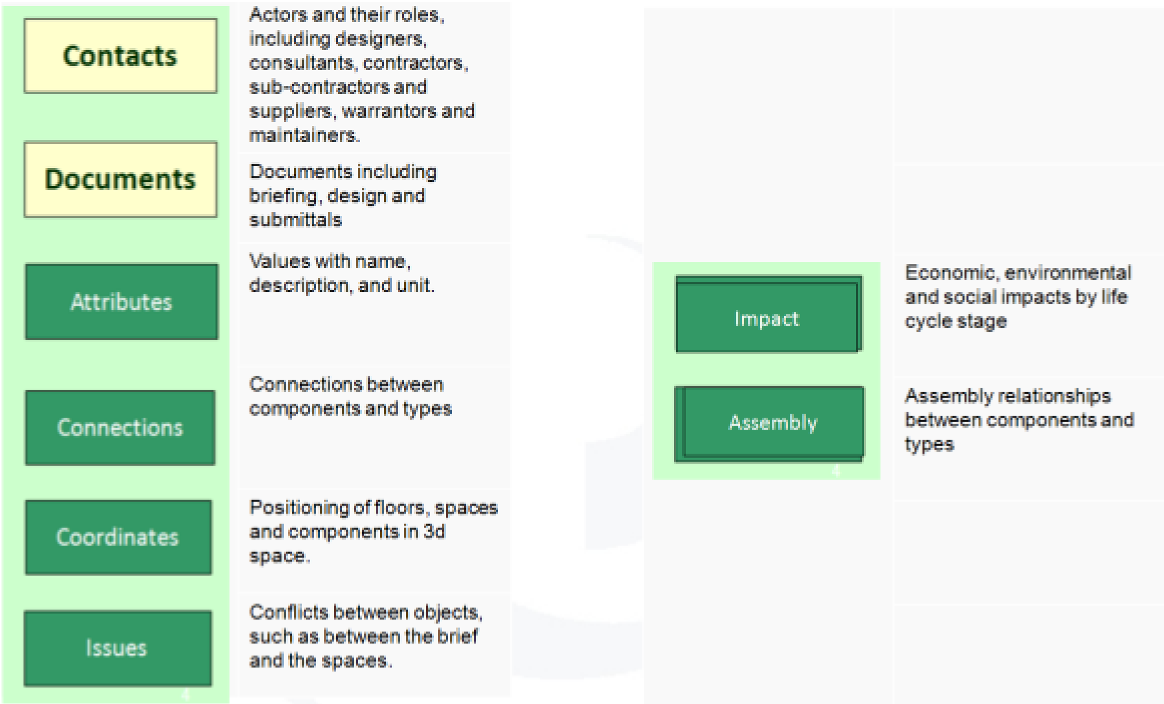


Figure 30. Various kinds of additional information can be associated to the facility and it constituents (Image: AEC3 Ltd)

APPENDIX 5. INFORMATION CLASSIFICATION SYSTEMS

Construction Information Classification Systems

Construction information classification systems (CICS) must cover entire project life-cycle and built environment (Gelder, 2012), for utilizing and making information accessible for project stakeholders (Kang and Paulson, 2000). CICS is categorization of information and objects according to particular characteristics (Jørgensen, 2010). In NATSPEC report following use cases were summarized for CICS (NATSPEC, 2008):

- Organizing reference material on construction products, technical matters, costs etc.;
- structuring the contents of individual documents in a consistent manner;
- coordinating information between individual documents found in sets of documents;
- facilitating communications between different members of a construction project team; and
- facilitating interoperability of digital systems.

ISO (International Organization for Standardization) 12006-2:2001 ("Organization of Information about Construction Works – Part 2: Framework for Classification of Information") defines the need for standardization of construction information classification systems as follows (Standardization, 2001): "Modern information systems for the construction industry, whether local or networked, need to handle data of many different types. All these data and the relations between them need to be defined and structured in such a way that the stored information is consistent and reliable within and between the different applications." Often this abstraction mechanism is using hierarchical structures for organizing faceted information with particular notation, i.e. identifier for facilitating quick orientation and navigation within CICS (mnemonics).

ISO standard 12006-2, currently being reviewed, has had significant impact on the various CICS developed in Europe and US towards internationally compatible classification systems (Trendafilova, 2010). It covers the entire lifecycle of facilities, including: construction works, design, production, maintenance and demolition, and to both building and civil engineering. Standard does not provide the detailed content of the tables but definers the common framework for classifying information.

The basic process model used in the ISO 12006-2 standard for developing classification framework (Standardization, 2001): “Construction resources are used in or required for construction processes, the output of which are constructed products.” Within these different but interrelated stages construction information is organized into 16 facets/classes as shown in

Table **2**. Each facet has either one or two principles of specialization. The underlying rationality of the ISO standard is that everything is connected through elements by their function with other information categories. Functional elements are considered as systems/assemblies, components common to most buildings that usually perform a given function regardless of the design specification, construction method, or materials used. This enables bidirectional linking of construction information throughout the processes and stages.

Some of the well-known CICS are Uniformat, Masterformat and Omniclass in US; Uniclass and Uniclass2 (unified classification) in UK; BSAB 96 in Sweden; DBK 2006 in Denmark; NS 3451:2009 Table of building elements in Norway; and Talo 2000 in Finland (RAKENNUSTIETO, 2013, McGregor, 2001). These CICS follow the structure of ISO 12006-2 except. Within this work Omniclass, Uniclass and Talo are studied more closely and are summarized in

Table **2**, summarizing the content of different CICS in comparison to each other and ISO 12006-2 (four groups: construction results, construction process, construction resources and property/characteristic).

It can be noticed that different classification systems have different level of detail and scope. Uniclass for example includes also civil engineering and infrastructure aspects for classification. Building 2000 (also known as TALO 2000) compared to the others has more narrow scope, it does not cover infrastructure (Trendafilova, 2010).

Table 2. Comparison of different national CICS (partially adopted from NATSPEC (2008) and Trendafilova (2010)).

ISO 12006-2:2001				OmniClass (US)		Building 2000 (Finland)	Uniclass (UK)	
General dimensions of classification	**Facet/Class**	**Principle of specialization**	**Table reference**	**Table reference**		**Table reference**	**Table reference**	
Construction Results	Construction entity	Form	A.1	Table 12	Construction Entities by Form		E	Construction entities
		Function or user activity	A.2, A.6	Table 11	Construction Entities by Function	Premise and Space Classification table	D	Facilities
	Construction complex	Function or user activity	A.3, A.6					
	Spaces	By degree of enclosure	A.4	Table 14	Spaces by Form		F	Spaces
		Function or user activity	A.5, A.6	Table 13	Spaces by Function	Premise and Space Classification table		
	Construction entity part	Classified by related tables for elements, designed elements and work results	A.7, A.8	Table 21	Elements	Building Element and Project Classification table	G	Elements for buildings
							H	Elements for civil engineering works
	Element	Characteristic predominating function of the construction entity	A.7				G	Elements for buildings
							H	Elements for civil engineering works
	Designed element	Element by type of work	A.8				G	Elements for buildings
							H	Elements for civil engineering works
	Work result	Type of work	A.9	Table 22	Work Results	Construction Work Section Classification table	J	Work sections for buildings
							K	Work sections for civil engineering works
Construction process	Work process	Classified by related tables for work result					J	Work sections for buildings
							K	Work sections for civil engineering works
	Management process	Type of process	A.10	Table 32	Services	Building Element and Project Classification table	B	Subject disciplines
	Construction entity lifecycle	Overall character of processes during the stage	A.11	Table 31	Phases		C	Management
	Project stage	Overall character of processes during the stage	A.12					
Construction resources	Construction product	Function	A.13	Table 23	Products	Construction Product Classification table	L	Construction products
	Construction aid	Function	A.14	Table 35	Tools	Worksite Equipment Classification table	M	Construction aid
	Construction agent	Discipline	A.15	Table 33	Disciplines		B	Subject disciplines
				Table 34	Organizational Roles		C	Management
	Construction information	Type of medium	A.16	Table 36	Information		A	Form of information
Property/Characteristic		Type	A.17	Table 41	Materials		P	Materials
				Table 49	Properties		N	Properties
							Q	Universal decimal classification

Some issues related to ISO 12006-2:2001 have been published (Gelder, 2012): no one definitive framework for classification; sequence of tables does not correlate with typical project sequence; some objects are not included in the tables; underlying rationality must be changed to classifying the objects by their composition instead of functional structure; and because of the flexibility of framework, it is introducing some inconsistencies between different national standards (Jørgensen, 2009).

Some of the authors have also reflected that updated or new CICS based on ISO 12006-2:2001 are complex in nature, meaning they have not been accepted in practice widely, and seem to lack definitiveness among some facets (Kang and Paulson, 2000). For example, the users of Uniclass may become confused in using facets [B, C], [D, E, F], [L, P], and [N] because the items in those facets are similar to one another even if their purposes are described.

Uniclass 2015

The Uniclass 2015 is the latest version of UK's classification systems, which is still under development as not all the tables have been yet finished. It is a further development of previous versions and developments of Uniclass, but significantly extends the scope. It is meant to be used by the entire industry, including the infrastructure, landscape, engineering services and building sector throughout the entire project life-cycle. Uniclass 2015 has been carefully structured to be in accordance with ISO 12006-2 Building construction – Organization of information about construction works – Part 2: Framework for classification.

Uniclass 2015 is divided into a set of tables which can be used to categories information for costing, briefing, CAD layering, etc. as well as when preparing specifications or other production documents. These tables are also suitable for buildings and other assets in use, and maintaining asset management and facilities management information.

Uniclass 2015 provides (Delany, 2015):

- A unified classification system for the construction industry. For the first time, buildings, landscape and infrastructure can be classified under one unified scheme.
- A hierarchical suite of tables that support classification from a university campus or road network to a floor tile or kerb unit.
- A numbering system that is flexible enough to accommodate future classification requirements
- A system compliant with ISO 12006-2 that is mapped to NRM1 and supports mapping to other classification systems in the future
- A classification system that will be maintained and updated by NBS.
- Within the BIM toolkit a database of synonyms to make it as easy as possible to find the required classification using standards industry terminology.

The tables are organized in hierarchical manner and allow the convergence from more generic to detailed during different lifecycle stages, which is well illustrated by NATSPEC in BIM Element Matrix as showin in Figure 41.

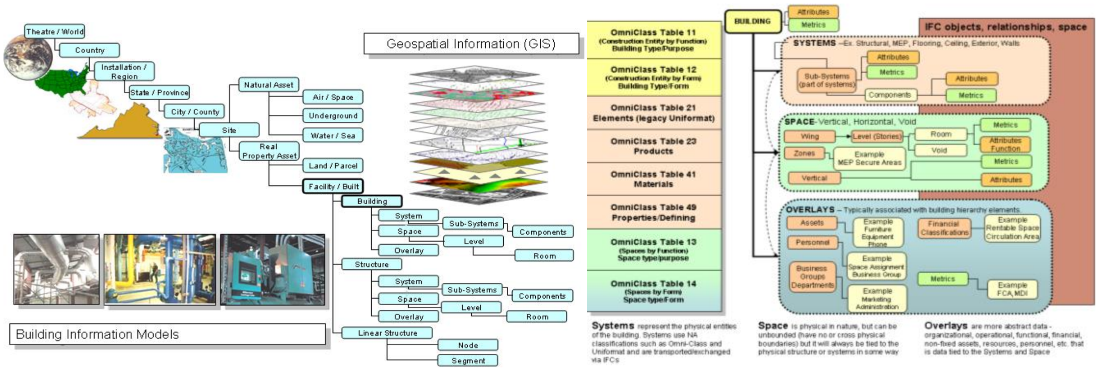


Figure 41. Overall information hierarchy (left) and BIM information hierarchy and classification (right). (NATSPEC, 2013)

All together eleven tables are planned to be produced, however, currently only four have been formally published, other four just a beta release and three are just drafts. The tables that are already in use as a formal or beta publication are shown in Figure 42, only missing CAD table from it.

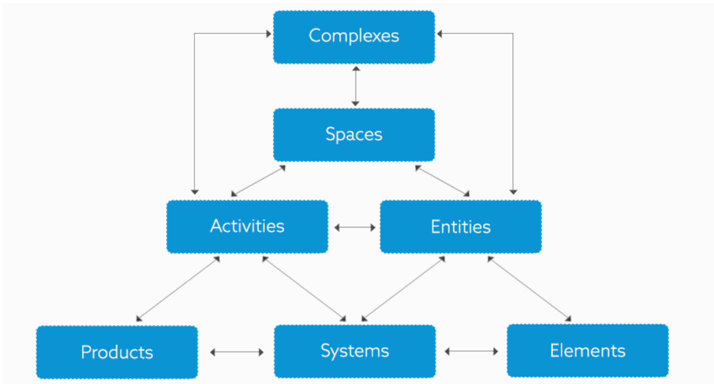


Figure 42. An hierarchy of tables and their relationships. (Delany, 2015)

Complexes: Describes projects in overall terms and can be thought of in terms of the provision of an Activity. Complexes can be broken down as groupings of Entities, Activities and Spaces depending on the particular use. An example of Complex is a university campus with all the building, landscape and infra.

Entities: Discrete things like buildings, bridges, tunnels etc. They provide the areas where different activities occur. Entities can also be described using the Spaces and Activities tables if required. The main architectural components of an entity are elements, for other requirements in an entity such as drainage, heating or ventilation, the activities table sets out these functions. These Elements and Activities are fully described in the Systems which in turn contain products.

Activities: Define the activities to be carried out in the complex, entity or space. For example, the Activities table also includes surveys, operation and maintenance and services.

Spaces/Location: Defined in buildings, spaces are provided for various activities to take place. In some cases a space is only suitable for one activity, for example a kitchen, but a school hall may be used for assemblies, lunches, sports, concerts and dramas. Also classed as spaces are transport corridors that run between two locations.

Elements: The main components of a structure like a bridge (foundations, piers, deck) or a building (floors, walls and roofs).

Systems: the collection of elements/components that go together to make a system or element to carry out the function. For a low temperature hot water heating system is formed from a boiler, pipework, tank, radiators etc.

Products: The individual products used to construct a system.

These tables have many uses and for example an asset manager needs to be able to find details of plant and equipment quickly when issues arise, and having them classified can help with this. The spaces within a building or other facility can be listed using their classification codes, along with all the activities associated with them. The systems serving each space and the products that form them can also be included by classification, providing a complete information trail. When a product reaches the end of its life and needs to be replaced, having it correctly classified makes it easy to identify which spaces are affected, so that arrangements can be made and people informed.

APPENDIX 6. ESTONIAN ORDINANCE ON CONSTRUCTION INFORMATION

In addition to the general objectives, the ordinance establishes the following general requirements to the construction documentation (**§ 3**): the head contractor is responsible for the proper documentation of construction and assures that the other contractors (typically sub-contractors) follow the documentation and preservation requirements; and construction must be documented systematically in chronological order and in categorized manner. Documentation must enable to identify:

- Construction quality and proficiency;
- Installed materials and products;
- Covered construction elements, structures and details' location and compliance to Construction Project/Design Documentation;
- Person responsible for the facility construction or its element.

In addition to document content, each document meta-data must include information about document time, location, creator or creators participating in the documentation and signing of it. Documents must be complied right after the occurrence of the event or commitment emerges. Document must be signed by responsible person at least three days after it is compiled and must be available either physically or in real time over the web-application.

Requirements to construction document

Additionally, according to § 4. 'Requirements to Construction Document', construction documents must be readable with open ware or in following other formats: Text (txt), Portable Document Format (pdf) or Open Document Format (odf), MS Office Word Document (doc), MS Office Open XML Document (docx), MS Office Excel Spreadsheet (xls) or MS Office Excel workbook (xlsx). Documents are not allowed to include changeable information, e.g. url-s. Imaging captured during the construction must be in following formats: Joint Photographic Experts Group (jpg), Graphics Interchange Format (gif) või Portable Network Graphics (png). Also videos must be in the format, which can be opened with open ware applications. Digital facility information models must be deliver in Industry Foundation Classes (IFC) format.

Requirements for construction imaging and video recording

The images of the covered construction work and other pertinent work must be taken in chronological order and systematically, so that together with the Construction Diary the construction progress is recognizable; it is possible to identify important construction elements (including structures and building services), its location and other relevant information. Location, is the most important aspect (e.g. its floor or placement on the grid).

As-built drawings or model

The ordinance does specify any requirements for the model, but the general principle established for documents also apply to that. Generally, the as-built drawing is the result of the surveying process for acquiring information about construction element's location and technical details.

Report of covered works

Generally, the principle of preparing reports (act) for covered works is done for all completed works that will be covered with the works in following phases, which means their later investigation is limited and requires additional effort and resources. Report must be complied after the review of competed work by responsible person of the head contractor or owner's supervisor. Report must include information about any deviations from the specification, evaluation of the work quality and images. Depending on the nature of work, report must also include information about the control procedures, schemes, act of measurement etc. In minimum, the report must be prepared for the following works:

- Foundation piling;
- Backfilling and its layers;
- Waterproofing layers (hydro isolation);
- Installation of water traps and roof wells;
- Reinforcement of blockwork;
- Wind proofing;
- Installation of thermal insulation;
- Vapor barrier;

- Sub-layers of roofing;
- Sealing of wall, ceiling or floor joints;
- Joining of precast elements;
- Sealing of precast elements;
- Piping, cabling, fixers, openings and installation of opening elements;
- Installation of ventilation systems;
- Installation and sealing of windows and doors;
- Fireproofing of structures;
- Installation of drainage systems and soli layers;
- Sub-layers of asphalt.

Minutes of meeting protocol

Work meeting is gathering of designers, engineers and contractors discuss subjects related to construction process and work and/or construction/project documents. In minimum it must include information about the meeting time, participants, meeting progress, all related issues and all decisions related to work or facility.

Requirements for building materials, products and equipment or building services systems certification and installation manual

Certificates of the building materials, products and equipment must comply with the corresponding legislation and must be documented. A photo must be taken of the used products' markings, which can not be later identified otherwise or require additional resources. The documentation of all tests, must include information about measurements, its methodology, person doing the measures and qualification.

Requirements for installation and instructions manual

Instructions and installation manuals must include all the necessary information for installing, identifying, using, maintaining, cleaning and utilization of facility and its spaces, elements, materials, equipment and products. Also necessary information for emergency situations. Additionally, documents must include information about building elements' serviceable time, list of jobs for maintenance and cleaning, maintenance interval, energy need, instructions for energy saving, instructions for monitoring energy and water consumptions. Spaces must include also information about its basic parameters (temperature, humidity, lighting etc.) specified by designers and engineers.