Feasibility study on the application of BIM data for facility management

Guðmundur Óskar Aðalsteinsson

Thesis of 30 ECTS credits
Master of Science in Construction Management
June 2014

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Abstract

As the BIM method gains momentum in the construction industry during design and construction phases of construction projects, operators and facility managers have not realised what benefits the method can bring them during the operational phase. This thesis aims at clarifying how BIM can be used for facility management and how the method can be standardized so that BIM models can be applied directly to facility management systems. It will explore how information is collected during buildings life cycle and how information is applied to the central BIM model by different project participants with different native BIM applications. A particular and qualitative research was conducted to locate problem areas within the method. The findings where that BIM is well suited for facility management and can enhance the operational phase by providing a solid information data source for the facility manager. There will however be obstacles to overcome in regards to technology but mainly in regards to changing building processes as fully integrated central BIM requires a major change in project participant's behaviour and working methods. As the BIM method becomes more adopted on building projects building owners will demand that the models can be used during the operational phase so providers of facility management systems will have to adapt to the method and in so provide building owners with a facility management BIM tools so the method can be used during the operational phase.

Keywords:
Building Information Modelling, facility management, COBie, IFC.

Útdráttur

Gerð upplýsingalíkana við mannvirkjagerð eða BIM hefur farið vaxandi seinustu ár og hefur byggingariðnaðurinn verið að tileinka sér aðferðarfræðina, aftur á móti hafa fasteignastjórnendur verið á eftir í að nýta aðferðina við reksturs fasteigna og svo virðist sem þeir hafi ekki áttað sig á hvaða kosti aðferðin getur fært þeim við reksturinn. Ritgerðin fjallar um hvernig hægt er að staðla upplýsingalíkön svo hægt sé að nota þau beint inn í fasteignastjórnunarkerfi, það er fjallað um hvernig uplýsingum er safnað á verktíma og hvernig þessar upplýsingar eru hengdar á líkanið af mismunandi aðilum í framkvæmdarkeðjunni. Rannsóknir voru framkvæmdar á því hvernig upplýsingum er safnað á framkvæmdartímanum og hvernig þessum upplýsingum var skilað inn í líkanið af mismunandi aðilum, einnig var skoðað hvaða hindranir geta legið í veginum fyrir að hægt sé að safna rekstrarlegum upplýsingum á hönnunar og framkvæmdarstigum verkefna. Hindranir sem hægt er að sjá fyrir að verði í veginum voru kannaðar en þær eru aðalega það að viðhorfsbreyting þarf að eiga sér stað og að breyttar verklagsaðferðir þarf að taka upp á framkvæmdartíma. Þar sem notkun upplýsingalíkana við mannvirkjagerð er að verða mun almennari aðferð við stærri framkvæmdir og notkun aðferðarinnar mun aukast í framtíðinni þá munu kröfur eigenda fasteigna fara vaxandi til fasteignastjórnunarkerfana að þau geti tekið við líkönunum og boðið fasteignastjórnendum uppá BIM verkfæri sem þeir geta nýtt áfram við rekstur fasteignarinnar og halda áfram að not líkönin sem upplýsingagrunna fyrir fasteignirnar.

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Abbreviations

AEC	Architect, Engineering and Construction industry
AECO	Architect, Engineering, Construction and Operational industry
API	Application Programming interface
BEP	BIM Execution Plan
BIM	Building Information Modelling
CAFM	Computer Aided Facility Management
COBie	Construction Operations Building Information Exchange
COBIM	Common National BIM Requirements
EPCM	Engineering, procurement, and construction management
FM	Facility Management
FSR	Federal construction agency (Framkvæmdarsýsla Ríkisins)
GIS	Geographic Information System
IAI	International Alliance for Interoperability
ie	Information Exchange
IFC	Industry Foundation Classes
IFMA	International Facility Management Association
ISO	International Organization for Standardization
LBNL	Lawrence Barkley National Laboratory
LCC	Life Cycle Cost
LOD	Level Of Development
NBIMS-US	United State National Building Information Model standard
O&M	Operational and Maintenance
OGC	Open Geospatial Consortium
PLM	Production Lifecycle Management
RIBA	Royal Institute of British Architects
UK	United Kingdom

1 Introduction

The use of BIM (Building Information Modelling) in the construction industry is on the rise and progressively more BIM models are being delivered from the building process. Building owners and facility managers will have a need for a platform so they can continue to work with the models as a source of facility management information source. As of now the models have not been standardized so they can be used in facility management platforms and the information that is applied to them are of no use during the operational phases as their structure is not well defined or none existence. The first chapter is a presentation of the thesis with reasoning on why this topic was chosen with discussion on what are the problems of being able to deliver a BIM model with facility management information. The aim of the research is discussed, research questions and objectives are presented and the correlation between these factors is deliberated on. The methodology will be reviewed and the structure of the research is introduced.

1.1 Statement of the problem

The BIM method has been on the rise for the past decade. The AEC (Architect, Engineering and construction) industry is adapting to increased demands for the use of BIM during the design and construction phase of construction projects. Building owners, private and public are increasingly requiring that BIM is used on their projects as the method has proven to have a positive impact on the construction process in many aspects e.g. clash detection, better visualization, energy analyze or its effect on buildings LCC (Life Cycle Cost); other parts of the method has been proven to save time and cost as well as delivering better product to the building owner.

FM (facility management) has not been as responsive to adapt to this new technology. Most of BIM models produced are not utilized during the operational phase of the building lifecycle but are shelved after the construction phase. Document and data needed for operating the building is handed over from the construction phase to the owner on cd´s or in boxes of drawings, warranties, instructions, replacement part lists and etc.[1]. The facility manager needs to produce his own set of data from documents received or collect them from the design-build phases which can be tedious, time consuming and could be avoided if the facility manager would receive the information regarding the building in a more structured and manageable way. The cost of this unstructured handover process is that a building owner is often paying for regenerating the same information up to three times during design and construction, at handover from construction to owner and when facility manager needs to collect his data from as-built building.[1]

Owners of facilities have not determined what information they need implemented into a BIM model so it can be used in a CAFM (Computer Aided Facility Management) system during the operational phase. This is a vital part of the problem as designers and contractors need guidance on what information they should attach to the model. The practicality of the information attached to the model needs to be determined.

The practicality of the BIM method and its effects on LCC (Life Cycle Cost) during design-build phases are well documented but until recently facility managers and owners have not taken interest in using the method in the operational phase so an exploration on how a BIM model will effect buildings operational phase is needed.

1.2 Aim and objectives

The overall aim of this research is to explore and research how FM information can be captured in the design-build phases of construction projects to populate BIM models and how the models can be standardized and used in the operational phase of projects in collaboration with CAFM systems. Define how this can be achieved and how that will affect the BIM process. The method of implementing the FM information will be explored from one single BIM application and how that information transfers to the CAFM system. The study will examine how the BIM method and BIM models can be used in FM to lower buildings LCC by providing an information system designed to capture as-built information throughout buildings LCC and reduce information loss.

1.2.1 Research question

The objectives of this thesis are divided into four research questions so the progress can be monitored and measured as the work progresses.

1. What information does a BIM model have to have so it can successfully influence the operational phase of buildings?
2. How is this information implemented to the BIM model?
3. How will implementation of FM data influence the BIM process?
4. How can BIM influence buildings life cycle cost?

These questions were thought to be of most value to clarify and understand how BIM models can be produced and used directly within a CAFM system and to find out what has been prohibiting these models from being FM information rich.

It was not considered to be of any value for the study to formulate a hypothesis because the aim is not to approve or disapprove anything but rather to study how the construction environment is and if it is capable of implementing BIM for information capturing and sharing during buildings lifecycle.

2 Theoretical framework

In this chapter the reasoning's for chosen research methodology is discussed and the reasons for what strategy is applied is justified. Deciding on the right research approach is important and should aim at answering the research questions. Choosing the incorrect research approach could have very negative consequences for the whole dissertation if the outcome of the research would not relate to the overall aim of the thesis of examining the feasibility of implementing FM information to BIM models. This chapter describes the theoretical framework that was applied conducting this research.

2.1 Research approach

BIM and facility management are two different worlds today, information that is generated in the design-build process has a tendency of getting lost at different handover stages in the building process or is inaccessible for owners and facility manager after construction handover. The research focuses on how BIM can be used to collect and deliver information from different disciplines during design-build phases and deliver them over to the operational phase and if BIM models can be used as a data source of FM information in a CAFM system.

CAFM systems have a firm footing in the facility management industry and are expected to hold their position as a tool for managing FM information during buildings operational phase. It is expected that there will be increased demand for these systems to be used as BIM tools for information sharing after construction handover.

The research focuses on how the BIM method can successfully carry FM information from the construction phase to the operational phase and what has to be done so this can be achieved. The AECO (Architect, Engineer, construction, and operation) industry will be examined to find out if actors in the field have considered the opportunities and benefits that BIM can add to facility management.

Different disciplines will be looked at, their views and opinions examined on BIM examined and compared to other disciplines to determine their capabilities of working on BIM projects.

The research will inspect what knowledge is available the information that is needed for FM and would bring the most value to the building owner. Also if there have been done any studies on the subject.

2.1.1 Research strategy, techniques and tools

The research strategy in this study is a survey conducted by interviews with different actors in the AECO industry in Iceland. The aim of the survey was to examine how FM information that is created during design-build phases of building projects can be passed over to projects operational phase with no information loss in the process.

The use of open question interviews was the most appropriate method of collecting data as it gives the participants the opportunity to express themselves on their views, capabilities, interest and limitations on the BIM method giving the researcher a good insight into where the market stands on BIM implementation.

The limitations of the study is that it will yield only qualitative data as the different groups within the sampling size is not large enough to produce trustworthy quantifiable data. It was however felt that the view from a wide range of stakeholders in the construction industry was critical to understand where obstacles of implementation are.

A particular research is applied to investigate how information is implemented into the BIM model and transferred to the CAFM system MainManager. For this purpose Revit Autodesk a native BIM application was used to apply FM information into a BIM model. That model was then converted into an IFC file and imported into MainManager. The limitations of this research are great as it is limited to one BIM software and one CAFM system. The research was conducted to understand how information should and could be implemented into the native BIM software and if the transfer to the CAFM software would be problematic.

2.1.2 Sampling

The sample size is limited to the Icelandic construction industry as the use of interviews would not be possible in the global market. The sampling size was limited to governmental agency, owners (FM), consultants and contractors, those where thought to be the most valuable stakeholders in the BIM implementation process. The focus on the home market allows for an in depth understanding of what different perspectives participants in the study have on the subject. The sampling method is stratified sampling where the targeted population is broken down into identifiable groups.

2.2 Structure of the of the thesis

The structure of the thesis is presented and discussed the thesis is structured into five main chapters. The chapters are focused on different aspects of the research clarifying how the research was conducted. The first two chapters describe the focus of the thesis and what strategy was applied; third and fourth are the research and the last chapter is the conclusion.

Introduction

The first chapter is the introduction to the thesis. It contains an introduction and a statement of the problem which is to be examined, aim and objectives of the thesis is clarified as are the research questions presented.

Theoretical framework

This chapter describes what type of research methods was applied, how the research was conducted and deliberations on what where the research limitations. It´s emphasis is on how BIM can be used for information gathering during the design-build phases of building projects.

Literature review

The literature review is divided into three parts the first part consists of examining the BIM method, what it is, how it is applied in the building industry and what benefits the method can bring to building projects.

Second part of the literature review is on facility management clarifying FM and its purpose is an understanding of what general key information is needed for facility management is collaborated on.

Third part of the literature review will explore where the BIM method is on standardization and how it can bring structure to the construction industry by providing proven methods of data capturing through the whole buildings lifecycle with the focus on FM information. The review is aimed at finding a bridge to connect between the two worlds of BIM and FM.

Research

The research chapter is divided into two sections the first is the particular research where methods of capturing information and delivering to CAFM system is explored. How that information should be inserted into the native BIM model is examined, transferred into an open standard BIM that can be used in a CAFM system.

The second section is the Implementation researches conducted by interviewing stakeholders on the building market and analyze and identify obstacles that need to resolve so implementation of BIM could be successful.

Conclusion and recommendations

The findings of the study is presented, collaborated on and the conclusions are presented to the reader recommendations of how the implementation process can be conducted is presented and discussed.

3 Literature review

The aim of the literature review is to examine what literature is available on the research subject. This literature review focuses on BIM, facility management and on how these two worlds can come together by producing a building model that contains information for the operational phase of building projects. The literature aim is to explore and discover what is already known in regards to the research questions.

1. What information does a BIM model have to have so it can successfully influence the operational phase of buildings?
2. How is this information implemented to the BIM model?
3. How will implementation of FM data influence the BIM process?
4. How can BIM influence buildings life cycle cost?

By focusing on answering the research questions knowledge is gained on the subject contributions to the thesis is gained and applied.

Information was collected from Reykjavik university library, Google scholar and relevant software vendors. Published journals will come from different sources but main source is “Automation in Construction” and “Science Direct”.

3.1 BIM Method

The earliest documentations of the BIM method reaches back to the late 1970´s and early 1980´s in Europe these systems were described as “Product Information Model” while in the USA they were described as “Building Information models”[2] later those would merge into what now is referred to as the Building Information Model or BIM which is descriptive of the system today. The system is described differently between diverse actors, Hannu Penttilä describes BIM as following:

> *“Building product modelling, product data modelling or building information modelling (BIM) is a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle.“*[3]

The description gives a clear indication of what BIM is about, that is the management of projects information throughout the projects lifecycle. GSA (U.S. General Service Administration) is more specific in their definition of BIM which is:

> *“The purpose of BIM is to make the design information explicit, so that the design intent and program can be immediately understood and evaluated. A BIM-based approach supports ‘on demand’ generation of documents (e.g., drawings, lists, tables, and 3D renderings) from a consistent BIM. In a sense, these documents present views of the current BIM. A BIM model, therefore, can live longer, contribute more to process efficiency, and provide superior accuracy than traditional 2D CAD drawings”.*[4]

Both of these definitions mention that the BIM model can be used for an extended period of time through the whole lifecycle of projects and therefore as well for the operational phase of the lifecycle.

The AEC (Architect, Engineering, Construction) industry has been adopting to the BIM process for the past decade realising the potential benefits it can contribute in time and cost saving of construction projects

even though the industry is still exhibiting a low maturity in BIM use[5]. The operational sector has not been as acceptable for the use of BIM and is trailing behind the AEC industry

3.1.1 BIM information

The whole idea of BIM is that information will flow unhindered between stakeholders on a building project and that each actor in a building project sees the benefits of accessing information concerning their discipline as soon as they are generated in the building process, it is a shared knowledge resource for the facility that depends on that all project participants insert, collaborate, extract, update or modify information in the model database that reflect their project disciplines. One of the main reasons for building defects are bad communication lines between different stakeholders in the project so describing BIM as a 3D model is a very limited view of the method as its primary goal is to collect, store and share all information on facilities to eliminate re-gathering and reformation of information.

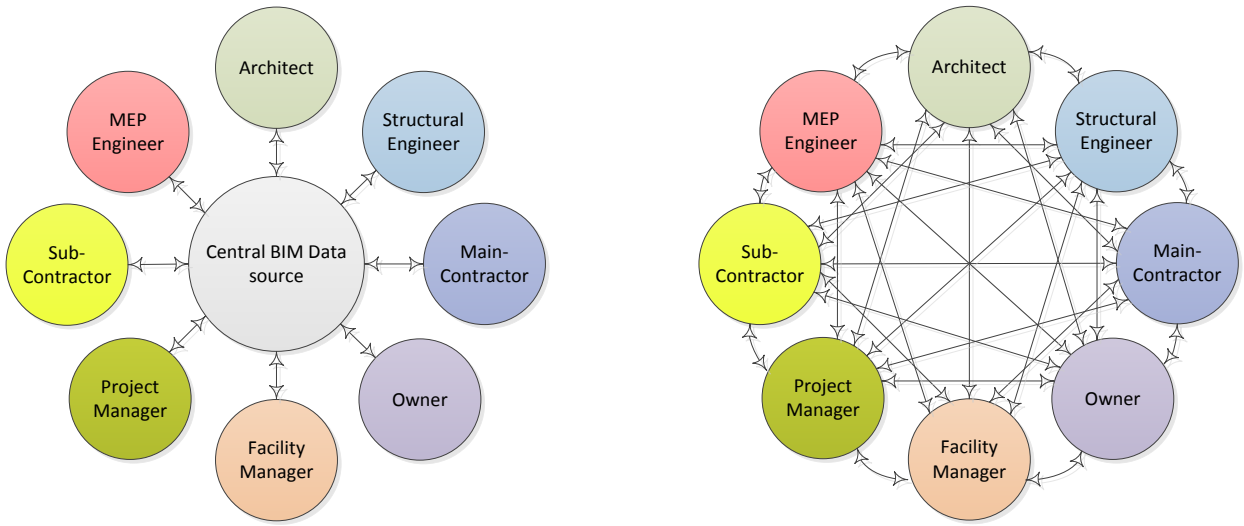


Figure 1 illustration of different type of information exchange BIM with a central model vs. traditional.

3.1.2 The BIM model

Many different definitions are available on what a BIM model is, different actors have their different description of BIM models as they have different uses for it. Criteria's that the physical model needs to meet so it can constitute as a BIM model is that it needs to be digital, spatial, measurable, accessible and durable so it can be used throughout the buildings lifecycle[2]. The BIM model is not just a 3D model of buildings, it has been referred to as a computer generated n-dimensional model or a n-D model which is used to simulate the planning, design construction and operation of a facility.[6]

The end model produced in the BIM process has been defined by the associated general contractors of America as a:

> *"A data-rich, object-oriented, intelligent and parametric digital representation of a facility, from which views and data appropriate to various users´ needs can be extracted and analysed to generate information that can be used to make decision and improve the process of delivering the facility".*[7]

This definition is in line with how a model suitable for FM would be described as it focuses on the information side of BIM and how that information is associated with specific objects within the model, it

also acknowledges how the model can be used for decision making by different actors in the whole construction supply chain.

The traditional method of drawing independent 2D views of buildings differs from the BIM model since the drawings are all independent of each other, meaning that if a change is made in the design of the building each drawing needs to be checked and updated manually whereas if a design change is made on the BIM model that change influences all sets of drawing in the model, similarly if a design change is made on a room in the model all data linked to that room such as m^2, m^3, material quantities and different room analyses change and are easily manageable in schedules produced in the BIM database.

All components in the BIM model are "smart" for example, an air conditioning unit within BIM would also contain data about its supplier, operation and maintenance procedures, flow rates and clearance requirements[8]. A building element such as a wall would contain material, dimensions, building element codes, fire protection codes, cost estimates and etc.

3.1.3 BIM Information Level

The Danish BIPS[9] have published standards that define different levels of BIM model completion the levels are seven that begin with level 0 representing the first design specification to level 6 representing the as-built building and is a model containing FM information. The AIA (American Institution of Architects) has published standards (Level of detailing, LOD100 – LOD500) that are in 5 levels but for this study the Danish standards is chosen to display as it incorporate the operations of facilities better than the American standards.

Information level 0

This level is used in the first phase a building programme as a part of the design specification or as a part of material presented for a design competition where requirements and constraints are presented and formalized. This level holds only the basic information on the project as terrain, surrounding buildings and GIS (Geographic Information System) information. The model is classified after type or function.[9]

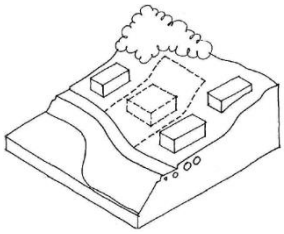


Figure 2 Example of a BIM model in information level 0[9].

Information level 1

This level is used for the conceptual design to determine the buildings form and function. Information about the construction size, shape and volume should be extractable from the model both gross and net. As a minimum the model should include volume the buildings outer geometry and rooms which are classified by function[9]. In this phase the facility gets its classification code, function and energy analysis are made which can be used during the operational phase.

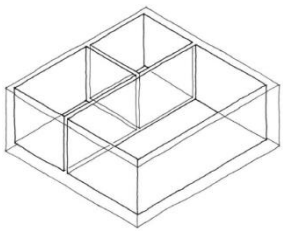


Figure 3 Example of a BIM model in information level 1[9].

Information level 2

This level is used for the project proposal phase the model is built on the base of the model in information level 1 it will further set the constructions physical and functional characteristics. The model can be used for an early tender with a contractor. As a minimum the model should include rooms that define their usability and critical structural objects that defined elements dimension like

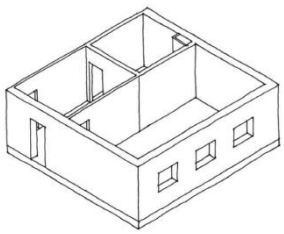


Figure 4 Example of a BIM model in information level 2[9].

walls, slabs and roof. Rooms should be classified by function and structural elements after type. Before a model in information level 2 is released different actors need to coordinate their work and a consistency control needs to be conducted[9]. Designers and consultants would start adding data to specific elements like minimum thermal insulation for walls or windows and other design specifications.

Information level 3

This level is used for the preliminary project to define the buildings main structure and to form the basis for the building permission application. The model should include all necessary building elements which can be used for the traditional main plan drawings, overview drawings and structural drawings. Before a model in information level 3 is released different actors need to coordinate their work and a consistency control needs to be conducted[9]. Buildings main components are identified and design requirements assigned to them as minimum needed for applying for a building permission.

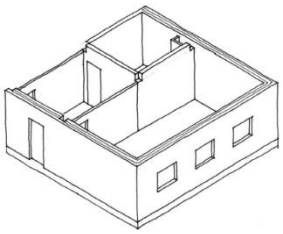


Figure 5 Example of a BIM model in information level 3[9].

Information level 4

This level is used for the main project and procurement to make the base for tender, cost calculation, bidding and production planning. All main drawings, overview drawings, structural and detail drawings should be tractable from the model. All building elements should have relationships to quantity calculations and building element specifications. Before a model in information level 3 is released different actors need to coordinate their work and a consistency control needs to be conducted[9]. All information needed by contractors should be in the model e.g. design requirements.

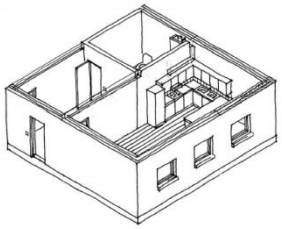


Figure 6 Example of a BIM model in information level 4[9-].

Information level 5

This level is used as a basis for production; therefore it should contain sufficient information so the building can be produced, included scheduled deliveries of building elements, components and materials. Information on geometry necessary for production should be in the model. Building elements should have relations to economics and logistics information[9].

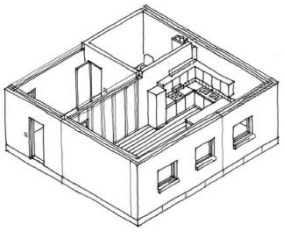


Figure 7 Example of a BIM model in information level 5[9].

Information level 6

This level is used as documentation for the finished building and should be completed as “as-built” model and should include information for operation and maintenance. Building components should have relations to operation and maintenance material[9]. This is the model that will be used in the operational phase, information pushed into the model derive largely from contractors and need to represent the construction with all information from main-contractor as from sub-contractors.

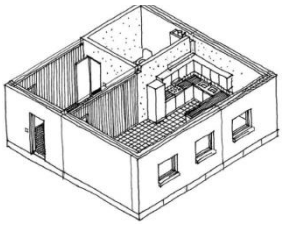


Figure 8 Example of a BIM model in information level 6[9].

The complexity of BIM models can be great for large complex buildings where many different actors work on the same model and each level needs to be synchronised between different actors that work on the

model. A BEP (BIM execution plan) is used to describe what processes and procedures are within the organization and how the model is coordinated and delivered with pre-defined data[10]. The different information levels of BIM models showcase how detailed the model has to be so it can be successfully used in the operational phase of the building project and what information has to be implemented and when.

A model that is intended to be used in facility management needs to reach information level 6 but in truth not many models reach that stage, most models never pass information level 4. At level 4 after tendering the contractor needs to get more envolved with the BIM project adding as-built information to the model as the model. Contractors have not been required to add as-built FM information in general, there has been pilot projects but no general requirements have been set by owners for contractors to follow. Owners have not defined properly what information is needed in the BIM model or what information should be gathered and inserted by which actor. The consiquences are that the models that are generated do not contain the appropriate information or are standardized for FM.

3.1.4 BIM Stages

Bilal Succar defined BIM to have three stages the first stage is an "*Object-based model synopsis"* in this stage an object based 3 dimensional software is used to create the building model which is generated by a single disciplinary (Architect, engineer or contractor). A model in this phase is primarily used to produce deliverables such as drawings, schedules, 3D visualisations and documents that are coordinated with the BIM model[11].

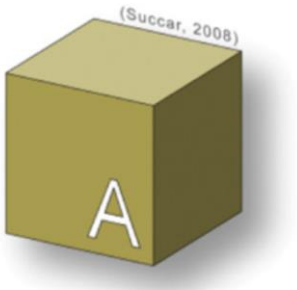


Figure 9 Illustration of a single disciplinary model[11].

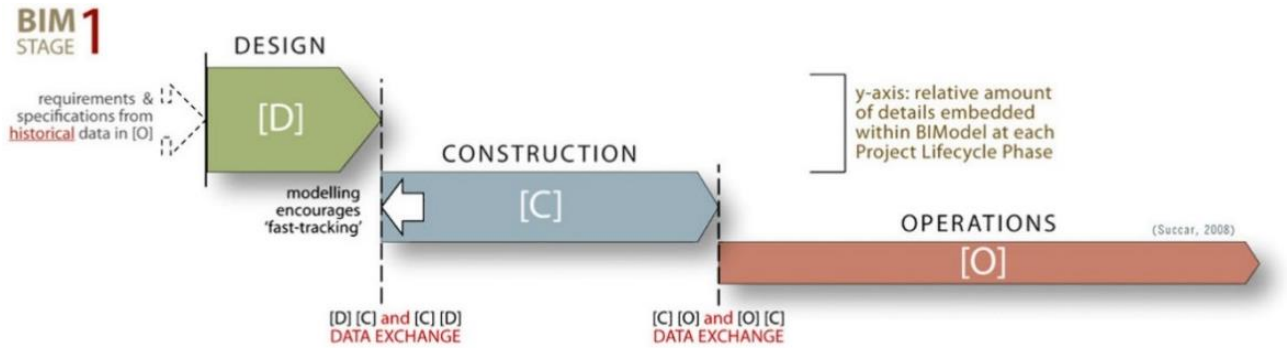


Figure 10 Project phases at BIM stage 1[11].

Stage 2 is the *"Model-based collaboration synopsis"* actors in this stage collaborate with each other for example Revit architecture and Revit structure through a proprietary format a .RVT or between ArchiCAD and Tekla with the IFC non-proprietary file format or between none 3D programs as time scheduling 4D, cost estimating 5D database software[11] as MS Project and Sigma enterprise and The COBie (Construction Operations Building Information Exchange) the 7D which can be interoperable through .xml format. This collaboration can occur within one or between two project lifecycle phases as design-construct, design-design or design-operation phases in this stage only one model needs to hold geometrical data.

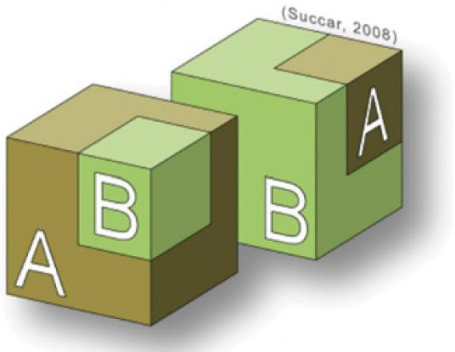


Figure 11 Illustration of a single disciplinary model with 2D BIM tool integration[11].

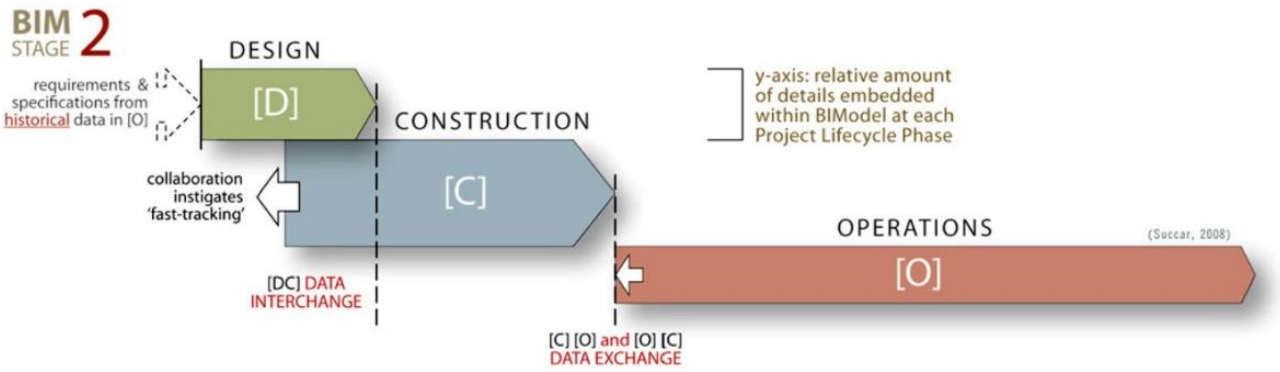


Figure 12 Project phases at BIM stage 2[11].

Stage 3 is a *"Network-based integration synopsis"* in this stage semantically-rich integrated models are created, shared and maintained collaboratively across project lifecycle phases. This technology can be achieved through model server technologies. BIM stage 3 models become interdisciplinary n-D models allowing complex analysis at early stages of virtual design and construction. From a process perspective, synchronous interchange of models and document-based data cause project lifecycle phases to overlap extensively forming a phase-less process[11].

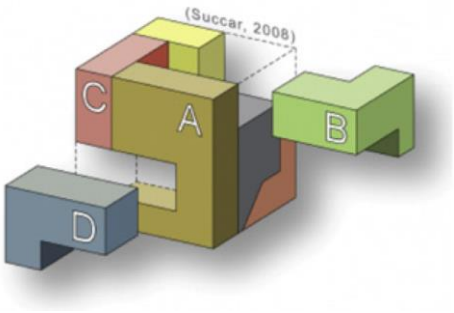


Figure 13 Fully integrated model with different disciplines working on a single model[11].

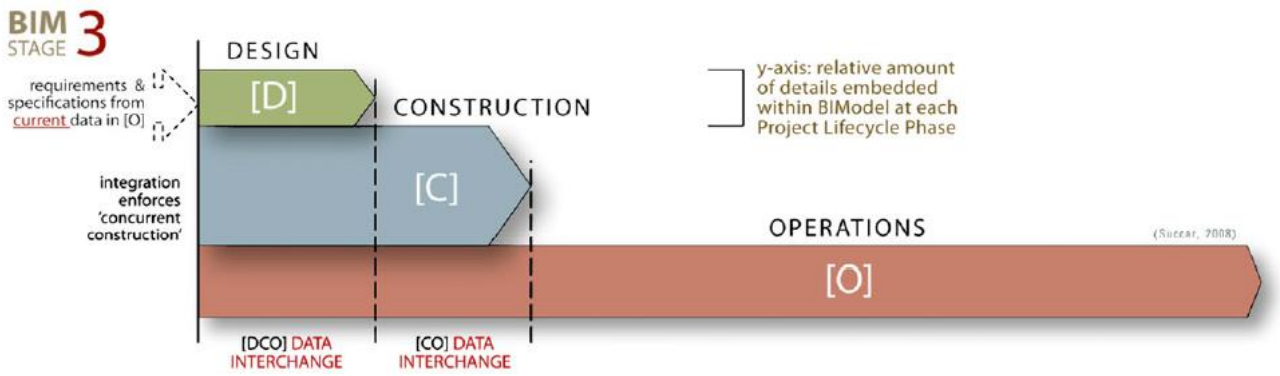


Figure 14 Project phases at BIM stage 3[11].

3.1.5 BIM Maturity levels

The BIM maturity model is used to ensure clear articulation on where current competence stands in regards to technology, standards and guidance and what relationship they have to each other. The “wedge” visualises the levels from 0-3 how work is conducted in each level and where technology stands[12]. The wedge was created in the UK (United Kingdom) so it represents standards related to the UK building industry. In 2016 all public construction projects shall be at minimum on level 2 showing the UK´s commitment to the BIM process.

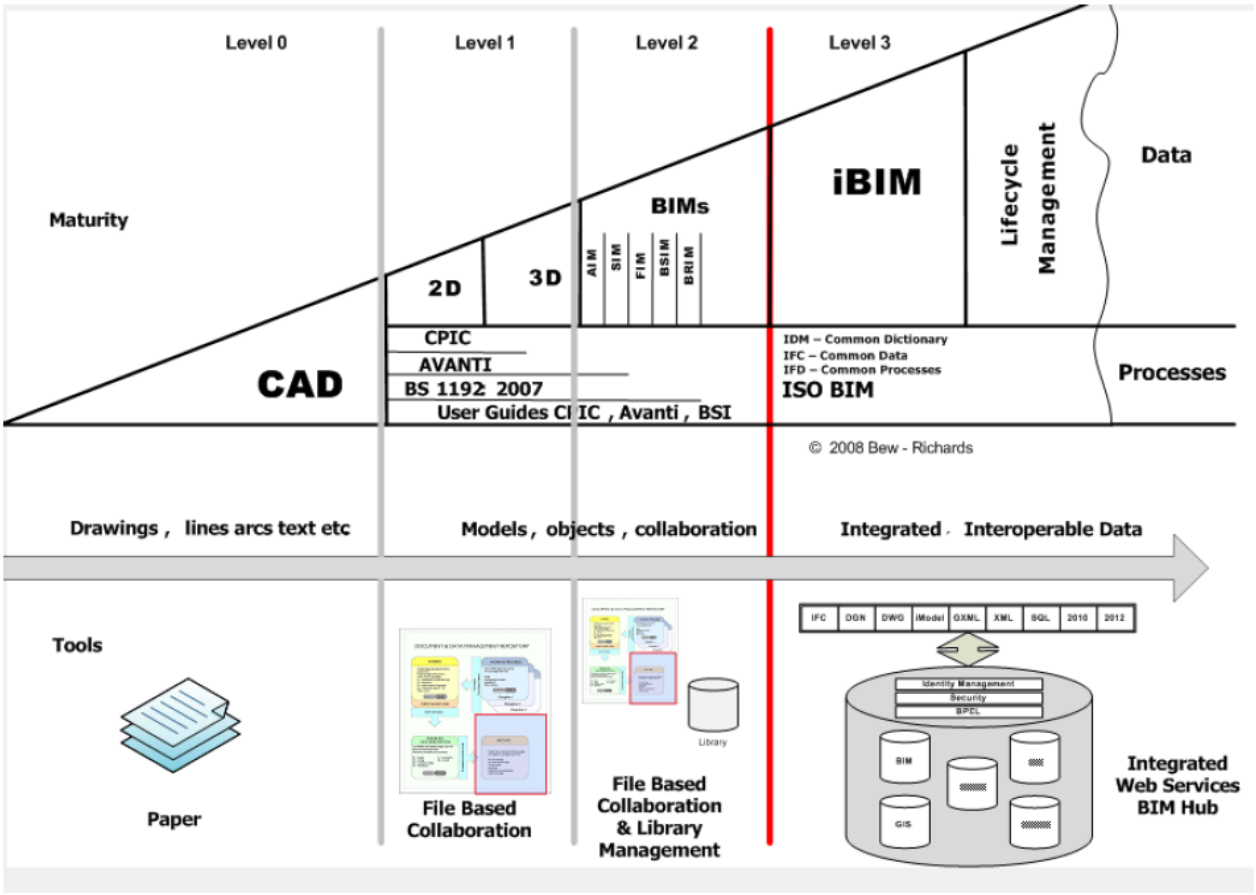


Figure 15 UK BIM maturity Wedge [12].

Stage 0

Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism[12].

Stage 1

Managed CAD in 2D or 3D format using BS1192:2007 (UK Standard) with collaborating tool providing a common data environment, possibly some standard data structure and formats. Commercial data managed by standalone finance and cost management packages with no integration[12].

Stage 2

Managed 3D environment held in separate discipline “BIM” tools with attached data. Commercial data managed. Integration on the basis of propriety interfaces or bespoke middleware could be regarded as

"pBIM" (proprietary BIM). The approach may utilise 4D programme data and 5D cost elements as well as feed operational systems[12]

Stage 3

Fully open process and data integration enabled by "web services" compliant with the emerging IFC/IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes[12].

It is possible to use the maturity wedge to analyse where different countries are in adopting BIM. The Icelandic construction industry is as of now using file based collaboration and are drawing in 3D and 2D the FSR (Federal construction agency) is pushing for more BIM collaboration and for the use of a central database. But at the moment the Icelandic industry is on information level 1 heading for information level 2. The nordic countries, Finland and the UK have reached level 2 and are pushing for level 3.

3.1.6 BIM Execution plan

The plan is an important part of integrating BIM into the project delivery process; a detailed BIM execution plan outlines the overall vision for the project as well as implementation details for the team to follow throughout the project. The BIM execution plan should be developed in the early stages of the project continually developed as additional participants are added to the project and monitored, updated and revised as needed throughout the implementation phase of BIM projects. The plan should define the scope of the BIM implementation in the project, identify the process flow for BIM tasks, define the information exchange between parties and describe the required project and company infrastructure needed to support the implementation[13].

By developing a BIM execution plan, the project and project team members can achieve the following value[13]:

- All parties will clearly understand and communicate the strategic goals for implementing BIM on the project.
- Organizations will understand their roles and responsibilities in the implementation.
- The team will be able to design and execute process which is well suited for each team member's business practices and typical organizational workflow.
- The plan will outline additional resources, training or other competencies necessary to successfully implement BIM for the intended use.
- The plan will provide a benchmark for describing the process to future participants who join the project.
- The purchasing division will be able to define contract language to ensure that all project participants fulfil their obligations.
- The baseline plan provides a goal for measuring progress throughout the project.

3.1.7 The MacLeamy curve

Using the BIM method moves decision making in the building process sooner in the project the MacLeamy curve shows how moving the decision making earlier in the building process makes it easier and less expensive to make design changes or counter design flaws in relation to the traditional building method. The curves where drawn by Patrick MacLeamy and are used when what benefits BIM can have on projects needs to be explained

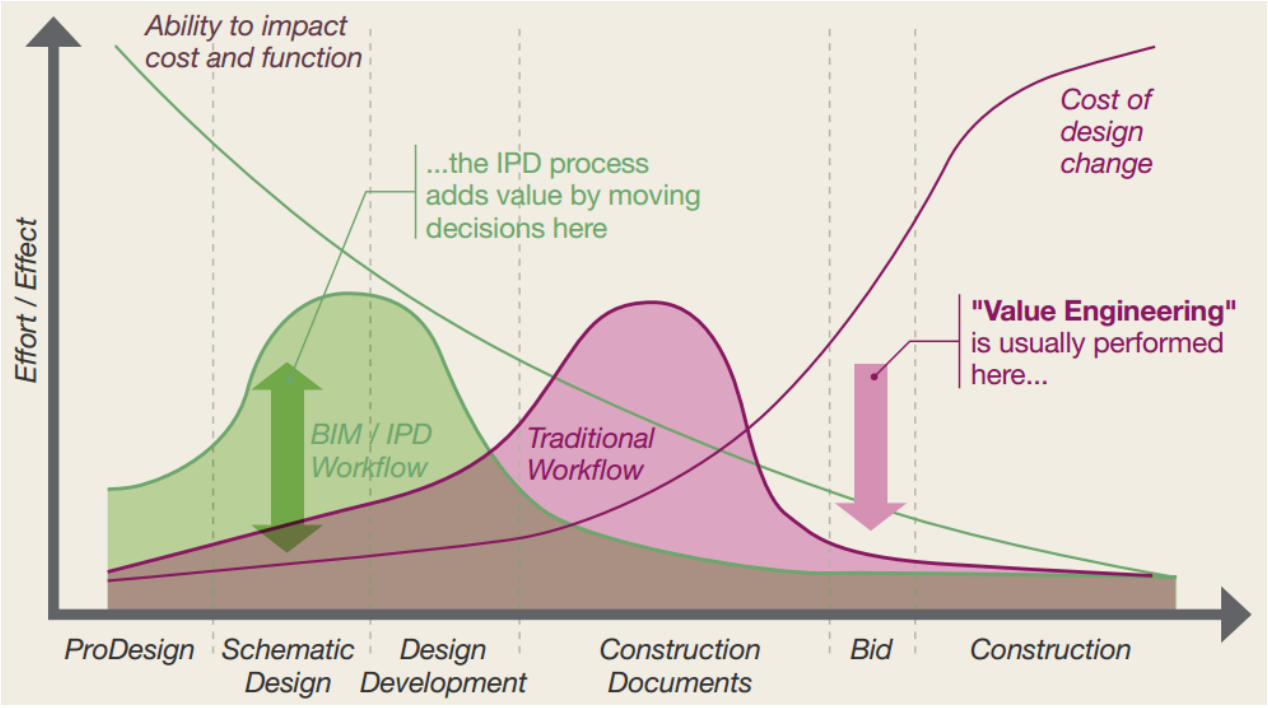


Figure 16 Illustration of the MacLeamy Curve showing how BIM can influence design and cost by shifting effort[14].

3.1.8 BIM Internationally

The BIM method is on different maturity levels in different countries this section describes what organizations are leading the implementation of BIM in relevant countries. The analysis is restricted to the countries that have been leading the adaptation to BIM in the construction industry.

Different countries have their own BIM standards and different organizations that contribute to writing and updating the standards. The different types of standards are necessary since each region has their own regulations and traditions within the construction industry so the standards need to be adapted to different cultures. The general purpose of the standards is to solve problems with ineffective exchange of information through building lifecycle.

BuildingSMART Alliance

> "BuildingSmart is a worldwide alliance driving the development of open internationally recognized standards, tools and training to support the wider uptake of building information modelling by the Architecture, Engineering, construction and facility management industries"[15].

The BuildingSmart alliance is a neutral, non-profit organization which supports the use of open BIM. The goal of the organization is to improve cost, value and environmental performance of buildings through the use of open sharable asset information. BuildingSMART has been in the forefront of implementing BIM. BuildingSMART develops and maintains the IFC platform which makes it possible for interoperability between different native CAD software.

The Scandinavian countries and the UK are a part of the BuildingSMART alliance using the non-proprietary format IFC (Industry Foundation Classes) as a tool for interoperability of native BIM models.

USA, NBIMS-US

The National BIM Standard-United states (NBIM-US) is the North American BIM standard. The standard is developed by the National institute of building science and is aimed at the North American market.

United Kingdom, Building information Modelling Task Group

In 2011 the UK published the Building information modelling working party strategy, the report announced that the UK government intend to require that all public infrastructure projects from the year 2016 shall be BIM projects with all building asset, documentation and other data in digital format. The aim of the strategy is to lower buildings LCC and reduce construction industry carbon footprint by increasing the use of BIM in the AECO industry[12]. COBie is mandated in this effort setting the focus on BIM for facility management.

Denmark, Det digital byggeri (BIPS)

"Det digital byggeri" (The digital construction) is the Danish organization that endorses the BIM method in Denmark. Their mission is to provide the bases for a better cooperation and productivity in the AECO industry by developing a digital infrastructure and standardize information use. Projects that exceed 5.5 million euros must be designed as 3D models and must fulfill a number of requirements regarding content and information levels for the various phases which are to be defined by the client individual projects[16]. Denmark is one of the leading countries in adopting the BIM method with BIPS having a strong influence on legislation.

Finland

In 2012 Finland released their Common BIM requirements or COBIM it was developed by a broad range of participants within the Finnish construction industry. It was developed to meet the need of defining what, when and how BIM should be modelled during the design-build-operate process[17]. The requirements consist of 13 chapters each chapter dedicated to their own aspect of BIM including facility management.

Norway

In 2016 all construction projects conducted by Statsbygg (Norwegian public construction authorities) and Forsvarsbygg (Norwegian Defence Estate Agency) shall support open standard BIM. Statsbygg released a

BIM manual in 2011 defining what general BIM requirements projects. Mandating BIM on all public construction projects is very ambitious showing how dedication they are to BIM.

Iceland

The Implementation of BIM in Iceland is led by Framkvæmdarsýslu Ríkisins (FSR) a governmental organization that has the purpose of collecting knowledge on construction processes and to be a leading organization within the Icelandic construction industry on standardization and information technology in the building industry.

In countries that have been leading the implementing of BIM the carrying out has been led by public organizations that underlines that a successful adaptation of BIM must be led by organizations that has a long time view on building projects and looks at how the operational phase can be improved by optimising the design-build phases and is prepared to invest in methods to improve the overall building process.

3.1.9 Conclusion on BIM

BIM is a method of designing a facility with object based parametric modelling enabling designers, contractors and owners to share information between each other within a digital model, which is a major change from the more traditional information exchange method. The benefits of BIM is well documented by multiple researches conducted over the past years showing the benefits the method can have on time, cost and value for all participants of the construction project. It is however important that the full capabilities of BIM can be achieved that the method is well understood between project participants and that they use a structured well pre-defined BIM strategy on the projects so the models which are a deliverable of the BIM method are mature and information rich enough to be used throughout projects lifecycles.

The main focus of BIM has been on the design-build phases of building projects and less effort has been on BIM for facility management even though the benefits of being able to use the BIM model through the whole buildings LCC has been theoretically proven. The focus is however shifting towards facility management with better BIM tools and deeper understanding of the method there will be more focus on using BIM for the whole buildings LCC in future projects.

3.2 Facility management (FM)

Facility management is a relative young concept of managing constructions, the method traces back to the 1970´s with the introduction of the office cubicles and the computer terminal to the workplace. In December 1979 Hermann Miller Research Corporation hosted a conference on "Facility influence on productivity" in that conference three founders of the National Facility Management Association (NFMA) later The International Facility Management Association (IFMA) where present those where George Graves, Charles Hitch and David Armstrong. In conjunction to the foundation of the IFMA and a BSc and an MSc degree programs where introduced at the Cornell University, New York and so a structure around facility management was created.

FM has evolved for the past decades from being looked upon as a poor relation within the AEC industry[18] the old fashion style of facility management focused solely on the cleaning, maintaining and repair aspect of FM this has changed and today the modern FM covers variety of functions within organizations that are designed to support organizations to meet there goal.

Different definitions exist one definition commonly used defines FM as:

> *"An integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization"*[18][19].

This definition emphasis that FM should support the main objectives of any organization which means that the FM strategy must adapt to whatever the objectives of the organization is at any given time supporting their core business objectives. The International Facility Management Association conducted a survey of close to 1000 facility managers from Canada, Australia, Asia, Africa and the USA to determine core competencies of FM, the study was concluded in October 2009 and the results were eleven core competencies[20]:

- Communication
- Emergency preparedness and business continuity
- Environmental stewardship and sustainability
- Finance and business
- Human factors
- Leadership and strategy
- Operations and maintenance
- Project management
- Quality
- Real estate and property management
- Technology

The study concluded that the previous nine core competencies of FM still remained but additional two were added the emergency preparedness and business continuity and environmental stewardship and sustainability[20].

3.2.1 FM Information

Access to information is one of the key elements that a facility manager needs to have so he can make informed decisions about facilities. He needs to be able to read the building and how it is performing over time and benchmark the performance of buildings to other buildings. Facility manager needs to be able to understand what type of building he is managing, what systems are in place, what components and where they are in the facility, manuals, warranties and etc. for a large building. This can be an overwhelming amount of information so for the facility manager it is equally important that he understands what information he doesn't need and is able to exclude information that has no value in operating and managing the facilities.

A clear definition and a detailed analysis of what information should be captured in the design-build phase needs to be done for each project there is however a common data set that will apply for all buildings the table 1 shows what basic information is needed for facilities, from what phase and from what discipline it comes from.

Phase	Discipline	Information
Pre-design	Architect	Information on buildings energy performance, quantities, sizes, and spatial information. Information can be used for LCC analysis and design comparison.
Design	Architect	Rooms: Spatial information, floor, wall and ceiling information. Component requirements. Zones: e.g. fire, access and etc. Construction codes.
	MEP engineers	Spaces: Energy analysis, requirements of MEP components. Zones: Different HVAC zones registered.
	Structural engineer	Structural requirements.
Construction	Contractor	As-built information, materials, manufacturers, installation dates, warranties, production information, spare part list, suppliers and manufacturer's instructions.
	Architect	Components placement, as-built design.
	MEP engineers	As-built MEP system placement.

Table 1 What information is expected to be delivered, when and by what discipline.

Deciding what information should be included is equally important as deciding what information should be excluded as when the FM manager operates the building he only wants to view information that has to do with the operational phase. Information generated in the design-construction phases that only are regarding construction of the facilities cannot be a part of the FM manager's dataset as this information will only hinder him in accessing this information that is of any true value to him.

3.2.2 Computer Aided Facility Management

The key to successful facility management is access to information, having the right information at the right time is vital for the FM manager so he can make better, more informed decision when needed. Managing buildings requires vast amount of data in the form of drawings, documents, instructions, maintenance

schedules and etc. all this data needs to be managed appropriately so it will come at use when needed by the facility manager. There is a variety of CAFM systems being used by facility managers, one of which is MainManager a web based system capable of storing and displaying information about key elements within a building. MainManager is used in this thesis as a reference system on how the BIM methodology can be utilized in collaboration with CAFM. Other systems include though not limited to Youbim[21] and ArchiFM[22] which are online CAFM systems with BIM integration these actors are foremost in incorporating BIM in facility management.

The purpose of CAFM systems is to assist the facility manager in storing information on facilities and they are a tool for analysing that information so changes in building performance can be monitored an reacted to by the FM manager. The FM manager's primary goal is to provide an adequate facility that fits the business operation at a reasonable price. The CAFM systems provide a tool so buildings performance can be optimized saving cost and providing better facilities.

3.2.3 MainManager

ICEconsult is an Icelandic firm that has been developing a web based facility management system since 1994. In the MainManager their focus is on optimizing facilities operations and maintenance. The MainManager system provides a platform for the facility manager to collect, extract, view and analyse information quickly and efficiently. Their solution is directed at maintenance & operations, project management, property management, energy management, space management and service management[23]. ICEconsult is looking at how BIM can become an integrated part of their MainManager system and are looking at solutions on how it is possible to standardize and streamline the model for easy integration.

3.3 BIM and facility management

Facility management relies on access to information created during the design, construction and operational phase of construction projects. In each stage of the building process there are different sets of information created, and this information has the tendency of getting lost during different handover phases of the project if the handover process is not properly defined. BIM as a process of storing and sharing information is theoretically a good method of capturing and delivering information between these phases and between different project participants. Information that is used for the operational phase of facilities can be collected during building's design-build phases. However for the BIM model to be usable for the operator the information within the BIM model needs to be sufficient, accessible and validated and so the process of collecting information needs to be well framed. There are many visible obstacles that need to be overcome before the construction industry can successfully apply the BIM method and deliver BIM models that can be used directly in the operational phase of buildings. Despite the obstacles the AECO industry and the public construction sector can see the value BIM delivers if applied properly and are therefore pushing for BIM implementation.

Actors within the FM industry are currently developing systems adopting the BIM method these actors are e.g. ArchiFM and Youbim in collaboration with governments they are pushing for better processes of capturing data through the design and construction stages of building lifecycle so that data captured can be used during the operational phase.

The capability of BIM for storing information is excessive so for this study the field has been narrowed down to four physical element that the model needs to incorporate. These four elements are rooms, zones, building systems and building components these four main categorize are then subdivided into specific element that will be analysed.

3.3.1 Information handover

The traditional method of information handover is that the FM manager receives boxes of information regarding particular facility and by cd´s, the amount of data that is handed over can be overwhelming and is often placed in storage rooms where they are held in reserve and without any use for the operator of the facility as the inaccessibility of the information is to great. The FM manager then needs to validate or recreate data by physically checking and documenting information that should already be available to him.

A study conducted in 2004 and published in 2005 estimated that annual loss in the USA due to lack of interoperability among computer aided design software used in the AEC industry is 15.8 billion dollars which is the sum of estimated cost burden for four key stakeholders in the AECO industry, Architects and engineers 1.2 billion, general contractors 1.8 billion, speciality fabricators and suppliers 2.2 billion and owners and operators 10.6 billion[24]. Even though the study is dated the issue of data loss in the industry is still a very pertinent issue that needs to be explored. In the end the lack of interoperability are largely at the cost of the owners as it is represented in the bid prices of designers, consultants and contractors. Owners are there for looking at ways of eliminating this data loss in the construction industry by providing a neutral platform of interoperability between different software platforms.

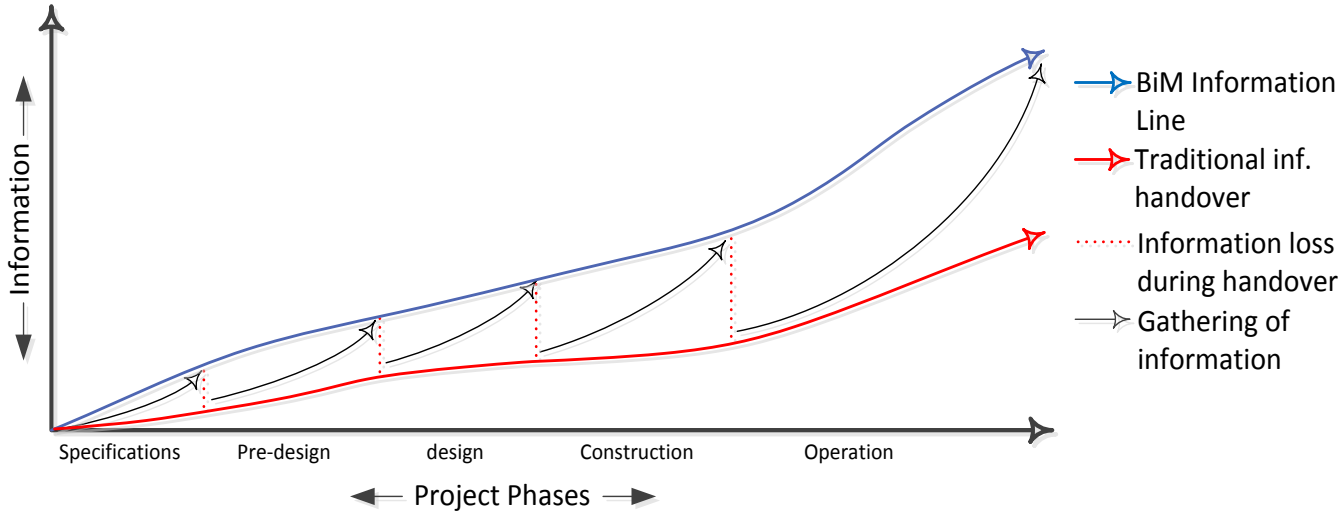


Figure 17 Illustration of information loss at different handover stages in projects[24].

3.3.2 Information Forms and Formats

There are different forms and formats available to execute information handovers, this chapter summarizes what type of formats are available for data collection and exchange within the AECO industry. It is important to understand what information formats are being used for the owner as he will be requiring the building information. Below are different information handover formats as described in the General Building Handover Guide.

Unstructured forms

Data that falls into this category are electronic or paper documents that have no formal structure. For these documents there is no other way of interpreted them or check their quality is for someone to actually read them. This type of information cannot be interoperable, even though the information is compatible with multiple software products. A good example is the on CAD layering for particular projects where design firms have created a standard on CAD layers. This creates the appearance of structure in the CAD files. However, the structure is not intrinsic; a user can place a furniture item on the wall layer. For this reason quantity take-offs from unstructured CAD files have always been subject to errors[25].

Structured forms

BIM software creates information in a structured form that are immediately machine interpretable. This permits use of computer tools to assist in managing, using and checking the data created during the AECO process. If the aim is to minimize the cost of manipulating and interpreting information between systems during information handover then structured data is the key to highly optimized design, supply chain streamlining and the ability to use information captured during the AEC phase in the operational phase of the construction without adding cost of retrieving them and loading manually into CAFM system. Example of this method is like the IFC structural data form to the LBNL (Lawrence Barkley National Laboratory) for energy and daylight analysis[25].

Proprietary format

This is a data format defined and owned by a specific software company. Most software outputs data in a proprietary format this format is often referred to as the “native” format. Because the format is in the ownership of a single software vendor he can at any time modify or change the format in that instance archived data may not be usable in the current version of the application. The vendor might also discontinue the product that outputs the format making the proprietary format useless.

A client can request that information is delivered in a particular proprietary format making the data accessible for him but that can limit the possibility of sharing the information with other organizations or additional applications such as analysis or the use the information when current generation of software is replaced[25].

Standard format

There are two definitions of standard formats:

"Defacto Standard" is a format that may have originated from a single vendor, but has been made publicly available and is supported by multiple vendors and products. A good example of this format is the .DXF format making the format usable for anyone that wishes to write an application to access information stored in that format. But as Autodesk decided not to extend the .DXF format to include its complete product data structure it is anticipated that there will fewer and fewer commercially available programs that can read and write the format[25].

"De jure standards" are those maintained by a standards development organization, such as International Organization for Standardization (ISO), The International Alliance for Interoperability (IAI) or the Open Geospatial Consortium (OGC). The standards are typically developed through a consensus process that considers the information requirements of many organizations. The standard is therefore often flexible and useful. The consensus process ensures that there are multiple organizations that have an interest in the standard a unilateral decision made by one vendor will not halt support for the extension of the standard. The downside of the "De jure standard" is that the consensus process is slow. The standard format are preferred for data that will be archived for extended period of time[25].

3.3.3 Industry Foundation Classes (IFC)

The Industry foundation classes or IFC is a neutral open platform which makes it possible to exchange building information between different CAD applications, the format can contain various information regarding the building hierarchy, element type, geometry, material, systems and zones to name a few. The open standard is developed by buildingSMART alliance and is designed to meet the need of interoperability between CAD software. The IFC makes it possible for different actors in the building process to use their own preferred software applications, which is important as designers, consultants, contractors and owners need to have their own choice in what native BIM application suits their needs the best as the different BIM applications have their different strengths and weaknesses depending on their disciplines.

It is central that a BIM model is compatible with this standard so it can be used by more actors within the construction and operational industry. Most leading BIM applications are compatible with the IFC format and it has to be required by the building owner that designers use CAD software that is compatible with the IFC format so it can successfully be used for data sharing between different applications and as a 3 dimensional platform in the operational phase of construction projects.

Using the BIM method in construction projects is a complex process with many different actors applying their own methods of work using different software applications, information created during that work is often inaccessible to the operator of the construction as they have not been standardized. The IFC standard plays a central role of facilitating and sharing data between all project participants, making the data more accessible to the FM manager during buildings operational phase. The format brings together project phases that have previously been dissociated from each other in the AECO industry[26] making FM an integrated part of the BIM process.

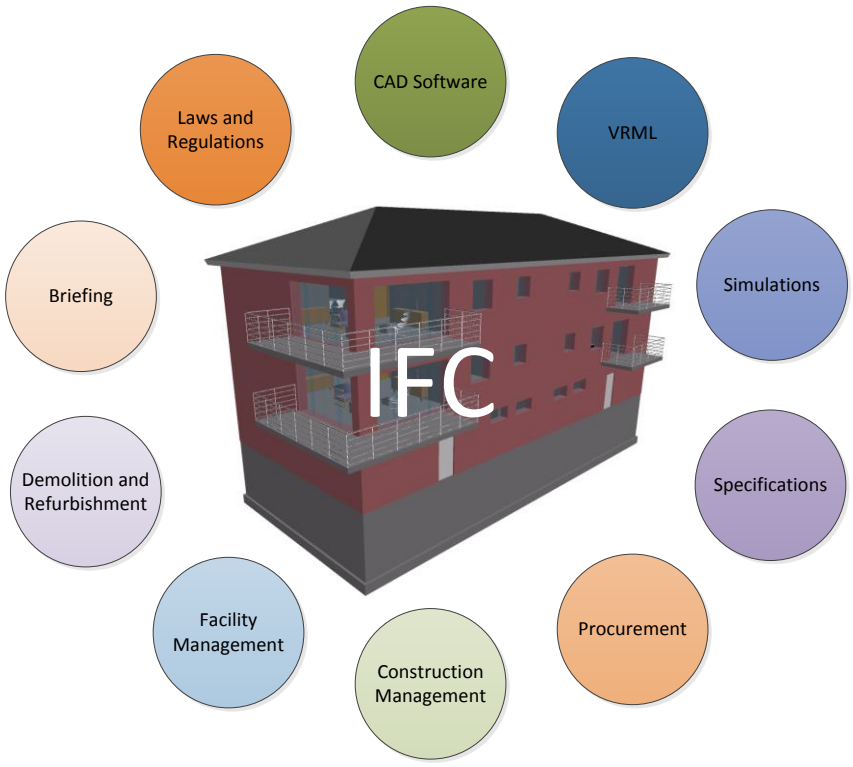


Figure 18 Illustration of how IFC can facilitate BIM for all disciplines.

3.3.4 Information Exchange Projects

The aim of the information exchange is to simplify and streamline the planning, design, construction and the operation processes using the United States National Building Information Model standard.

There are number of different information exchange standards available or in development; they have different characteristics and focus on collecting different types of data but are all a part of COBie. The purpose is that the systems can be merged into a single model describing the facilities. The table below exhibits what ie (information exchange) projects have been included in the NBIMS standard, projects that are pending submission and who are under development[27].

Project	Status
BIM Service Interface exchange (BIMSie)	Pending NBIMS submission
Building Automation Modelling information exchange. (BAMie)	Pending NBIMS submission
Building Programming information exchange. (BPie)	Submitted to NBIMS-US V3
Construction-Operations Building information exchange. (COBie)	NBIMS-US Version 2, Updated for NBIMS-US Version 3
Electrical System information exchange. (Sparkie)	Submitted to NBIMS-US Version 3
HVAC information exchange. (HVACie)	Submitted to NBIMS-US Version 3
Life Cycle information exchange. (LCie)	Submitted to NBIMS-US Version 3 as COBie appendix
Quantity Takeoff information exchange. (QTie)	Under development
Specifiers´property information exchange. (SPie)	Under development
Wall information exchange. (WALLie)	Under development
Water System information exchange. (WSie)	Submitted to NBIMS-US Version 3

Table 2 Different information handover projects and status US.

3.3.5 Construction Operations Building Information Exchange (COBie)

In 2005 the facility maintenance and operations committee of the national institute of buildings science formed a project team with a grant from the National Aeronautics and Space Administration their objective was to identify the requirements for the information exchange during construction to operational phase. The format has been in constant development since and is now recognized as an international standard of data exchange within BIM software. The purpose of the method is simply to change the format of deliverables from physical paper documentation to open standard digital format to be used in FM[28]. The COBie method is not a product or software but a method of collecting data through building lifecycle.

One aspect of BIM is that it is a single, non-redundant information repository that supports a broad range of activities in the building lifecycle, including design, analysis, cost estimating, procurement, detailing, construction simulation, maintenance and operation. Different actors in the AECO industry use different BIM platforms and therefore it is an non-negotiable requirement that the BIM model is interoperable between different platforms[25].

The COBie method enables capturing and sharing data from diverse BIM platforms during the building lifecycle to make it accessible and usable for data sharing during operational and maintenance phase of the building. The information captured is non graphical and can be viewed in a spreadsheet format insuring that clients, owners, operators and occupiers receive as complete and useful information as possible, the information can act as a supplementary index for 2D or 3D displayed information within a CAFM system as the spreadsheet can reside outside the actual BIM model. The method specifies how FM information is

collected and stored during the BIM process making it possible to be utilized by FM managers. One definition of COBie is:

"COBie is an information exchange specification for the lifecycle capture and delivery of information needed by facility managers"[29]

Another definition of what the purpose of the COBie format is:

" To improve the life-cycle building information interoperability using commercially available release of Building Information modelling (BIM) planning, design, construction, and commissioning software and the computer aided facility management (CAFM) and computerized maintenance management system (CMMS) applications used in facility management"[30].

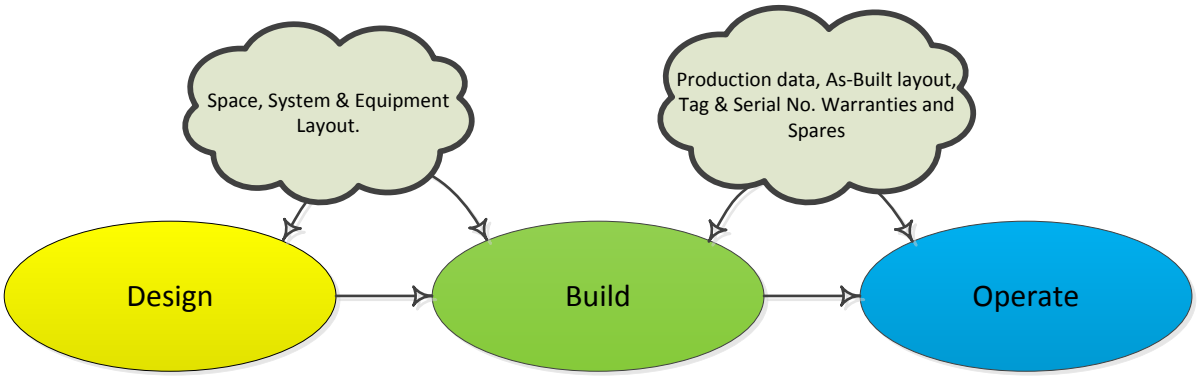


Figure 19 Illustration of what information is captured and when using COBie[12].

The format does not provide answers on what the information deliverables should be that is still the work of each individual owner or FM manager to define but rather how information is collected and presented during buildings whole LCC. It is capable of presenting the data as the lowest common denominator a spreadsheet via programs as Microsoft Excel and open office, as an .xml file or in the IFC format the purpose of the spreadsheet is to allow all project participants to take part in a tender that requires COBie information to be delivered. Owners and operators need to define what information they want in the model based on their needs, the type of building and what information brings the most value to the owner.

Using a spreadsheet to present data from COBie exports has been identified as the most common way of displaying the COBie information because it is the simplest form of communicating the data between project participants enabling all actors in the supply chain to engage in and to work with structured data. The COBie data can be displayed as a IFC model delivering richer geometrical data than the spreadsheet but working with that format demands more knowledge from the participants than what has been defined as the lowest common denominator, the spreadsheet[31] enabling lower tiers to of the supply chain to capture data by adding directly into the spreadsheet. In larger projects this method is however too cumbersome to work with as large facilities can have thousands of components installed so a more capable BIM software will be needed to insert the data adequately.

In the UK using the spreadsheet format is thought to be a bridge for the some years until a fully interoperable central BIM database will be fully functional and the UK has reached BIM maturity level 3. One of the main reasons for the spreadsheet format is that a public construction agency can´t demand that

participants in a tender acquire themselves expensive applications for inserting the data into the BIM model making it possible for everybody to participate in the tenders.

Using the BIM method is much more than just about delivering a good looking 3D model of a building but rather it is a different culture of working on design, construction and operation of facilities. The COBie format of data transfer enables data capturing during facilities whole life cycle focusing at collecting information for facility management. Implementing the method to a BIM project will add a whole new dimension to the BIM method or the 7thD.

3.3.6 COBie data drop

For Building information to be of value it needs to be collected and validated continuously throughout the buildings lifecycle, studies have shown that collecting data at the end of the design and construction phase of buildings is costly, time consuming and leads to considerable rework for the facility manger. COBie provides a method of collecting that data in a structured way as they are generated during projects lifecycle. This information needs to be validated at certain milestones during the project lifecycle. That is done with the COBie data drops. In the UK data drops are coordinated with the RIBA (Royal Institute of British Architects) work stages which represent different phases of the project. The data drops are placed before a project changes from one stage to another to secure that all information that was defined in the COBie scope has been inserted before the handover to the next phase and to respond if there has been any changes that influence the scope.

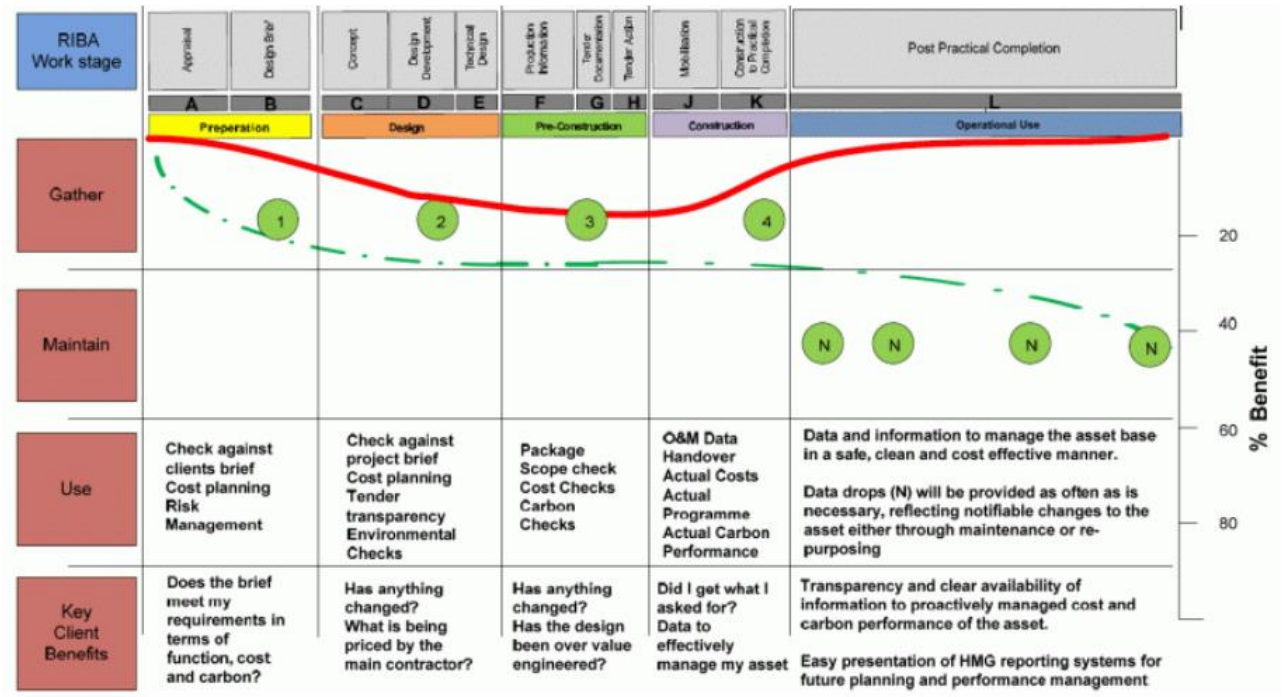
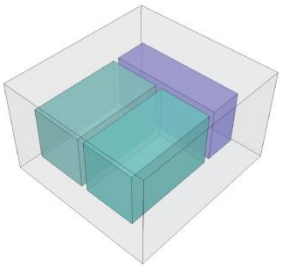


Figure 20 Illustration of where COBie data drops are conducted on the base of the RIBA work stages[12].

COBie Drop 1: Requirement and constraints, massing model

The first data drop consists of information on design constraints, specifications, function, cost and carbon. Client's requirements and constraints are documented and room data sheets can be generated from the model. Data sheets for rooms are generated which typically request the required function, environmental condition and performance of finishes in rooms.

The model on this stage is often a massing model indicating space allocation and overall site location[32].



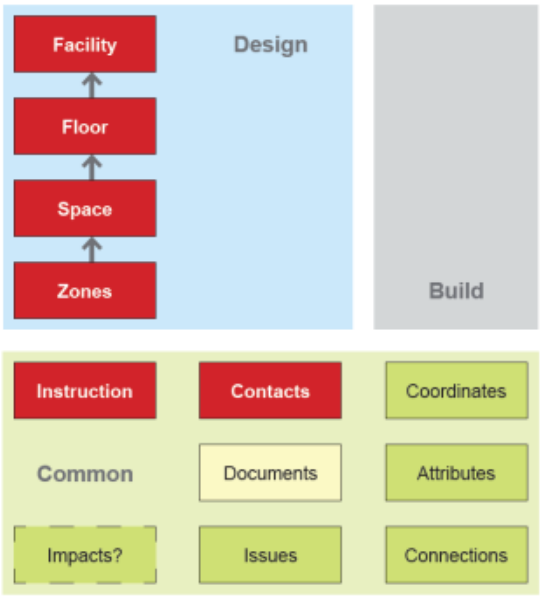


Figure 21 Illustration of what COBie information should be implemented during pre-design[30].

COBie Drop 2: Outline solution

Second drop is before the tendering phase, information is checked and validated to ensure that interpreted design and specifications are consistent with the clients brief in terms of function, cost and carbon and that potential suppliers and supply chain can demonstrate capability and integrity through the competitive process and be selected to deliver the assets.

The model can be used for tendering. Data can include e.g. functionality of space, environmental condition of space, actual finish and list of furniture and equipment for each room. In this stage various schedules can be produced[32].

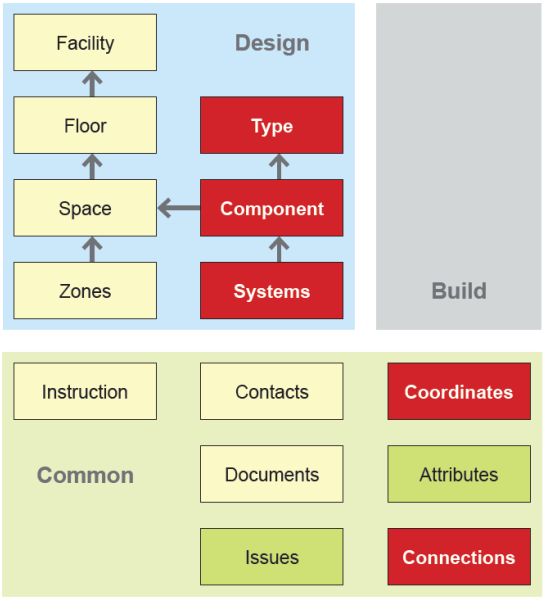


Figure 22 Illustration of what COBie information should be implemented during design[30].

COBie Drop 3: Construction Information

The rationale for the data drop is to approve the „agreed maximum price“. The checks are to ensure the developed design and specifications are consistent with the clients brief in terms of function, cost and carbon performance.

The model is a fully coordinated technical solution developed from solutions in drop 2 the model can be used for construction. Fully coordinated technical drawings can be generated for construction. RDS can be generated for construction. Various schedules can be produced to order[32].

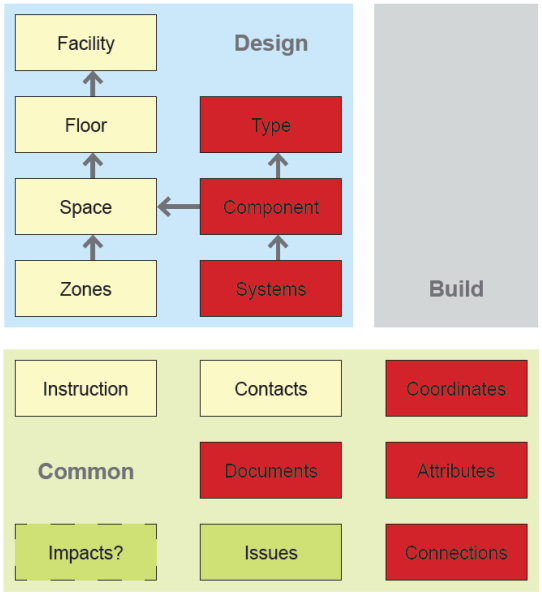


Figure 23 Illustration of what COBie information should be implemented for construction [30].

COBie Drop 4: Operation and maintenance Information

The rational for the data drop is to take position of the Operations and management information. The data being collected is the operational and detailed function information supplied by the product manufacturer. Particular attention needs to be placed on the needs of the first year of operations as many installed processes may invalidate warranties if incorrect applied in the first year of operation.

The model represents the building as built and contains all information provided by various contractors to maintain it. Information can be extracted from the model that is relevant for facility management. The likely accuracy for information gathered at this stage is to be 100%. The model now represents building “as- Built”[32].

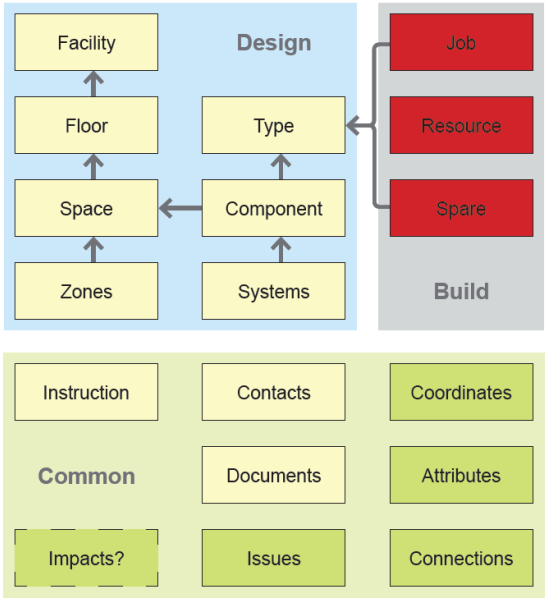


Figure 24 Illustration of what COBie information should be implemented during construction phase [30].

COBie Drop N: Operation and maintenance post occupancy

Data drop 5 is not properly defined but the concept is of post-occupancy information review is to check how the asset is actually being used.

3.3.7 COBie scope

The COBie scope is the owner's definition of what information should be inserted into the COBie dataset it serves as an instruction manual on how information shall be inserted into the BIM model and by which project participant. A good COBie scope is necessary so all actors within the building process know what they are expected to deliver during the construction process. The scope needs to be well defined from the building owner, as he is developing the scope he needs to understand what information carry the most value for him and what information is not as valuable, the purpose of the scope is to limit the information as well as adding them as information overload is not useful for the FM manager.

The scopes can be as different as there are different facilities e.g. a factory that has many different systems as numerous technical equipment focuses a lot on maintenance, repair and collecting manuals while a sport stadium focuses more on different zones for security reasons easy access to toilets for facility users quick clearance in case of emergency the scope should represent these different aspects.

3.3.8 COBie Processing and Validation

There are two different ways of managing and working with COBie data through the building lifecycle one method depends on the actors uploading, dropping and validate files manually several times over the project phases the COBie file itself will be imported and exported from various applications during its lifetime. This will require significant care and attention so information collected during the building process doesn't get lost. This is a process without a central BIM database.

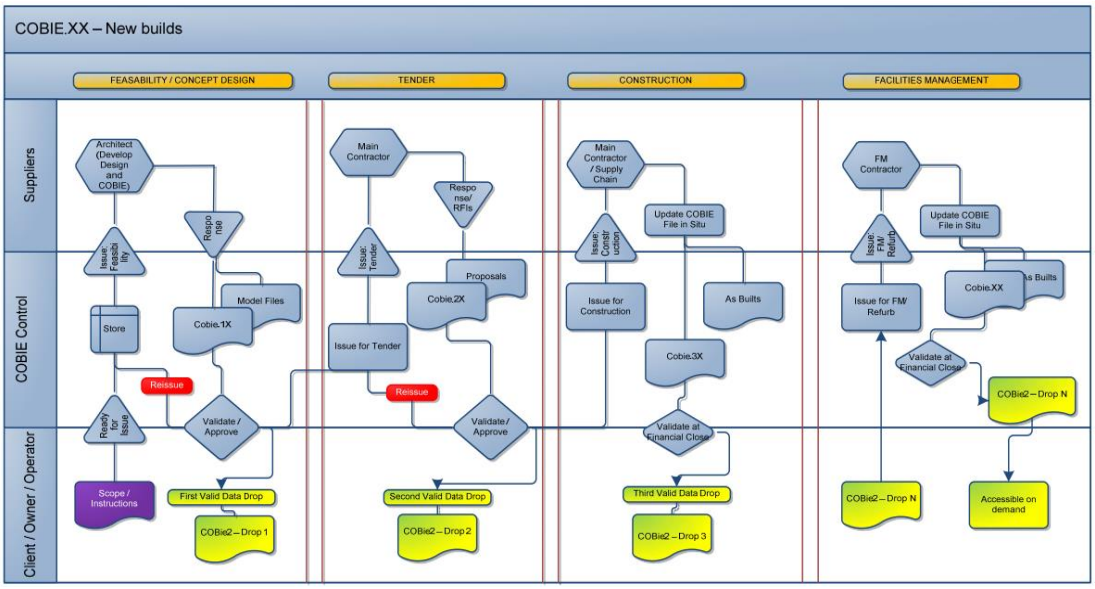


Figure 25 A process map of COBie validation process without a central database[12].

The other method relies on a central database that resides permanently within the COBie control environment where actors can push and/or pull information when it is appropriate. This method relies however on software vendors to make their applications compatible with the dataset[33]. Many BIM software vendors have embraced COBie and made their applications ready to work with COBie data.

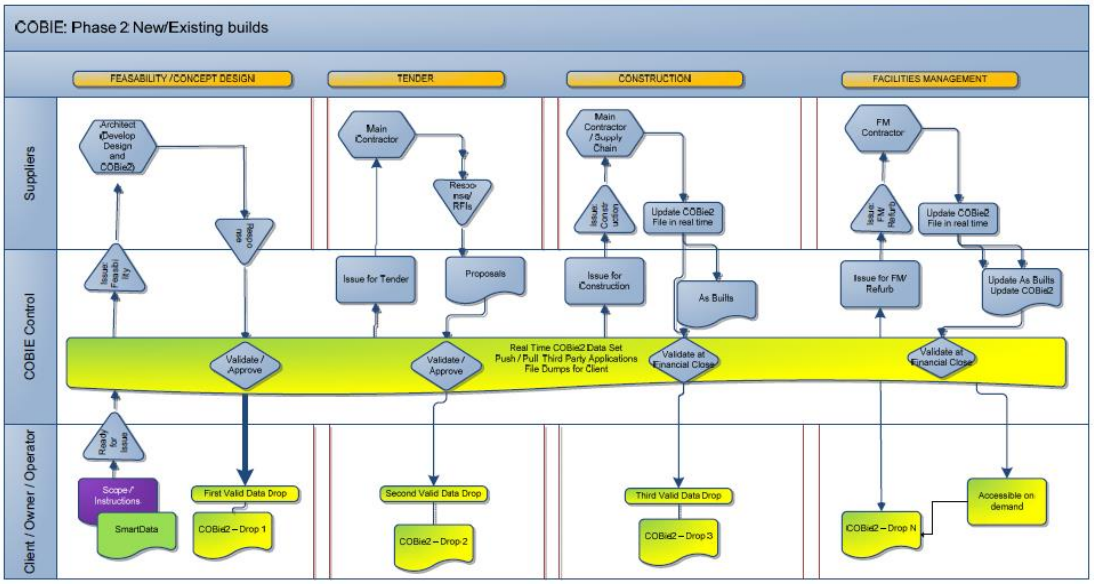


Figure 26 A process map of COBie validation process with a central database[12].

3.3.9 Information exchange (ie) programs in development

The National Institute of Building Science and Building SMART alliance are working on a variety of different formats if ie projects. These projects aim at simplifying and streamlining the planning, design, construction and operation of facilities by using the BIM method.

This chapter is a short introduction of what those projects are and where they stand in development.

BIM Service Interface exchange (BIMSie)

The standard aims at automating interaction between online BIM services giving the industry opportunity to innovate with BIM in the cloud. The goal of this project is to create an open API (describe sets of technologies that enable websites to interact with each other) for online BIM WebService[34]. The project is pending NBIMS submission.

"BIMSie: The standard Application Programming interface (API) for BIM Web Service to get BIM in the cloud[34]".

Building Automation Modeling information exchange. (BAMie)

The objective of this project is to develop Industry Foundation Class (IFC) Model View definition for the modelling of control and building automation system through a facility, and create several example files, using the common BIM file models, that demonstrate the delivery of such information[35].

The project is pending NBIMS submission.

Building Programming information exchange. (BPie)

The objective is to consolidate international specifications for the contracted delivery of architectural programming information by the evaluation and consolidation of previous project results and create the necessary verification tools and models to ensure repeatability of the results of commercial software testing in project-specific contexts[36].

The project has been submitted for the NBIMS-US Version 3.

Electrical System information exchange. (Sparkie)

The engineering research and developing centre, working with subject matter experts and software companies, lead the development of a domain-independent facility control framework enabling improved management and control of facilities and the resources that they consume. This framework includes the definition of the expected resources required, components, assemblies and systems using these required resources and a feedback loop which compares plan resources to actual resource use. The objectives is to provide an open standard format for the components, assemblies and connections that distribute and use electricity within a facility[37].

The project has been submitted for the NBIMS-US Version 3.

Heating, Ventilation and Cooling information exchange - HVACie

HVACie is focuses on capturing data regarding heating, ventilation and cooling systems of facilities. HVACie is an extension of the IFC coordination model view definition. It is intended to ensure products, product assemblies, properties and connections between pipes, ducts, and other HVAC equipment. The objective is

to provide open standard format for the components, assemblies and connections that distribute and remove water from the facility[38].

The project has been submitted for the NBIMS-US Version 3.

Life Cycle information exchange – LCie

BuildingSMART alliance information exchange projects may be used to directly support Chief information/Technology PLM-based efforts to facilitate system integration and associate change management. The purpose of the LCie project is to demonstrate this potential. The first demonstration in the domain of managed asset information has resulted in the submission to NBIMS-US Version 3[39].

The LCie system aims at creating a baseline for different vendors using BIM objects on what information specific object should contain.

The project has been submitted for the NBIMS-US version 3.

Quantity Takeoff information exchange. (QTie)

The QTie program is the expected result of a project aimed at reducing waste by the cost estimators and other members of the project team. There are three different types of quantity take-offs investigated in this project those are QTie for Counting, QTie for Quality and QTie for methods. When the project is complete you will be able to use QTie by including one or two sentences in contract clause where you currently specify the delivery of estimating deliverables. QTie is an example of a project whose goal is to create non-property performance-based specifications for the delivery of facility information[40].

The project is under development.

Specifiers´ Properties information exchange – Spie

The objective of SPie is to coordinate the development of a United States open standard for product data utilized by architects, engineers, specifiers, contractors, subcontractors, procurement personnel, operators, and maintenance personnel to better select, install, and operate their facilities. These are minimum common sets of properties needed by all stakeholders. Manufacturer's and their associations can "build out" from the starting point of specifiers' property sets to provide installation, operational, sustainability and any other properties[41].

SPie data allows manufacturers to deliver product information to specifiers and designers in a form that is useful for modern design practice such as BIM. It uses the existing and widely supported international standard buildingSMART IFC model to communicate the shape, symbol and properties of manufacturers' products[41].

The project is under development.

Wall information exchange. (WALLie)

The objectives of WALLie is to define wall types explicitly through an international accepted wall layering convention that can be used as an external reference to solve the problems that are hobbling the wall construction sub-industry today. This layering standard will allow architects, general contractors, speciality contractors, manufacturers, suppliers and owners to speak a common language[42].

The project is under development.

Water System information exchange - WSie

The objective of this standard is to provide an open standard format for the components, assemblies and systems that distribute and remove water within a facility.

The requirements for WSie indicate the need to describe the geometric location and properties for three water systems elements piping components, control components and mixing/transformation components. As such WSie is an extension of the standard IFC coordination model view definition[43].

The project has been submitted for the NBIMS-US version 3.

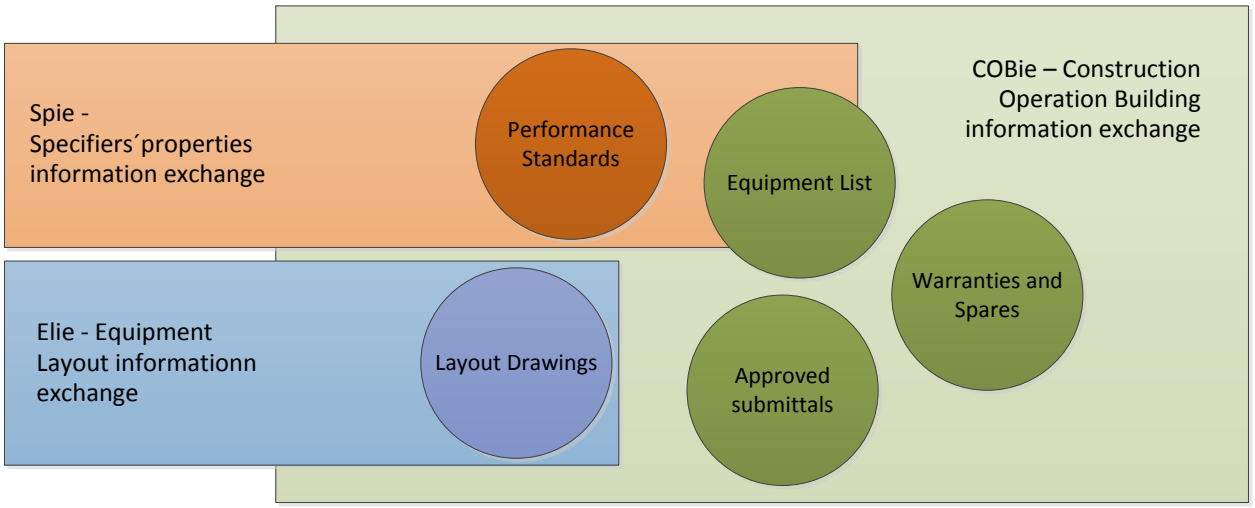


Figure 27 A pie chart showing how different ie programs fits within the COBie program.

3.3.10 Responsibilities

COBie demands that actors that are responsible for inserting information into the COBie file are identified by their contact information and from what firm they are. This is done to established individual responsibility for their datasets. Applying this rule will discipline the industry as defects in the dataset can be traced to responsible individual and/or firm and they can be held accountable if data from them is not valid.

3.3.11 COBie responsibility matrix

During the course of a COBie project, different team members will have primary responsibilities to create COBie deliverables. Given that many teams will use different building information Modelling tools, particularly during the design stage to create the required information, the identification of COBie responsibilities should be explicitly included in the team´s BIM execution plan[44].

The matrix allows the teams to colour code different parts of the COBie deliverables to define precise requirements as to what individual, from which relevant firm, will be responsible for the production of specific data within COBie[44].

While project teams will define specific individuals within the firms, the following general responsibilities for the production of COBie data should be observed[44].

1. Regardless of the form of contract the architectural firm is responsible for the coordination of all design development (35% design) deliverables.
2. Regardless of the form of contract, the architect firm is responsible for the coordination of all design disciplines input to the construction document design (100%).
3. Regardless of the form of contract, the general contractor shall be responsible for the beneficial occupancy and the as-built construction deliverables.
4. For projects that employ third party commissioning, the commissioning agent may assist the general contractor to coordinate and validate the quality of the general contractor deliverables at the beneficial occupancy and the as-built construction deliverables.

Defining and clarifying who is responsible for delivering what specific information and marking it in the COBie deliverables will increase information validity as all information inserted into the COBie file will have a specific individual that is responsible for that particular data.

3.3.12 Classification system

COBie is based on the OmniClass classification system. OmniClass is a classification system for the construction industry and is very helpful on organizing digital information. COBie uses the OmniClass table to organize information created by designers and product manufacturers so that it can be submitted to facility managers efficiently. This classification system can however be changed to whatever classification system the owner prefers to use in the project.

3.3.13 Life Cycle Cost

Life cycle costing is a method of predicting what will be the total cost of design, build and operations of a facility will be. The aim of the method is to lower the overall cost of the facility from design to disposal. The LCCA (Life Cycle Cost Analysis) method is used to calculate what the overall cost of the building will be by calculating initial cost (design-build), fuel cost, operational cost, maintenance, repair, replacement, resale, salvage, finance and none monetary benefits and costs. The LCCA is performed in the initial stages of the construction project.

Many CAFM systems have LCC modules implemented in them and have key monetary figures available for maintenance and operations procedures, if BIM models would contain the right information e.g. material, quantities, spatial information, building elements then it would be possible to calculate buildings LCC relatively easily. It will be possible to compare different architectural models to each other when a design is chosen from a design contest and as more and more models are delivered in this way a database would emerge from the CAFM system where different designs can be benchmarked against other buildings in the same class.

The value that this could bring building owners is great as design decisions can be taken on the base of credible data gathered from other physical buildings making owners more informed and better capable of participating mores in the design process.

3.4 Conclusions on relations between BIM and facility management

Here are the findings from the literature review presented an discussed the purpose was to examine what could be done so BIM models could be used during buildings operational phase. This chapter will present the findings on what knowledge is available on the subject and the findings from the literature review collaborated on.

3.4.1 BIM and facility management

BIM and facility management are closely related as the overall aim of the BIM method is to lower buildings LCC by providing a method of information sharing between all actors in the construction industry. BIM models that have been generated in the past have not included information needed for facility management other than spatial. COBie provides a solid structure of capturing information during buildings lifecycle, it provides a standardized platform that CAFM systems can base their integration on as it brings structure to how information is collected, inserted and displayed.

3.4.2 Technical issues

The technical issues are minimum most native BIM software support the IFC standard and are developing more and better tools for exporting data from their native BIM applications to the IFC standard so in the future this technology will only become more sophisticated an better. Using the COBie method requires as simple format as a spreadsheet so there should not be any large technical obstacles in the way of implementing the methods. It will however demand some work from all participants of the project to insert information into the COBie parameters and secure that they follow through to the IFC file.

3.4.3 A model for FM

BIM is an information model with emphasis on the information. Many models created are essentially 3D models missing the Information part entirely. The whole idea of BIM is LCC with better communication of

information between all project participants, if a project is BIM it includes the operational phase as well modelling a 3D model only for the design-build phases and leaving out buildings operational phase does not constitute a full BIM project. If the full benefits of the method is to be had then stopping at building handover and not using the model during the operational phase is as mildly said as possible, not taking full advantage of what benefits the method can bring to the project.

3.4.4 LCC

90% of building projects cost is generated in the operational phase that leaves 10% of the cost during the design-build process. It is clear that improving the design-build phase of buildings can have dramatic impact on the operational phase of the building projects. BIM with COBie are a good tool for streamlining the building process and help all actors take better decision based solid information.

Using BIM and COBie will make the facility manager more involved in the pre-design phases of construction projects letting the operator take part in the design phase right from the start, which is crucial as the operator has a different view on the construction process then participants that are not going to operate the facilities. For the facility manager it is totally acceptable to spend money on the 10% as he will gain that spending multiple times during the operational phase.

Having a model that has documented the whole design-build-operational processes will make the FM manager much better capable of operating the facilities, information on every component, zones, system, elements and other information that he himself took active part in defining in the start of the project are available to him right at project handover.

4 Research

There are two separate researches conducted in the thesis the first is a research focusing on how FM information can be added to a native BIM model using COBie, parameters are established, and the information transferred to the MainManager CAFM system through the IFC format. The second research was aimed at the Icelandic AECO industry to determine how capable it is of implementing BIM with COBie information and to find what obstacles are in the way and how they can be overcome.

4.1 Practical application of FM data

The first part of the study is aimed at analysing and studying how information is applied to a native design software and how that information can be transferred to the MainManager web-based software solution. For the study the BIM software Revit AutoCAD was chosen to display the capabilities of capturing information and delivering them to an IFC file. The aim of the study is to analyse how information flows between the platforms and examine if there is any data loss when the model is converted.

For the study some key requirements where established and performed to analyse how this can be performed and to establish proof of principle.

4.1.1 The model

A short definition of what minimum information was needed in the model for facility management and a 3D model was constructed from that predefined criteria's:

Spaces	Quantities
	Materials
	Manufacturer
	Supplier
Zones	What spaces belong to which zones
	Different zones, technical, energy, fire and etc.
Components	Installation date
	Components category
	Manufacturer
	Warranty expiration
	Production Information
	Component placement
	Manufacturer instructions
Building elements	Construction code
	Material
	Thicknesses
	Manufacturer
	Supplier
	Production Information
	Manufacturer's instructions

Table 3 research test subjects

Figure 28 Visualization of the test model.

The model is a representation of a 3 storey building with a basement. The 1st floor is a retail area representing a commercial zone, the 2nd and 3rd floors are residential areas with 4 apartments 2 on each floor. In the basement there are storage areas and a technic room containing building components.

4.1.2 COBie Revit extension

BIM software creators have acknowledged the need to facilitate capturing of information used for the operational phase of buildings for Revit 2014 there is an application extension available. The extension sets up Revit so it is easier for the application user to fill in the COBie information. It sets up different COBie schedules and adds parameters that are defined as being the minimum requirements for a COBie project. The extension is useful in minimising work for the application user by filling in certain parameters automatically that would otherwise be repetitive as the identification parameters, when it was component was placed in the model, it´s location and what space it is associated with.

4.1.3 Schedules

The COBie schedules are automatically generated when the COBie extension is activated; they are a key tool for working with the COBie data within the native application. Users will however have to adjust the schedules after each project as the COBie information applied in the extension is only the minimum requirements for a COBie project other specific owners requirements must be added to the schedules.

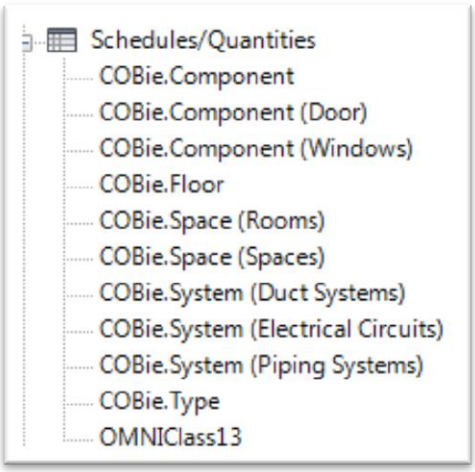


Figure 29 Schedules created by the Revit COBie add-in.

4.1.4 Parameters

There are different types of parameters within a Revit model the purpose of the parameters are to associate information to specific objects they can also be used to control objects spatial properties as length, width and height.

There are Instance parameters, Type parameters and then there are parameters that are associated with each BIM element called family parameters. These parameters are intended to carry information about individual objects within the project and all have their own function as will be explained. There has been some tendency for parameters to get lost when they are transferred to the IFC format so the delivery of these parameters need to be monitored closely.

Instance Parameters

These are parameters that are associated with a certain individual objects within the project. Information like warranties, installation dates, serial numbers and other information that can only relate to a one specific object shall be inserted here. All input into these parameters must be unique no double naming of components is allowed the COBie guide[44] gives clear instructions on how object identifications should be done[45].

Type Parameters

Type parameters contain information that has to do with a certain type of objects these can be door types, window types, wall types or etc. Information associated with these parameters will be shared between all objects of the same type within the model, so information in these parameters can be such as fire rating, materials, colour codes, U-values or other information that can be sheared between the types[45].

Shared parameters

Parameters that can be shared between different projects for instance within an architect or engineering firm there can be a set of shared parameters that are used between different project and families the parameters are pre-defined and stored outside the actual project[45]. These parameters can be used as COBie parameter database within firms.

Project parameters

These are specific to a single project file and cannot be sheared between projects but can be assigned to a multiple categories of elements. These parameters are mostly used for scheduling, sorting and filtering in a project[45].

Family parameters

These are mostly used for controlling variable values of the family such as materials and dimensions. They can also be used to control parameters in the project that the family is hosted in. There are known issues with converting family parameters to IFC, consultants have struggled with this as being able to build a family component library with all information embedded in the families. Therefore until that issue is solved using the COBie add-in is sufficient. That problem has been identified so an initiative has begun to fix this problem and with better IFC exporters that will become possible but for now it is better to use the instance and type parameters[45].

4.1.5 Components/Revit Families

Components are individual objects within the project they refer to for example doors, windows, furniture or mechanical objects these components are called families in Revit AutoCAD. Components are hosted by different elements within the project, doors and windows are hosted by walls while furniture is hosted by floors or levels, this depends on what Revit family template the component is created in. to those individual components information is linked to by the their instance or type parameters.

4.1.6 Door

To examine how reliable the transfer of information from Revit to MainManager is the COBie information attached to door family in the Revit model was filled in and exported to an IFC file, uploaded to a web based viewer and analysed on the MainManager system. The parameters that were filled in were minimum information needed for facility management. The COBie extension fills in automatically many of the parameters in the system such as COBie.CreatedBy, COBie.CreatedOn and COBie.Component.Space. Other information was manually placed in the parameters.

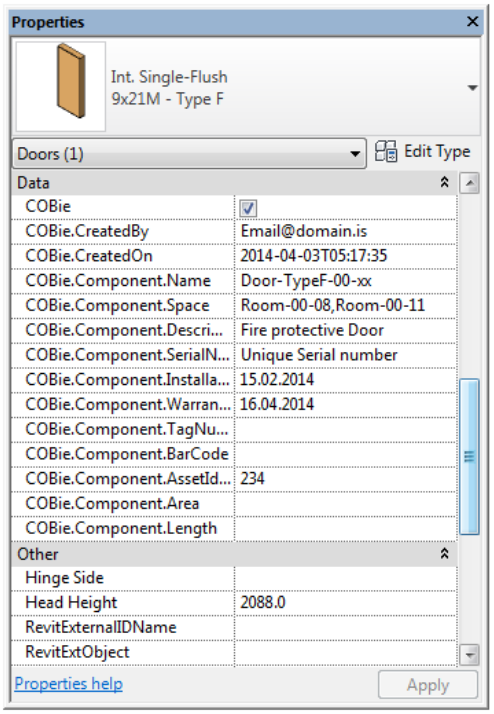


Figure 30 Illustration of how information is added to a door in Revit, the property panel is for instance

4.1.7 Rooms

A room within a BIM model can be data rich, rooms cannot just hold basic data as definition, size and volume but also more detailed information. Rooms are used to store information such as colour codes, finishes, flooring and descriptions of the rooms function they will store relevant quantity information as m² and ceiling height. Rooms are used by architects for designing and managing information about occupied areas within the building. Architectural objects within the model are linked to the rooms like windows, doors and furniture. Spaces are created in the same way but in Revit MEP but not Revit Architecture rooms are different from spaces in CAD software's as they store different type of information they can however be viewed in the same way.

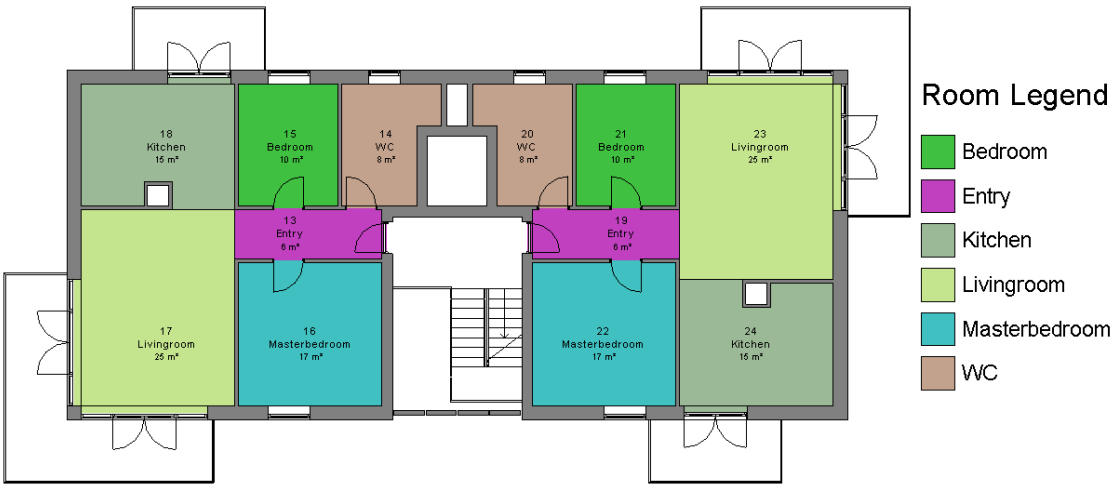


Figure 31 Example of a basic room legend created in Revit architecture visualising rooms after colour scheme.

4.1.8 Spaces

Spaces are created using Revit MEP they are used for calculating and analysing heating and cooling loads. COBie information that is associated with the zones are description of individual spaces and their link with different zones of the facility. Mechanical equipment within the facility is automatically linked to the spaces so navigating to a certain mechanical components is done within the spaces. Information on individual spaces is exported to the “spaces” tab in the COBie sheet.

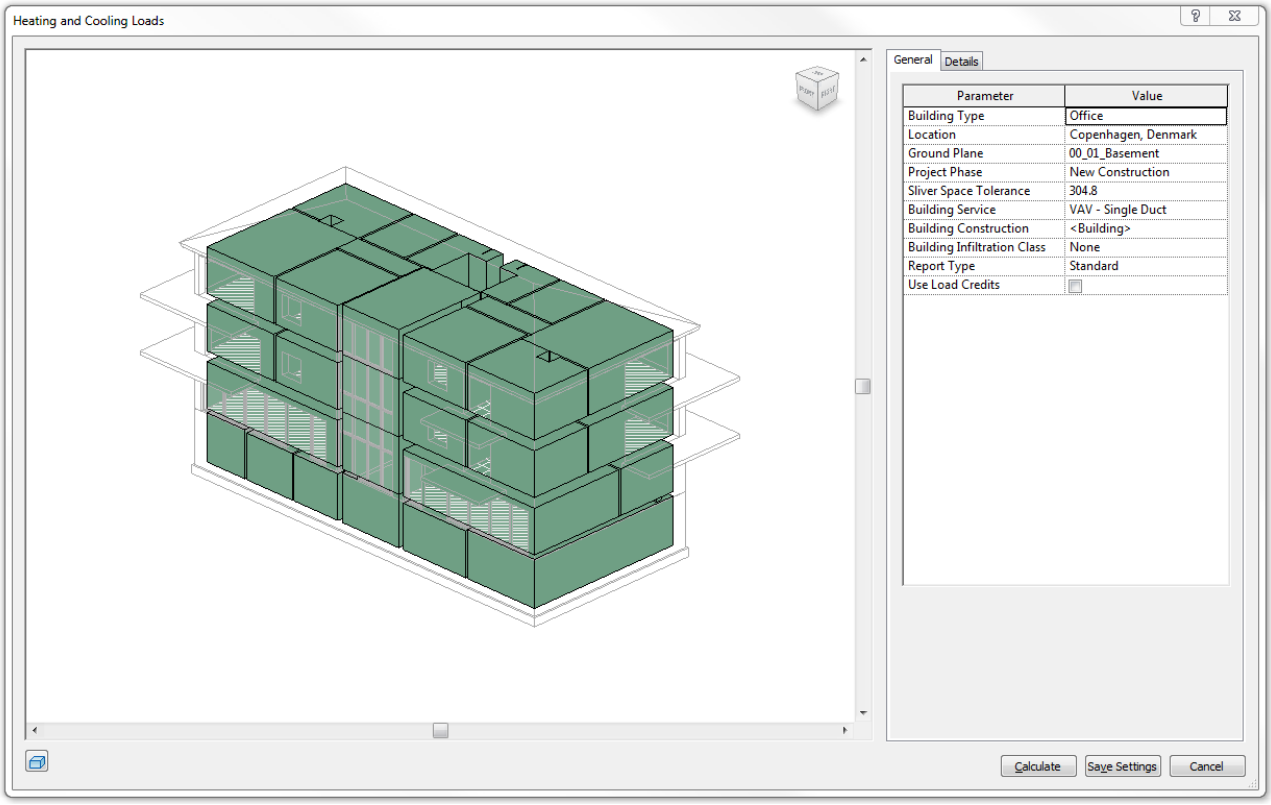


Figure 32 Calculation panel in Revit MEP visualizing spaces created and heating and cooling loads calculator.

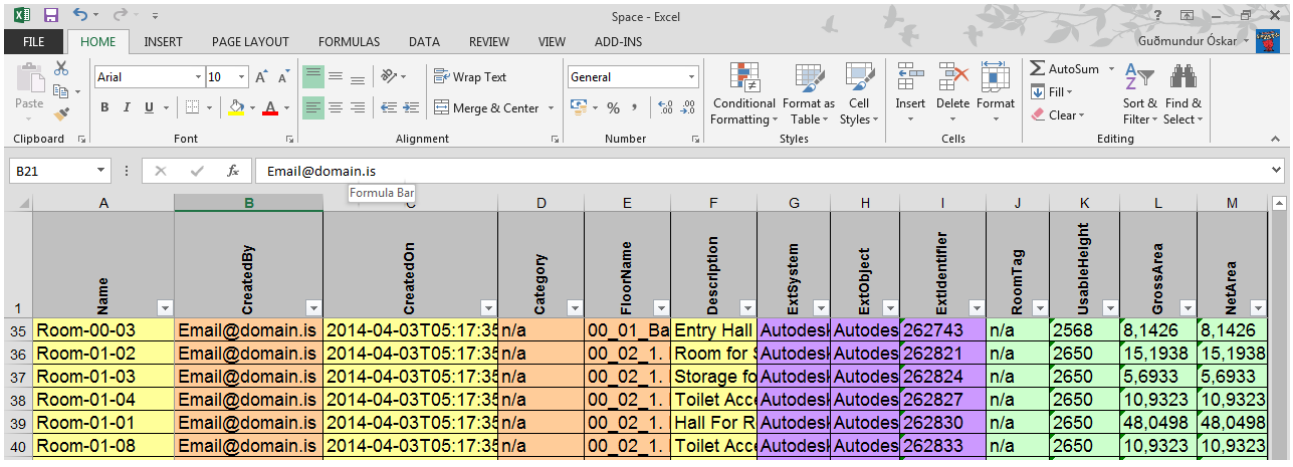


Figure 33 Spaces exported to a COBie spreadsheet with the COBie add-in.

4.1.9 Zones

The zone manager within the COBie extension is useful in creating different zones within the building as Revit only has one zone function the HVAC zone which only applies to spaces but not rooms. The extension allows the user to create multiple zones depending on their function e.g. fire, access, ventilation, technical or energy. The system uses the “drag and drop” method of assigning spaces or rooms to zones created in the Zone manager. The zones created are exportable to the IFC file and to the COBie spreadsheet.

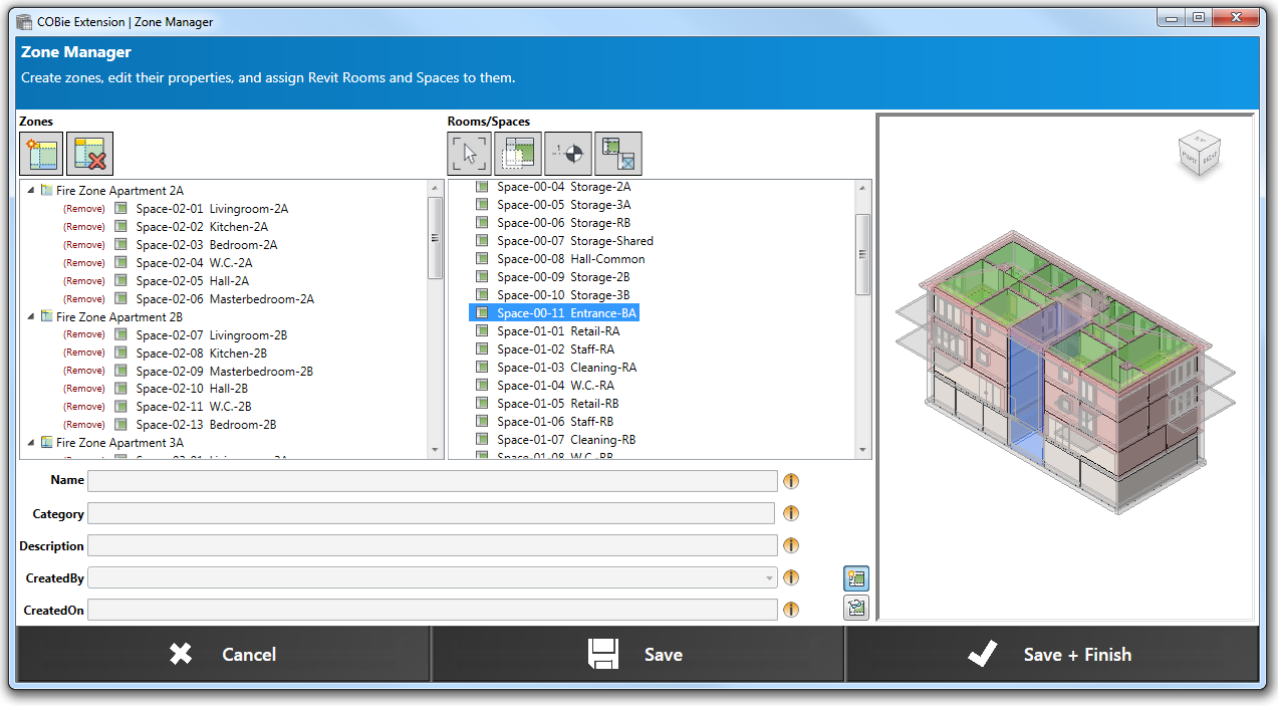


Figure 34 Illustration of the zone manager in the COBie add-in.

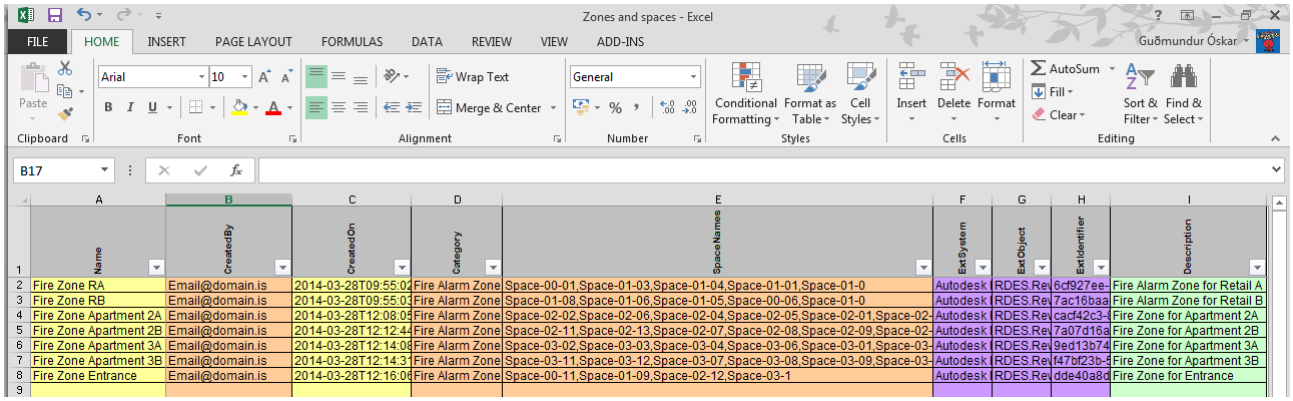


Figure 35 Illustration of how zones can be exported to a COBie spreadsheet.

4.1.10 Building classification codes

The OmniClass construction classification system is embedded in the Revit system so there is no conflicts in using that classification system with the COBie method. There is however not possible to change the classification to another within the Revit CAD system.

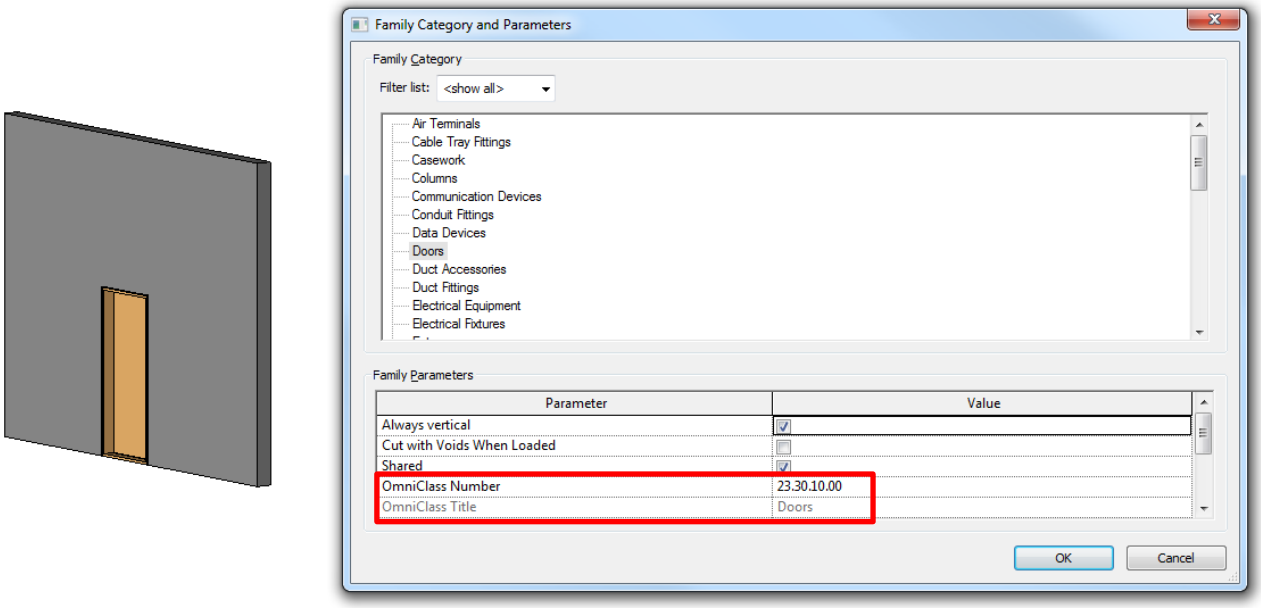


Figure 36 OmniClass classification system embedded in Revit families.

Building classification codes in COBie can be added where other type of classifications codes are used as different countries have their own classification systems, in Iceland there is no standard classification system in use, in Norway it is the TFM (Tverrfagligt Merkesystem), Denmark has the DBK (Dansk Bygge Klassifikation) and Sweden has SFB (Samarbetskomittén för Byggnadsfrågor) classification system more classification systems are in use so if those systems need to be added those parameters have to be inserted and manually filled in.

As Revit has the OmniClass classification system embedded in the software and the default system in COBie is OmniClass then using that system between the two would limit the chance of wrong codes being inserted.

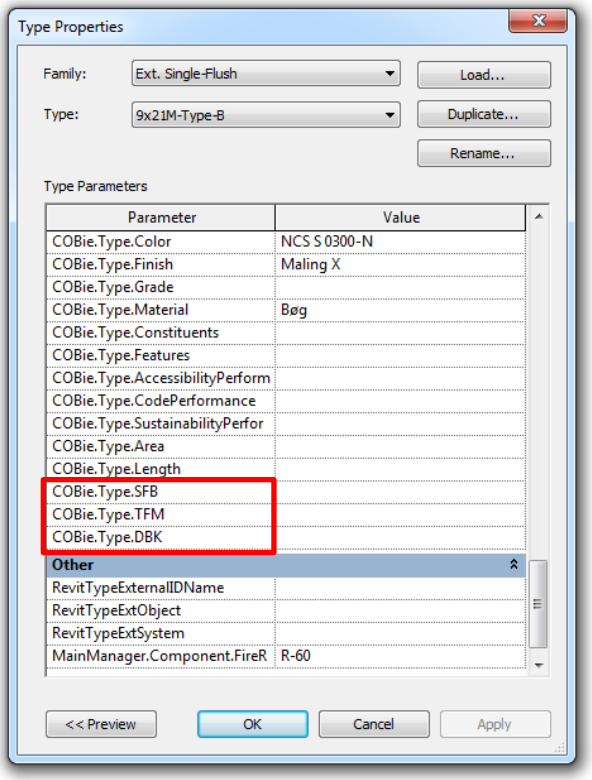


Figure 37 Illustration how different classification codes can be inserted in type parameters.

4.1.11 Contractors

Contractors working on a COBie project are expected to deliver information on as-built project e.g. warranties, information manuals, Type numbers and etc. for that they will need tools for implementing the information. Their work is not to establish the parameters but rather to insert information into the predefined parameters as they appear during the construction phase. For that it is possible use the basic spreadsheet but for larger projects that is not an efficient choice of applications. Other applications are available for better visualization and access to the parameters.

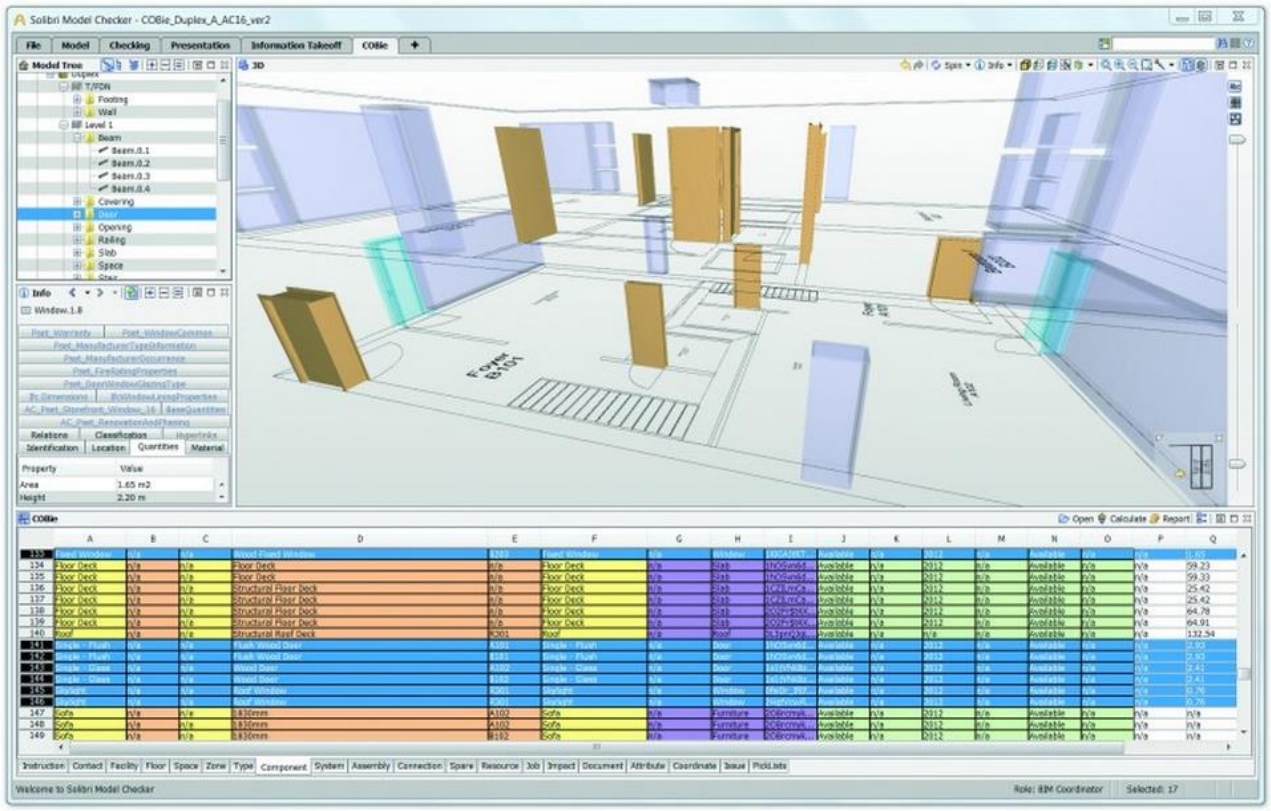


Figure 38 Solibri IFC viewer with COBie integration.

Many different solutions are available for the contractor to choose from both as applications and as a web based BIM solutions one solution working on integration of COBie is Solibri making it possible to work on the COBie spreadsheet linked to the IFC file offering a 3D view of the model while project participants adds information to the COBie spreadsheet.

There is room for better COBie tools for contractors on the market as their needs of working with the model is different to e.g. the consultants that have expertise of working on large complicated BIM models on their own native BIM platforms. They only require a simple easy to use 2D platform to work on.

4.1.12 MainManager

To test how information would flow beetween Revit Architecture and Mainmanager the native BIM model was exported to an IFC file format, uploaded to a web based IFC viewer and casted into MainMange. In that process there was not detected any data loss in the process all parameters associated with specific elements, spaces and zones transfered without any problems. No familie parameters where hovewer detected which was expected as they did not transfer to the IFC file.

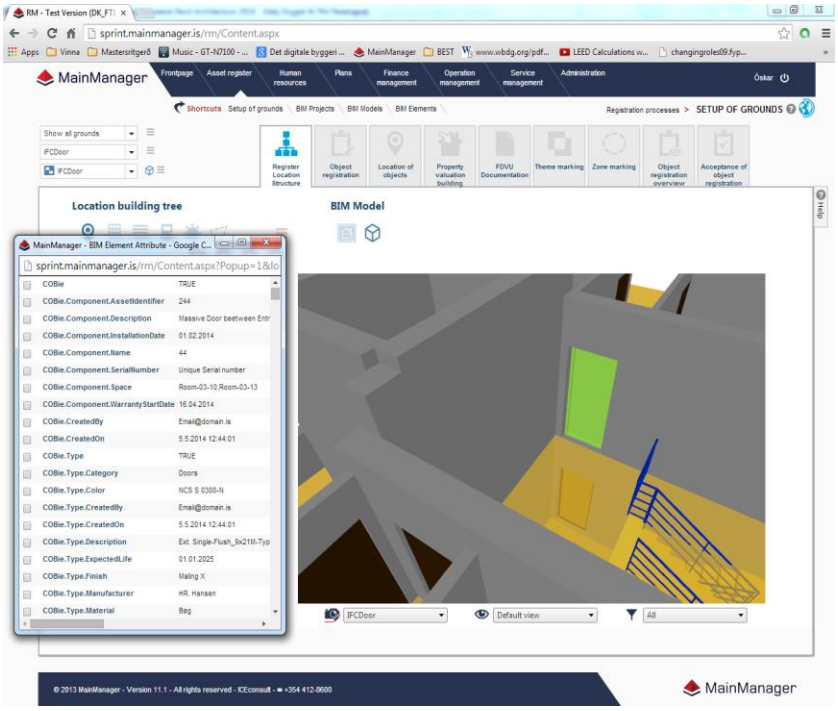


Figure 39 Visualisation of COBie parameters in MainManager associated with door component.

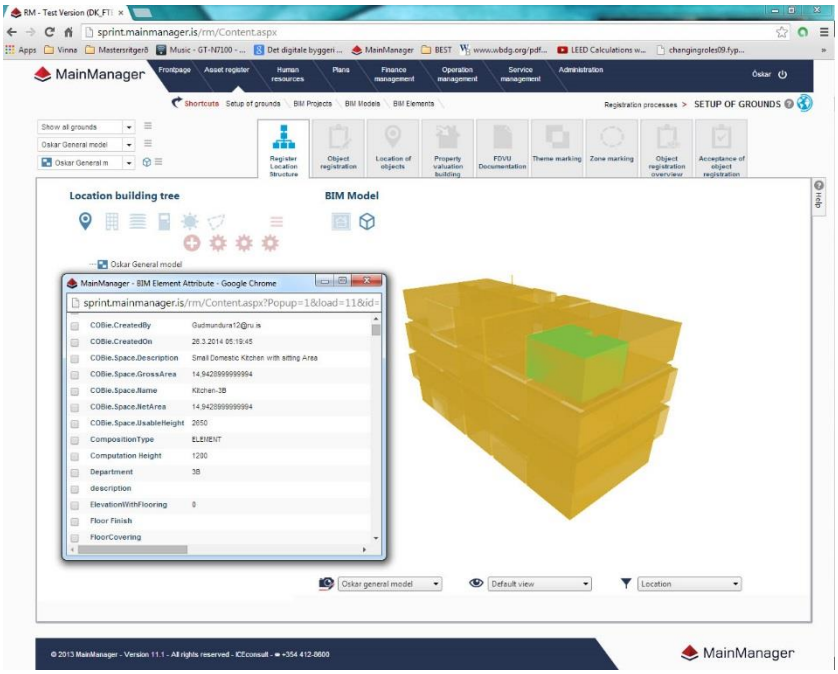


Figure 40 Visualisation of COBie parameters in MainManager associated with spaces.

4.1.13 IFC exporter

With Revit comes an intergrated IFC exporter giving the designer/consult good controles over how the model is exported to the IFC file format these exporters are in constant devolpement they are beeing fine tuned and enhanced with every new release making the exports from the native BIM to IFC more efficient.

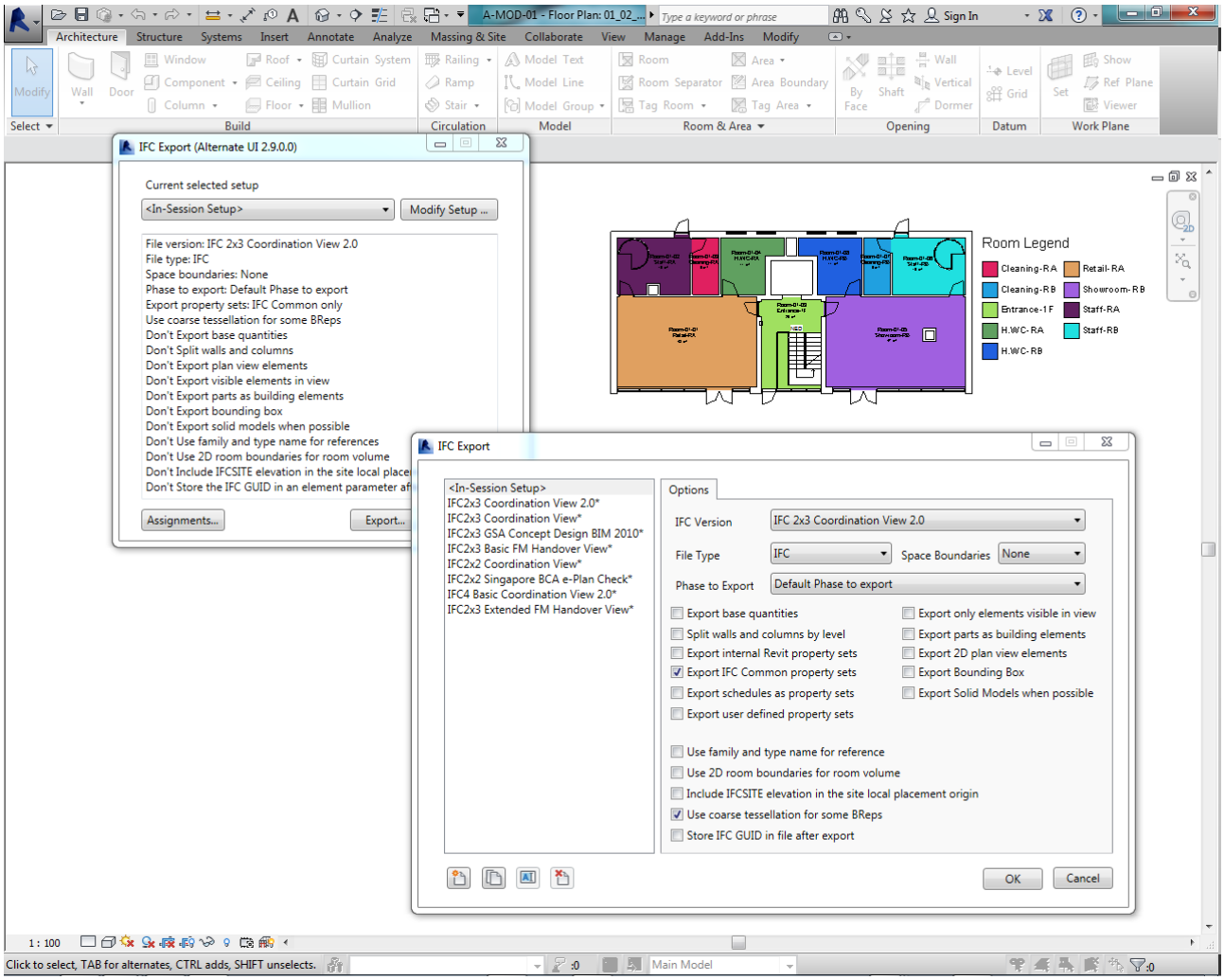


Figure 41 IFC export platform in Revit AutoCAD.

4.1.14 Practical application of FM data findings

This particular research was conducted to analyse how FM information is implemented into a BIM model and to find if there were any challenges in transferring that information to the MainManager system through the IFC standard some basic FM information were used to examine the routine.

The main conclusion is that there was no data loss detective, the transfer of information from the native Revit AutoCAD model is relative straight forward. There is an export tool embedded into Revit making it easy to export the native model to IFC. An issue was found with the family parameters as they will not convert to the IFC format so making a database of Revit families with COBie information embedded could be problematic.

The COBie extension from CADD Microsystems for Revit 2014 proved to be very helpful in setting up Revit for COBie, the tool provides that all basic parameters are inserted into Revit and fills in automatically many basic parameters e.g. COBi.CreatedBy, COBie.CreatedOn and COBie.Component.Space minimising repetitive work and COBie schedules are automatically generated. All of this function can be manually done however the add-in makes the work much easier. Other CAD programs support the use of COBie but were not a part of this study.

The Zone tool provided in the COBie add-in of Revit 2014 is extremely helpful in creating different zones within the facility as Revit only has the possibility of making one HVAC zone the plug-in makes it easy to make as many zones as you need and associates them with the spaces. Zones are easily converted into COBie deliverables.

Both COBie and Revit use OmniClass construction classification system it is a specified construction classification system for electronic databases other classifications as DBK, SFB and TFM systems can be used in COBie by adding parameters and manually inserting the code. The more logical approach would however to adapt the work process to OmniClass as it is a part of the overall COBie strategy.

Revit Architecture is well capable of collecting COBie data and delivering them to an IFC file format modellers needs to understand the parameters and be capable of proper use of schedules so the work of adding parameters and information to the parameters becomes effective. Family parameters cannot hold COBie data as they are known to get lost in the conversion to an IFC file the IFC exporting tools are becoming better so that is a problem that is being worked on. The COBie add-in for Revit is easy to use and requires limited training.

From the MainManager system all COBie deliverables were identified and no data loss detected from the instance parameters or the type parameters.

4.2 Qualitative study

The Qualitative research is based around collecting information from different sources within the Icelandic AECO industry about the use of BIM and COBie. The aim is to collect different views on the methods between the diverse stakeholders that would be expected to work on BIM projects and analyse where current knowledge on these methods stands, where friction between stakeholders can be expected and how implementation of the COBie could affect bid prices. The most logical approach was to apply a survey conducted by interviews of semi-opened question giving the interviewees the opportunity to respond at will and hopefully add to the research. It was chosen to apply interviews since Iceland is on a low BIM maturity level, so asking questions on COBie which is a part of the BIM strategy would be difficult without being able to explain the method before asking relevant questions as knowledge was expected to be lacking on COBie.

4.2.1 Interviews

The aim of the interviews was to gather different opinions and views on BIM and COBie the use of interviews was necessary since the COBie method of collecting facility management information is new and is not well known in the Icelandic AECO industry so the method would have to be explained to the interviewers to seek their responses on the subject. The interviewees where categorized after their position In the AECO industry and the questions adapted to their involvement in the project process so the questions are not identical between the groups. The questions evolve around what opportunities there are in the field and what conflicts there can be expected implementing COBie and how that can influence bid prices. The use of opened semi structured questions was decided so participants would have the opportunity to collaborate on the subject.

4.2.2 List of Interviewees

Group	Organization	Interviewees	Position
Public Organization	FSR, Framkvæmdarsýsla Ríkisins.	Ingibjörg Birna Kjartansdóttir, Constructing Architect. MSc. Construction management.	BIM expert.
		Haraldur Arnórsson, Constructing Architect. Cand.Scient.Techn Information technology.	BIM expert.
Owners	Fasteignir Ríkissjóðs.	Vigfús Halldórsson.	Head of constructions.
	FASTI, Icelandic Facility Management association.	Hannes Frímann Sigurðsson.	Director of Fast.
	N1	Hafsteinn Guðmundsson.	Head of construction department.
Consultants	EFLA	Arinbjörn Friðriksson, Building engineer.	Director of building department.
	Mannvit	Ingvar Rafn Gunnarsson. Structural Engineer.	Consultant.
		Árni Viðar Björgvinsson, Technical drawer.	Consultant.
	Verkís	Stefán Friðleifsson. Building engineer.	Structural engineer and project manager.
Contractor	ÍAV, Íslenskir Aðalverktakar.	Páll Á. Pálson.	Project manager.
	Sveinbjörn Sigurðsson ehf.	Ármann Óskar Sigurðsson, Civil Engineer.	Executive manager.

Table 4 Research participants.

4.2.3 Interview reflection

Research participants all showed great interest in applying the method on projects especially where owners interested in exploring what benefits using the method could bring them in the operational phase of buildings. The value of applying COBie to the BIM process was acknowledged by all participants and in their opinion what was needed was that building owners would require and define the method so it could be applied to construction projects other obstacles that where identified where technical difficulties of converting native BIM files to IFC format these difficulties were not seen as the big hurdle to overcome but the behavioural issues where thought to be the big problem making the change from standard construction methods over to BIM was recognized as the big difficulties that has to overcome before full advantages of BIM could be seen. Solving the behavioural problems will take a lot of training, coaching and time but can be overcome. Transcripts of the interviews can be found in appendix A.

4.3 Qualitative research findings

The objective of the qualitative research was to examine how prepared the AECO is to implements BIM method and produce in the process a usable BIM model capable of carrying FM information over to the operational phase and through buildings LCC. The research was aimed at discover what obstacles are in the way and if the industry saw the value in applying the method and in using the model after construction handover. An opened questioned interviews were taken from a broad view of participants in the construction industry to get the widest views, they were grouped after their disciplines and questions adapted to their roles in the construction project.

First part of the findings is analysis of the interviews with the aim of capturing what views different stakeholders have on the subject.

In the second part the findings are discussed what problems where identified and what was discovered that was unexpected from the interviewees responses.

4.3.1 Analysis of the Interviews

In the interviews participants were encouraged to speak freely about their view on methods of information handling within the AECO industry for the purpose of finding what obstacles could be in the way of implementing BIM with COBie and if there was any room for improvements. Analysis of their responses consists of identifying key trouble areas that need to be worked on if implementation of BIM with COBie will be successful.

Maturity stage

Iceland is on a low BIM maturity stage the interviewees have knowledge on BIM but not a lot of experience of working on BIM projects and an in-depth knowledge of the information part of BIM is lacking and can be improved. The general working method is still in sending information manually between project participants a central database is not a general working method. The capabilities of larger stakeholders of working with 3D models are good.

General information handling

There are challenges in the collecting, storing and delivering information that is used during buildings operational phase. There are multiple reasons for these challenges but one reason which shines through in the interviews is that a clear definition of what information is to be delivered to the facility manager at the

end of construction phase needs to be improved. The need for standardization in construction handover was expressed and how that standardization from building owners would help other project participants in delivering what is expected of them.

Knowledge

Overall knowledge on BIM as a method of information sharing over the whole LCC can be improved all actors in the industry need to understand better how the method can improve the overall construction process by providing a superior information sharing and be of benefit to all actors, a lot of the focus on BIM was on the geometrical model but lacking on the general information aspect. Training will be necessary when BIM will be implemented especially among smaller stakeholders. The knowledge on COBie is none existent with the interviewees other than FSR that have some knowledge on the standard.

Technical Issues

The technical issues are some but all interviewers felt that the technical obstacles could be well overcome they would though need some work. The main technical issue is that information tends to get lost during the transfer from the native BIM software to the IFC file this is a problem that the consultants will solve.

The contractors were more pessimistic on the method wanting to use the traditional method of collecting information and delivering them to a third person to insert into the model. The contractors expressed however that they would take part in a tender that would require them to insert the information themselves however the methods and requirements would have to be well defined. Doing COBie demands information that is created on the building site to be inserted by the contractor so this is a field that needs to be looked at as the tendering process and different stakeholder responsibilities can clash with the method.

Tools to support the contractors in inserting FM information is lacking and they can be improved the contractor needs to be able to examine the building in an IFC viewer and insert FM information as they are generated during the construction process they do not need to have the ability to change any geometry so a simple 2D platform with easy interface would help them.

Value

All participants in the study see value in BIM and COBie both for the design-build phases and for the operational phase. Especially the facility managers that are looking at buildings LCC which expressed a great interest in the COBie of delivering information from the design-build phases to the operational phase of facilities. All participants felt that requiring a model that would carry information throughout buildings lifecycle would be of great value.

For the contractor the value is in being able to identify design requirements fast and easy on the building site and overall access to information regarding buildings.

BIM was also viewed as a good tool for decreasing building waste and for preventing building defects by providing a more strategic method of information sharing and facilitate decision making earlier in the building process. The immaturity of the construction supply chain prevents however that full benefits can be achieved.

The value for the facility manager was thought to be greater for larger facilities and for organizations managing large facility portfolios the opportunities in the method were considered great. For smaller units the value in collecting and storing information was not as clear.

LCC

The common view was that BIM and COBie would have a positive effect on constructions LCC. Looking at the whole building lifecycle adding cost to the design-build phase was viewed as normal and acceptable by the owners. However different actors have a different view on LCC operators focus more on LCC than other stakeholders in the industry for those that are designing or building facilities that they will not operate the focus is more on keeping construction cost down rather than the LCC.

Defining information

The absence of a clear definition on what information is to be collected and how it should be delivered was expressed, that definition needs to be specific to each facility or facility manager depending on the value the information will bring to him operating the building or to the contractor building the facility and what value information from the designers will bring to him. The definition of information was thought to be one of the most important aspects of getting the method right, for each actor being able to access the right information quickly and effortlessly is the key to success. Methods of information gathering, storing and delivering needs to be standardized so design-build partners know what is expected of them in regards to information delivery

The need for more involvement of facility managers in the design phase was expressed by defining requirements for the projects, what information would be needed in the models for facility management that would bring the operator to the front of the building process giving them a better chance of influencing design decisions that can add value in the operational phase.

Cost

Requiring that the BIM method will be applied to a project will cost the owner in the design-construction phase of the construction. In the interviews numbers where mentioned as added cost of 3% of building cost or about 20% of design cost. This added cost was thought to be small in relations to the added value the method can bring to buildings LCC. The facility managers all expressed their will to pay for the method. The consultants and the contractors emphasised that they would have to get paid for the added cost that the method would bring to them so it is a consensus between the interviewees that the method will add cost in buildings design-build phase but has a great chance of lowering overall LCC.

Limitations

The limitations of implementing the method is mostly the immaturity of the Icelandic construction supply chain as a whole e.g. Suppliers don’t sell material in specific lengths creating waste on building site, design milestones are not respected by clients, lack of standardization and dated working methods that is hard to change. Technical capabilities of larger consultants are good but where expressed to be lacking with smaller actors.

Tendering formats

The tender formats will be an issue the Icelandic AEC industry is relatively immature and small. Different tendering format are often used so actors find themselves placed in different contractual relationships depending on projects. Understanding of different tendering formats is often lacking causing confusion in the construction process.

Project phases

The project phases are not respected enough e.g. the pre-design phase has the tendency to stretch over the construction phase causing troubles with all actors of the project. The construction industry needs to adapt to a more structured ways of building methods. COBie requires that certain information is validated before project moves from one stage to the next if the phases are not respected that can be an issue.

Behaviour

The construction industry is full of habits, old practices and work methods that need to change if actors are going to do more collaborating work together. The BIM process depends on sharing information efficiently and quickly between actors on project so the need for behavioural change in the industry is recognised.

As-built

When a building is constructed a lot of decisions are made on the building site, clash collision tests are not conducted properly and some design issues are left to the tradesmen to solve on the building site. This could cause problems in the as-built model all changes need to be implemented to the as-built model.

Information access

FM managers need easy access to information and only the information that is useful to him. Having different design and construction information is of no value and need to be excluded from the FM model. Easy access, reliable and a clear well understandable interface is crucial for successful use of the model in the post construction phase.

4.3.2 Discussion on the findings

There is an overall interest in the BIM method with all the interviewees though the focus is largely on the 3D geometrical model the use of the method as an information database that can be used as an information delivery system within the whole construction process and operations is not as well recognized. The interest varied between interviewees as their value of using the method is different, the owner organizations see a clear value in implementing the method and where willing to add cost to receive a model containing all as-built information, the consultants saw the method as exciting and thought that they could produce a model containing FM information and the contractors could see value in the method but they see it as a tool for them to view the building on building site and have access to design requirements but do not want to insert information direct to the model. This is one of areas that need to be worked at as BIM depends on instant sharing of information. The reason was expressed that they do not have the authority to insert the as-built information and that it has to be done by a representative of the owner that validates and accepts the information from the contractor.

The technical issues of implementing BIM and COBie are not great all participants in the study were equipped or could relatively easily equip themselves with tools necessary. The issue is more to do with knowledge, training and being prepared to work in a different way than before, changing this is not just that individual stakeholders in the system have to change but rather that the system itself is dated and needs to evolve to more of a production process rather than a traditional construction process. Lack of discipline in the industry was expressed e.g. building phases not being respected; tendering formats not acknowledged and project processes not followed this lack of discipline causes defects in the overall building project and needs to be solved with or without BIM. If The BIM implementation is to be successful it depends on information delivery between actors that is valid and they can depend on.

The BIM method is gaining momentum, public projects in Iceland, UK, Norway, Sweden and Denmark all require BIM to be used in construction projects though there is difference in at what level and what specific requirements apply in individual countries the European Union is also pushing for the use of BIM. Despite of this clear dedication to the method it is not included in any school curriculum so there is perhaps one of the main reasons for how unknown the method is that the educational system has not caught up with it yet.

The cost of using applying BIM in a project was seen as small in compare to the gains that can be had, however it will cost and it depends on who is construction the project and if he is going to operate the building himself if he is willing to spend extra on BIM. The benefits were clear from the point of view of an owner organization but from the point of view of the contractor the benefits where less clear.

Based on the interviews there has been substantial work done on what information needs to be carried from the design-build phases to the operational phases, and actors are practicing best practice of collecting information and using them in the operational phase. The facility manager should as well focus in the information that he doesn´t want as those that he wants as collecting, validating and storing useless information is wasteful.

5 Findings

The aim of this thesis was to explore how FM information could be implemented into BIM models and how the models could be standardized four research questions where established and they will be answered in this chapter based on both the literature review and the researches. Recommendations on what strategy can be used when implementing the process of collecting and gathering information is presented and collaborated on.

5.1 Conclusion

The overall aim of this research was to examine how BIM models can be used for facility management, how they could be standardized and how information is applied to the models. For the research four questions where established which the research was aimed at answering, these where thought to be fundamental questions about how this objective can be achieved.

What Information does a BIM model have to have so it can successfully influence the operational phase of buildings?

This question cannot be answered in a general way as for each facility different type of information need to be generated depending on the type of structure and organizations business objectives. There are however common information that apply to all facilities e.g. spaces need to be identified, zones established, identification of different project participants, spare parts, warranties, manuals, installation dates, building classification codes and component data. Other information needs to be defined by the building owner based on what value information is to him and his organization.

Facility owners need to take more active part in defining what information is needed they have to define for each individual facility what information is needed, how it should be delivered and when. One way of delivering this information to the designers at the pre-design phase is by using the COBie scope, delivering the owners requirements at project start. This definition has not been done and so the models that have been generated have not carried any FM information.

How is this information implemented to the BIM mode?

The information is inserted into parameters generated during the design phase of the project from the COBie scope there is however no standardize method of generating the parameters as it depends on the native BIM software which designers use. For the study Revit Architecture was used to display how the parameters where created and an external add-in was used for showcasing how information is implemented and how support to COBie is within Revit AutoCAD. However there are limitations to this study as it only includes one native CAD application other BIM applications do however support COBie.

The implementation of information is straight forward and will not cause any significant challenges to consultants or designers as they are used to working on CAD applications, for the contractors this is a significant change of procedure as the COBie method demands of them to change their working methods from collecting information from the subcontractors and deliver it to the building owner at handover to implementing as-built information as they are created during the building process with BIM achieving greater maturity stage.

More demands will be put on sub-contractors to implement their disciplines information into a BIM model in the future but as of now they are not well equipped technologically to do so and the tools that are available for implementing the information are in development.

Demanding that main-contractors and sub-contractors deliver their own data into the BIM model will require substantial change in the overall construction process as different stakeholders contractual relationships need to change.

How will implementation influence the actual model building?

A BIM model starts as a 3D representation of a facility as the project progresses it is populated by different actors with different disciplines all working on their own native application so you can argue that there is no “actual” model building but rather that a BIM model develops with time as different actors implement data that they are responsible for delivering. Different disciplines have their own applications that they use to populate the model there are architects, structural engineers, mechanical engineers, cost planners, project managers and contractors which all use their own preferred applications to populate the central information model.

BIM is a process of storing and sharing information throughout buildings lifecycle so the question is rather how implementation of BIM will affect the building process and how that process can be standardized and streamlined so the final deliverable is a BIM model containing FM information that can be used directly in a CAFM system.

COBie is a valid information exchange program that focuses on capturing information from the whole building lifecycle making the facility manager an integrated part of the construction process moving the focus of cost from the design-build to the operational phase where considerable gains can be had. It is a method of securing that names and numbers are unique, that schedules of doors, windows and components are uniquely numbered and associated relevant spaces, these practices are not new, COBie changes only how they are captured and stored in a central database during the design-build-operate phases. Applying COBie to projects will standardize the process of collecting and delivering FM deliverables to CAFM systems making it possible to map different models as they will be standardize.

The biggest obstacle to overcome is the immaturity of the Icelandic construction industry the whole supply chain needs to be adapted to more collaboration on projects, stakeholders need to understand the needs of other stakeholders in the supply chain e.g. what information they need and when. The industry has to be more disciplined; project phases need to be respected and old working procedures changed. This conversion will take time and effort.

Applying the BIM method to a project will rise the initial design-build cost there will have to be expenditure in BIM tools, education and training, as with all new methods and systems there is a learning curve to overcome in the implementation phase. The cost of Implementing COBie to a BIM project will increase the initial design-build cost, but the benefits of having a model at construction handover are undisputed.

Applying BIM will not increase time consumption on projects its main focus is in eliminating waste and defects in the building process by eliminate repetitive- and rework on building projects the implementation phase could however cost some time and money.

How can BIM influence LCC of buildings

The whole idea of BIM is to lower buildings LCC by streamlining design, build and operational processes. BIM is an information system with the aims of lowering cost of waste, time and defects. Using BIM with COBie will make the facility manager a part of the pre-design process where it is easy and most effective to influence the design that will bring savings in the operational phase.

BIM demands that building owners take more active part in the design stages of building project with the focus on the operational phase. It is apparent that too much focus has been on lowering construction cost and on the expense of the buildings overall LCC. Using the BIM method makes the facility manager an integrated part in the design phase of building projects by defining what information is needed in the model and to assist designers make design choices that will benefit the buildings operational phase.

By applying BIM to building projects the design effort is moved earlier in the design process making it easier and less expensive to make changes in design the process provides superior communication lines between different stakeholders during the whole building lifecycle preventing flaws due to bad communication. The method is also aimed at reducing waste from building sites.

Loss of information during buildings lifecycle is great and re-gathering of information is expensive for the building owner BIM provides a method of collection and storing information reducing that information loss drastically.

5.2 Recommendations on implementation

Here are presented the recommendations on how implementing COBie can take place, As COBie is a new method of gathering and delivering information on facilities problems can be expected in the implementation projects. What measure can be taken to counter problems that arise during implementation as stakeholders adapt to the new method are collaborated on.

5.2.1 Implementation support

The support of public organizations is vital for successful implementation of both BIM and COBie, there needs to be consensus on what method is applied in collecting, storing and delivering FM data on building projects so project participants can expect the same delivery process on all projects making it easier to estimate accurate bid prices. Different type of methods of delivering processes is confusing to the bidders and can hinder a successful adaptation in the industry if the process doesn´t get support of large owner organizations like the government.

5.2.2 BIM coordinator

Projects need to be overseen by a BIM coordinator that oversees how information is implemented into the model securing that information is available for all relevant disciplines on the building project at the right time he also conducts clash detections securing that the BIM model is up to date during the building process.

5.2.3 UK government BIM implementation strategy

A special task force was created to oversee the BIM implementation the task force has created a plan of how BIM can be implemented in the UK construction industry the plan divides the process into different steps that will be taken towards full BIM. One of these steps are COBie delivered in a spreadsheet format making all actors in the building industry capable of working with BIM data. The plan is to improve

information delivery in three progressive steps towards large improvements in what information is delivered and how they are delivered. Implementing BIM and COBie in Iceland can supported by monitoring and observing how the UK implementation is conducted.

5.2.4 BIM

COBie is a part of BIM so the foundation needs to be strong, the overall BIM strategy needs to be clear and well defined. As the method becomes more adopted and more practiced in the industry it will gain better footing so adding different requirements to the strategy will become easier. Owners and facility managers need to acknowledge the method and require that it is used on their projects letting it evolve and gain strength.

There needs to be support for those that are adapting to BIM as it demands that they adapt to other working methods than they are used to and that will take time and energy.

5.2.5 COBie guide

The guide lists all the owner requirements and it is a guide on how the information should be implemented to the BIM model the guide is specific for each individual project listing what information is inserted to each specific component or space. It specifies what naming rules should be used and what characters shall be used to avoid misinterpretation between the different BIM applications.

5.2.6 COBie scope

A rigid COBie scope needs to be done for every project the scope lists all information that is needed in the model for facility management and instructions how it should be implemented into the model. The scope is delivered to the designers during pre-design stage listing the owner's requirements to the project. The scope is a part of making the facility operators an active part of the design process bringing owners needs to the design phase of the project.

5.2.7 BIM execution plan

The BIM execution plan is fundamental to the success of the BIM strategy it specifies the roles and responsibilities of project participants at different phases of the project it contains detailed information on the BIM deliverables and on how the process that create the deliverables should be executed. Each project has its own BIM execution plan.

5.2.8 Value management

Value management is the process of analysing a project with the aim of identifying where the greatest value can be gained in a project by identifying required functions and finding alternative solutions that can lower buildings LCC. Value management is designed as workshops where different actors of the supply chain come together to find alternative solutions on a physical building project. The same method can be applied to a BIM method where participants would come together to identify what information is needed in the BIM process and what information isn´t needed by evaluating its function for each discipline. The value management team would consist of those stakeholder that are responsible for adding information the owner, facility manager, project manager, contractor, engineer and architect. The method would have to be adapted as it would be applied to a digital building rather than a physical one. A timeline can be created with post-it notes identifying what information needs to be available in the model when and for what stakeholder.

The aim of conducting a workshop of this type is to get all project participants on the same level of understanding of what information is needed, when and delivered by whom. It creates consensus and deeper understanding on the project.

5.2.9 Project phases

Project phases need to be monitored closely. The tendency is that the phases are not respected. Not respecting them has a negative effect on information flow on the whole project. Participants of the project need to recognise what phases are in the project and when the project has transferred between phases information in the model needs to be validate

5.2.10 Contracts

Contracts between projects participants need to be well defined where the actors understand what is expected from them and what are the consequences are if they don´t meet the clients requirements. This is especially important during the first implementation projects if the actors are unclear of the method or what role they play in the process.

The owner needs to define accurately what information he wants delivered, when and what the consequences are for project participants not to deliver information that they are responsible for. In future projects when BIM has become more widely used and the method better understood these contracts will likely become not as important as inserting information becomes more of a common practice for the project participants.

5.2.11 Database

A central database has to be agreed on before project kick off the database needs to be able to transfer all information from the native BIM applications to the central file and be able to display the BIM model for all project participants. There are different types of databases to choose from a logical approach is to use a web based database so all participants can access the information conveniently from anywhere.

5.2.12 Responsibilities

All responsibilities need to be clear, who is responsible for delivering what information, when and in what format. The client needs to define how and in what format he will accept the FM handover information as the responsibility of delivering the information to the IFC file can be on either stakeholder. It is common for the designer to handover information in the native design format file format so it will be the responsibility of the owner to transfer the information to the IFC file this needs to be established before project start.

Defining responsibilities between project participants can be done with the COBie responsibility matrix defining and colour coding who has the responsibility of delivering what information in the project. A different responsibility matrix has to be done for each individual project as stakeholders responsibilities can change.

5.2.13 Classification system

What classification system will be used needs to be agreed upon, some native BIM models like Revit use the OmniClass system and so does COBie as default the most logical respond is to use that system for BIM and COBie. If participants require other type of classification system can be used it will then become a part of the COBie scope that lists what classification system is implemented.

5.2.14 Tender

The use of different tendering forms needs to be acknowledged. The use of multiple formats in the Icelandic industry can cause confusion to project participants as their relationships can change depending on what tendering format is used in each project. Project participants need to understand in what process they are in and where they stand in the process at any given time.

Partnering projects would be well suited for implementing COBie on a BIM project as the architect, engineer and the contractor have a contractual relationship between each other making it easier to understand and acknowledge each other's needs during the design-build phases.

5.2.15 AECO industry

The Icelandic building industry is immature and needs to develop more before a fully collaborative BIM can be achieved. Working on a BIM project requires a certain amount of trust between different stakeholders they have to be flexible and there has to be a change in behaviour and attitude for the method to take full effect. Old costumes and work methods can be hard to change but as the BIM method will become more common in the building industry it will have to adapt.

The owners will have to support the implementation by requiring BIM on projects, monitor its progress and provide guidance on the method, this will be done primarily by public organizations but large property owners need to take part as well as the method is greatly beneficial to them.

5.2.16 Top Down

Implementing BIM and COBie on projects will need the participation of executive members of owner's organizations the implementation will cost and there will be complications on the way that need to be meet so the support of executive persons is vital for successful implementation.

5.2.17 Project Stakeholders

Special care should be taken and attention paid to the first COBie implementation projects. As the method is new it demands of different stakeholders that they change their working methods and adapt to a different working procedures so identifying key stakeholders is crucial for the pilot projects.

The primary stakeholders need to be identified and their possible influence on the project, failure to recognise key stakeholder in the BIM process and meet his needs can have influence on the quality of information delivered from them and the BIM process as a whole.

By identifying them as stakeholders in the project and making them a part of the effort you have a greater chance of succeeding with the project as they are more likely to participate and unlikely to stand in the way if they feel as a part of the project and their needs are meet or acknowledged. The stakeholders can be defined as a person or as a group of persons that have invested interest in success of the project and within the environment that the project is delivered[46].

Main stakeholders when it comes to producing, defining and delivering a BIM model that can be used in facility management can be defined as:

1. Government
2. Architects
3. Engineers
4. Suppliers
5. Main contractors
6. Facility managers
7. Software vendors
8. Owners
9. Project team
10. Users of facilities
11. Computer engineers
12. Project managers
13. Sub-contractors
14. Administrative Support
15. Top managers
16. Project Sponsors
17. Labours

Figure 42 Stakeholder Power/Interest matrix.

5.2.18 Project Scope

For projects there needs to be a clearly defined project scope especially during the pilot projects. The scope is used to maintain control over the project and is a definition of the required end result. All requirements to the project shall be listed and all information that is necessary for the success of individual projects shall be clearly defined. The scope should be brief but complete[47]. The project scope should be monitored by the project manager to reduce the risk of scope creep.

To properly define the scope it is possible to use the project scope checklist it lists

Project objectives

Project objectives are used to answer the question what, when and why so the objectives for a project aimed at delivering a BIM model that can be used in facility management can be defined as:

"Use the BIM method with COBie in the design-construction-operate phases to produce information rich 3D model that can be utilized immediately at construction handover to reduce buildings life cycle cost"

Deliverables

It is essential for major deliverables to be identified that is the expected outputs from the project over its lifetime. For a COBie project the deliverables can be associated with what information level the model is on and how it is developing.

Milestones

Milestones are a significant event in the project that occurs at a certain point in time they should represent a rough cut estimate of cost, time and resources for the project. These milestones could be associated with the COBie data drops where certain predefined information that should be delivered in the database will be validated.

Technical requirements

Technical requirements are defined securing that they can deliver proper performance. For example what database will be used in the project and it´s minimum speed and connectivity to alternative systems.

Limits and exclusions

The limits of scope should be defined. Everything that is not expected to be included in the project should be clearly identified so they don´t lead to false expectations, expanding resources and time spent on the wrong problems: For example information regarding landscaping is excluded or Information regarding specific components.

Review with customers

Using the scope checklist requires a thorough review of the scope with the owner of the facility to ensure that there is a common understanding of what the project will deliver. It I crucial to avoid conflicts in the long run when all parties have mutual expectations to the project. What needs to be discussed are the deliverables, what deliverables are expected and when, what are the key accomplishments and what are the projects limitations or what is not included in the project.

5.3 Discussion

It is clear that BIM offer great opportunities in streamlining construction processes as there are a lot of gains to be achieved in reducing waste, reducing time and in reducing defects in the construction process. Requiring that BIM include FM information for building operational phase is the next step in BIM adaptation sometimes referred to as the 7th dimension. As COBie is a method of standardizing information gathering and delivering it will be used in more projects in the future as there is no other standard in use.

5.3.1 Education & Training

As BIM becomes more used in the construction industry the need for teaching the method becomes more and more imminent and the question can be asked why it is not a part of any educational curriculum. The knowledge on BIM is lacking which is noticeable as many actors refer to BIM as a 3D model that can be produced. The focus on BIM as a method of sharing information by object based design is not as well-known and needs to be better introduced. The educational system plays an important role in that aspect of teaching other methods than only those that can be seen as "standard". BIM is a part of the public construction strategy if that strategy is to be successful then better knowledge on the method is important.

When BIM and COBie will be implemented some training will be required the larger and more advanced consultants are well capable of performing that training for their own staff as they are well equipped in both knowledge and in technology. The smaller actors will have to seek training and update their equipment if they want to take part in BIM projects.

When contractors will be obligated to insert as-built information to the BIM model they will have to seek training in how they insert as-built information and they will have to acquire appropriate BIM software for that task. The difference between applications that is used by designers and contractors is that the design software can change the models spatial geometry while the application for contractors should only allow for updating information of predefine building parameters a web based solution would be a good solution for the contractors.

5.3.2 Technical opportunities

As BIM provides the method of sharing information between projects participant's opportunities of providing BIM tools for data sharing appear. One of the hurdles of implementing COBie is the participation of the contractors, providing those with a tool that will assist them in inserting information that they are responsible for would be useful in the overall process. The validation process of that information would then be done by the facility manager.

5.3.3 MainManager & BIM

The purpose of this thesis was to examine how BIM models can be standardize so they can be used in the MainManager web based CAFM system however MainManager cannot become an end station for BIM models, parameters that are based within MainManager need to be fully updatable to the model so if the owner of the model needs to use e.g. for refurbishment he is capable of accessing it with all parameters fully updated with operational information. There are many opportunities in the BIM method for CAFM systems as they can be used as validation tools for COBie data or in the pre-design phase for LCC analysis to name a few.

5.3.4 **Further research**

COBie is dependent of successful BIM procedure there are obstacles in the adaptation of the overall BIM strategy in Iceland it needs to be determined what these obstacles are and how they can be overcome. The immaturity of the industry was apparent; a study of what these limitations are is needed so they can be countered.

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Appendix

Appendix A – Interviews

Government

FSR is a governmental organization pushing for a wide adaptation of the BIM method in the construction industry. If there is to be a change within the building process it should be led by a public organization that has a long term view on construction projects as their focus is on improving buildings LCC. It was felt as important to have their opinion on the process.

Interviewees:
Ingibjörg Birna Kjartansdóttir, BIM expert.
Haraldur Arnórsson, BIM experts.

- *What is the government's strategy on implementing BIM and using structured methods of capturing data?*

BIM is a part of the public construction strategy, our part in the BIM adaptation is to support different stakeholders within the AECO industry for BIM adaptation supporting that consultants adopt a wider use of BIM, we are aiming at getting on BIM maturity level 2. Effort is also on the contractors working in collaboration with us by guiding them on how the process works, in that case the plan is to move the focus on BIM for facility management.

BIM requirements have been set for designers and contractors on projects that are under construction but not for facility management, the starting demands for contractors are to link time schedules and progress schedules to the BIM model.

- *What is needed so the models can be used during the operational phase?*

The most important thing is that they are standardized and that "in the beginning the end should be viewed". The models that have been created have not been used during the construction stage or projects operational stage as there has not been anyone that could utilize them so all feedback from those stages is missing in the BIM process.

- *Are there any plans of requesting BIM models that can be used during projects operational phase?*

There is a project in the horizon that is planned to use as a pilot project for implementing operational information and to bring the facility manager as a consultant to the project start phase, the facility managers role will be to provide information on what data should be applied to the BIM project e.g. which is in their opinion the right way of doing BIM. That project is scheduled to start this year.

- *Do you believe that savings/value can be gained by using structured methods of capturing information during design, construct and operate process?*

Yes definitely, now it is the responsibility of the designer to implement data in the model but where BIM has reached greater maturity it is the responsibility of each actor in the building process to implements their required information to the BIM model. Where the BIM method has reached over maturity level 2 the lines between different actors in the project get thinner and responsibilities of delivering information is equally sheared within the project group. However we have not reached that level but are aiming for it.

Contracts between actors need to be clearly defined so information gathering and delivering will be successful, first-hand information delivered will always be more reliable and have better quality than if they are delivered through a third person in the project process. FSR is in the process of working with a main-contractor on how this can be achieved. The focus is not on the sub-contractors since it is not always of a greater value to include them in the process though it depends on their discipline.

- *What is your knowledge on the COBie Standard?*

Some knowledge but not in-depth, the next step in the BIM adaptation will be to implement COBie standard on a pilot project.

- *Are there any plans if implementing the COBie or other structured method of capturing data in public construction projects?*

FSR is not the operators of facilities so it is not ours to determine if COBie will be used or other methods, they will however support the implementation of COBie. The organization in charge of operating buildings in the ownership of the government is Fasteignir Ríkissjóðs (Governmental facilities) they will define what method is chosen but in collaboration with the FSR. The FSR has the position of consultants they cannot determine what method is used or from what vendor. Their view is that COBie support the open standard thinking and is a viable choice for data capturing during the construction process for Facility management.

- *What benefits can be gained in public construction projects using BIM and what affect can it have on building Lifecycle cost.*

The benefit is clear a BIM model is a visual information database; it can reduce information loss between actors drastically. All analysis, simulations and LCC analysis are embedded in the model giving the operator better chance of using the data. Going BIM on construction project has proven to deliver better design deliverables which results in better construction which then results more efficient buildings. Our neighbor countries are now focusing on BIM for facility management believing that it will bring value to the owners.

- *What limitations/challenges have risen when implementing BIM in regards to information gathering?*

There are technical issues to be looked at for some reason the COBie standard was adjusted to the UK marked before it was implemented, there could be some issues there that needed to be looked at before implementing. But it is mainly the knowledge and the skills of those that will work on the projects that need to be improved. The lack of support on BIM is noticeable in the educational system as the method is not a part of any curriculum.

- *Has it been considered what information a BIM model needs to contain so it can be used in FM?*

There has not been a clear definition of what information is required in the BIM model. The view is however that a scope is needed, defining each project taking into account different views of diverse stakeholders and different regulations that applies for different projects.

The minimum requirements could perhaps be what information accumulates over the design and construction period and then other specific requirements required by each individual client.

Owners and facility managers

The views of facility owners/operators is important since they will gain great value from the BIM adaptation as the information that will be collected during the design-construction phases will be used by them. Their position is also that they will have to require that BIM and the COBie methods will be applied on their projects so the views that they have on the methods are vital for further analysis.

Government Facilities (Fasteignir Ríkissjóðs)

The role of the organization is to be a specialised, professional and efficient administration of governmental real estate's their objective is that governmental organizations have suitable and convenient housing for their operations. In the beginning of the year 2012 they oversaw 1.241 facilities at 985.759m² they have the opportunity to benefit substantially if better practices of data capturing would be implemented during buildings LCC.

Interviewee:
Vigfús Halldórsson, Head of constructions at Government Facilities.

- *How is information handover conducted, what requirements do you set for information handover, are there any quality systems in place.*

It is routine to put requirements in our construction contracts that information should be delivered in specific format either .DWG or .RVT files so the files exist if there is a need to use them for maintenance or refurbishment. This information derive mainly from the designers there has not been a lot of information delivered from main-contractors, the information has been coming from the design phases and as-built information's if there has been any changes done in the construction process, the designer are in charge of delivering them.

We are working on defining a quality system of information for handover.

- *How reliable has information that you receive from handover been in past projects.*

There is no reason not to expect that the information isn´t reliable though it is hard to evaluate overall information quality without physically checking the information.

- *Do you consider it added value to BIM models if they could be used in buildings operational phase?*

Yes definitely.

- *Has it been considered to request that BIM models on new constructions projects can be used during the operational phase?*

Yes, projects have been requested to be done in BIM because it is considered to bring value to the projects.

- *What benefits do you see in requesting a BIM models that can be used in Facility management?*

It gives the opportunity to follow constructions building materials, building components and better organize maintenance on facilities. It gives the FM manager a tool to visualize what type of materials is used and where in the building e.g. floors, walls and ceilings color codes or materials. Great benefits can be achieved in being able to collect data about spaces from the office before work starts.

- *What limitations do you see in requiring a BIM model that can be used during the operational phase of a building project?*

There are no particular limitations other than that the design firms are unequally prepared to participate in BIM projects some will have to train their staff and update their equipment which can add cost. Firms are perhaps not ready for the conversion to BIM without having some projects lined up.

- *Do you know of the COBie standard and what is?*

No, but after a short presentation on COBie the interviewee was positive in the regards of implementing COBie.

- *What limitations/challenges do you expect implementing a structured method of gathering data like COBie?*

None particular, it only has to be considered how much information should be asked for in the model and definition of the project scope has to be clear. The model has to be divided to the construction model and the operational model, giving the FM manager the chance of accessing the information he needs easily and without excess information that doesn't regard him and is only used during the constructional phase cluttering the interface making access to information difficult.

- *Has there been any discussion of implementing a method of data gathering like COBie?*

No.

- *Would you be interested in requiring and paying for a BIM model that can be used during the operational phase?*

Yes, and there are some five facilities that we have had drawn up in 3D to be used in the operational phase so COBie would add to that interest.

- *Has it been determined what information a BIM model needs to contain so it can be used in FM?*

No, it has not been determined but discussions have been on collaboration with the FSR and ICEconsult (producers of MainManager) of defining what information is required for facility management within the models.

FASTI (Icelandic facility management association)

The association was founded in 2003 and has the purpose of supporting professional expertise on facility management by organizing meetings, seminars, presentation and to share knowledge on facility management between members and other foreign facility management organizations[48].

Interviewee:
Hannes Frímann Sigurðsson, Director of FASTI.

- *How is information handover conducted, what requirements do you set for information handover, are there any quality systems in place.*

There has not been many BIM models delivered from the construction phase to operational phase ready for use in facility management, there has only been two BIM models in total that have been designed to go over to operations in Iceland.

- *How reliable has information that you receive from handover been in past projects.*

There is room for improvement of information collected and received from design-build phases of construction projects.

- *Do you consider it added value to BIM models if they could be used in buildings operational phase?*

Yes it would be of great value for FM managers to have BIM or 3D models available during the operational phase.

However the immaturity of the whole construction supply chain limits the capabilities of BIM as the idea of using BIM e.g. for reducing waste by defining material sizes as Icelandic material vendors often don't offer their products in specific lengths or sizes but rather only in standard forms which increases waste from the building site.

- *Has it been considered to request that BIM models on new constructions projects can be used during the operational phase?*

Yes, it has been required, BIM Iceland lead that initiative by organizing two groups, one group had the goal of standardization for which he used the Norwegian and the Finnish standards, the other group's task was to define what information had to be implemented into the model, from that studies we received a report from BIM Iceland on standardization.

- *What benefits do you see in requesting a BIM models that can be used in Facility management?*

The benefits are quite obvious for FM managers that operate large real estate portfolios as it is nearly impossible to have oversight over all the facilities, BIM will assist with keeping track of information in a structured way e.g. technical specifications, manuals and type numbers regarding the facility and its core elements. The BIM system will become the manager's decision making tool where he can from his office make decisions on variety of tasks, maintenance, checks and on possible trouble spots in the building with better insight.

The value of BIM for the manager e.g. is in being able to make decisions in the office without having to send specialised people on the premises to inspect the physical building and analyse problems.

The benefits for small facility managers the benefits are less if any as they probably have more understanding of the facility that they operate than any application can provide them.

- *What limitations do you see in requiring a BIM model that can be used during the operational phase of a building project?*

Designers have to upgrade to BIM software, many have already made the change and are very capable in using the applications so the technical issues are not the big issue. The designers are also enthusiastic to compete on projects that require BIM so if you would require a project to be designed as a BIM project you would receive variety of offers from designers and consultants. The design-build market is however still immature in regards to adopting to new working methods and adopting to changes so improvements can be made there.

- *Do you know of the COBie standard and what is?*

No, but is familiar with other methods of capturing information during the design-build phases as the Norwegian and the Finnish standards.

- *What limitations/challenges do you expect implementing a structured method of gathering data like COBie?*

The maturity level of the construction supply chain could challenge the implementation.

- *Has there been any discussion of implementing a method of data gathering like COBie?*

Yes, in Collaboration with BIM Iceland.

- *Would you be interested in requiring and paying for a BIM model that can be used during the operational phase?*

Yes definitely, being informed and knowing what benefits the models can have on overall LCC an approximately 3% rise in building bid prices is acceptable and normal taking in an account the benefits and savings the method that can have on the project. The cost will probably come back threefold for each individual project there could however be some initial startup expenditures, but that cost will come back in relatively quickly.

- *Has it been determined what information a BIM model needs to contain so it can be used in FM?*

Yes there has been some studies done on what information is needed in the models but further studies are needed. There needs to be a clear definition of what information is relevant and carries value to the each individual facility, overloading information into the BIM model would be costly and it can get in the way of the facility manager accessing the information he needs quickly and efficiently.

It has to be acknowledged that building components and the information that they carry will become obsolete with time and unusable, for example components provided by a particular supplier during construction phase will possibly not be available when the data is supposed to be used making the collecting, gathering and storing of that data wasteful.

The focus should be on moving parts of building components, spare parts and technical information on specific components within the building that needs maintenance or special attention.

N1

N1 is an oil distribution company that owns and operates numerous gas stations, repair shops, administrative offices and a warehouse.

Interviewee:
Hafsteinn Guðmundsson, head of construction department.

- *How is information handover conducted, what requirements do you set for information handover, are there any quality systems in place.*

It has been one of my main objectives here in this company to increase and standardize information collection and handover from the design-build phases over to the operational phase. In the past the designers criteria have been lacking so we have been working on improving that criteria. We have used the MainManager system to collect those information e.g. the usual method is that the designer or the contractor delivers a handbook on ventilation system but we use MainManager to make the handbook by calling in the information necessary from different relevant project participants. We are aiming at applying this method to other parts of the facility as well.

- *How reliable has information that you receive from handover been in past projects.*

It mostly depends on how demanding we are on the information and we need to require them. We spend a lot of time with designers, contractors and suppliers defining how the information should flow between us to assure that individual components are functioning as they are supposed to do. Collection information from suppliers and manufacturers can be an issue so there is space for improvement.

- *Do you consider it added value to BIM models if they could be used in buildings operational phase?*

Yes in larger and with more unites this system as you describe it would definitely be of value to the facility manager and the owner it would help in decision making.

Defects in the Icelandic construction industry is enormous, whether it is defected building material, poor design, delays, accidents or other defects, so there is great gains to be had to by applying structured method of collecting and sharing information within project participants whether you apply BIM or any other method.

- *Has it been considered to request that BIM models on new constructions projects can be used during the operational phase?*

Yes, we have been looking at different FM systems since 1994.

- *What limitations do you see in requiring a BIM model that can be used during the operational phase of a building project?*

No particular limitations, we have been working with designers to improve their work methods around information gathering especially when working with smaller constructions and when the designer is not a part of the larger design firms.

- *Do you know of the COBie standard and what is?*

No.

- *What limitations/challenges do you expect implementing a structured method of gathering data like COBie?*

It is mainly political will and that the owner is willing to pay for the use of the method.

- *Has there been any discussion of implementing a method of data gathering like COBie?*

Yes but we have been looking at the MainManager system as the data gathering and validation system so we are using a structured method.

- *Would you be interested in requiring and paying for a BIM model that can be used during the operational phase?*

Yes we would certainly be interested in looking into the BIM method for our projects, looking at only the cost of defects in the building industry if using BIM could lower that cost and that would retrieve large amounts of the cost in implementing the BIM method. All design will become better focused and better disciplined making defects better detectable in the design phase. This however depends on that the method is well executed throughout the building processes.

As we look at building projects in a long time span, about 30 years we would rather spend money on the design phase than in the operating phase so we would be prepared to invest in a product that would save cost during buildings LCC.

- *Has it been determined what information a BIM model needs to contain so it can be used in FM?*

Yes we have, we have tried to define what information is relevant to facility management we define for our projects what information we need for facility management.

Contractors

Information that is needed for facility management generates during the construction phase when the contractors is working on the projects and so it was felt that their view would be important to the study. Information in specific components, installation dates and information from sub-contractors all come through the main contractor. These information need to be loaded into the model and it is crucial so the success of the BIM project that this information handover is conducted properly and that the information is trustworthy.

Sveinbjörn Sigurðsson hf.

A main-contractor that has operated in the construction industry for over 70 years founded in the year 1942 the company has a large portfolio of projects containing over 30 kindergartens, sport facilities, apartment blocks and schools. For its long tradition and in depth knowledge on the construction industry their view would benefit the study.

Interviewee:
Ármann Óskar Sigurðsson, Director of Sveinbjörn Sigurðsson hf.

- *How is your knowledge on BIM?*

It is very basic, personally I have had some introduction on it and how it can work as support tool on building sites.

- *How do contractors collect and deliver information on a building project?*

It is custom today that the client specifies what information should be delivered on construction handover, one of the first things that is done is that all relevant information on the main-contractor and sub-contractors is submitted to the client. All use of material needs to be validated by the client and approved before the construction process starts. It is primarily the responsibility of the client to decide how he wants the information delivered.

- *Do they use structured or unstructured methods of collecting data?*

We use structured method of collecting and storing information which is a part of our in house quality system.

- *How is Information Handover conducted?*

In the end of individually project each installer of a HVAC system delivers a handbook with all drawings, documentations, manuals and etc. this is done for each individual HVAC system, plumbing and electronic system within the facility. These handbooks are delivered from the subcontractors.

Other information on building components such as floors, walls and ceiling finishes are handed over after the client's requirements sometimes in paper format or scanned and delivered in .PDF digital format.

- *Is there a quality system in place within the organization?*

Yes there is a quality system in place, the client's requirements can however clash with the quality system that we use in certain instances.

- *Do you think there is added value in streamlining and improving information gathering during the construction phase of building projects?*

Yes that would be beneficial but then you would need to streamline client's requirements and if all clients used the same system it would make all information gathering and handover more sufficient. But then the focus should be on the clients and their handover requirements.

- *What information would you consider to be important to you during the construction phase and do you think BIM could help in delivering that information to you?*

That depends on the size and scale of the construction in smaller projects there is not much value in the method as those working on the project have to have experience and knowledge in the tool that is providing the information. So there is a question of what real value it will have out on the field limiting yourself using only technical equipment for doing relative simple tasks may not always be helpful or add value.

- *Would you be interested in participating in a project that aims at delivering a BIM model with all as-built information included in digital format?*

Yes if the contractor doesn't have to by any expensive tools to perform the tasks and if he could deliver that information in either Word or Excel format.

- *What is your knowledge on the COBie Standard and are you aware of how it is evolving.*

No is not familiar with it.

- *What problems/conflicts could arise if COBie method or other structured method of collecting Data would be implemented?*

First and foremost it is the tendering and the tender formats that are used today. The clients that we are working for use different type of tender formats which often will not comply with this structure.

- *What can be done to counter those problems/conflicts?*

The best solution would be that the client would define his requirements receiving that information from the contractors and implement the information to the model himself or his representative. It has to be taken into account where the liability stands and who is going to use the information. Expecting the contractors to implement information themselves will cause problems.

- *What do you think is needed so COBie can be successfully implemented?*

The clients need to be responsible for implementing the information perhaps the method could be used when the design is on the hands of the main-contractor. There will always be a level of complexity to the coordination of the information. The complexity level of the method needs to be as low as possible and the method can´t become obsolete within 2-3 years.

- *Are subcontractors ready to deliver COBie data in acceptable quality in digital format?*

That is not the issue the subcontractors can deliver the information to the main-contractor as they are doing today in digital format, the question is however how information will be pushed into the model and to standardize that format.

- *How will implementing a structured method of collecting data (COBie) to building projects influence contractors bid prices?*

This will definitely increase building construction cost, applying this method will increase the bid prices. The value for the client is however clear he needs to be ready and willing to pay for the extra work that is included in the method.

ÍAV – Íslenskir Aðalaverktakar

The company is one of the larger construction companies in Iceland they have been a part of some of the more complex building projects that have been undertaken in the past as Harpa music and conference centre, heavy industry facilities, office buildings and etc. some of the building projects that they have been a part of have been designed as BIM projects.

Interviewee:
Páll Á. Pálsson, Project manager

- *How is your knowledge on BIM?*

The interviewee has good knowledge on BIM and has worked on buildings that have used the method e.g. Harpa music and conference center. Today he is managing a BIM project in collaboration with the FSR the new Icelandic federal prison on Hólmsheiði.

- *How do contractors collect and deliver information on a building project?*

As we are not the operators of the facilities that is under construction then our primary responsibility is to gather information from our sub-contractors and suppliers and deliver them to the client, which he then needs to accept or dismiss. This information can then be implemented into his BIM model if he wishes to do so. But it is not our responsibility to implement the information to the BIM model.

- *Do they use structured or unstructured methods of collecting data?*

In the tendering process when we are looking for suppliers or contractors that can deliver necessary product for the project their prices include delivering information on relevant product or systems, the suppliers or contractors guarantee that the information they deliver is valid and is in check with the specifications provided by the client. What information is to be collected and delivered depends on the work contract that we have from the client.

When we are requesting approval of a product and/or material from the client we use a form system that we fill in what we are about to get approved in compliance with the clients work description. There are often some exchanges between the contractors and the client but eventually the information is approved and then we have the information stored in our mapping system, that information can then be translated into the building handbook.

- *Is there a quality system in place within the organization?*

Yes there is a certified quality system in place which guides us how information is collected, if information is missing, what has been approved and what needs to be approved.

- *Do you think there is added value in streamlining and improving information gathering during the construction phase of building projects?*

As of now we are intermediary between the subcontractors and the client there is no immediate need for us to check information from subcontractor because the architect will handle that for the client after we have delivered the information. But we certainly keep an eye on the information and if they are not in compliance with the work description we will go over it.

When material/components arrives on a building site there is a system of checking and validating that the material is as promised and that information on that specific material is correct. The client can then in the commissioning stage again check the validity of those materials or components.

- *What information would you consider to be important to you during the construction phase and do you think BIM could help in delivering that information to you?*

Yes without a doubt, when the client has approved of a certain material if he would implement that information into the BIM model. Then we could have a pc or a tablet in the workplace where contractors could see what material should be used, where in the building and what design requirements are for a particular component.

- *Would you be interested in participating in a project that aims at delivering a BIM model with all as-built information included in digital format?*

Yes it would be very interesting to participate in a project with this requirements and being a part of the methods evolution. It will however require some financial obligations that need to be looked at. Our position is however that we do not wish to directly insert information to the model we would rather only have a viewer. The reason is that we don't have the authorization.

- *What is your knowledge on the COBie Standard and are you aware of how it is evolving.*

None.

- *What problems/conflicts could arise if COBie method or other structured method of collecting Data would be implemented?*

The BIM model needs to be correct from the start, you will need to be able to trust the model. The other issue is that the designers are often using BIM partially and then drawing in 2D so the BIM database is still incomplete. This is a combination of problems with the human factor and technical factors. Our duties are to collect information and deliver them to the client that should not purpose any problems but then the information needs to be validated and pushed into the model which could be some work.

Other issue is to get all stakeholders to be aware of what tendering structure is ongoing the difference in what position different stakeholders are in depends on the tendering method, so it is important to take into account what tender methods are used for each project and what obligations diverse actors in different projects. A solution to this is that the client defines what obligations each firms has in the project.

- *What can be done to counter those problems/conflicts?*

The individual that pushes information into the model should be the architect or some representative of the client.

- *Can COBie be successfully implemented?*

Yes.

- *Are subcontractors ready to deliver COBie data in acceptable quality in digital format?*

Yes they are, manufacturers supply the material in digital format if it is requested by the client.

- *How will implementing a structured method of collecting data (COBie) to building projects influence contractors bid prices?*

If the designers inserts the information there would not be any significant rise in prices, however if it would be required that the contractor would insert this information then that requirement would be a part of the tender and would have to be well defined by the client so every bidder would bid on the same base then the cost would reflect the scope of the client requirements.

Consultants

The consultants will play different roles in the implementation of BIM and COBie they will be have the responsibility of inserting design information into the model and they will often stand by the side of the client as consultants.

Mannvit

Mannvit is an international consulting firm offering comprehensive engineering, consulting, management operation and EPCM services.

Interviewees:
Ingvar Rafn Gunnarsson, Structural Engineer.
Árni Viðar Björgvinsson, technical drawer

- *Do you use a structured method of capturing and storing information during Design and Build phase of projects?*

No there is no predefined method that is followed when working in collaboration with architects the information flow is free between project participants.

- *What is your knowledge on the COBie Standard and are you aware of how it is evolving.*

Yes some knowledge of its existence but not in-depth.

- *What limitations/challenges do the designers expect implementing COBie?*

Mostly lack of knowledge on the BIM method and that the view of some actors is that designing in full BIM is not efficient because so many obstacles are solved by the tradesmen on the building site. So the main problem is that Iceland has not reached high enough BIM maturity level. It is a common preconception that BIM is some kind of a software solution rather than a process.

- *Do Consultants think that main contractors are ready to collect data in a structured digital format and deliver it to the BIM manager (Or whoever manages the BIM model)?*

Yes, the larger firms are capable of performing the task, the question will however always be who is going to pay for the process. Training could be necessary but it is not that complicated. In our experience when we worked on Harpan the music and conference center the main- and sub-contractors adapted to the technology fast. They need to see the point of applying the method.

- *Do you think it would add value to a BIM model if it is constructed with information enabling it to be used during the operational phase of the project?*

Yes without a doubt, where it has been used in the building site it has been of great value and with no doubt it will benefit in the operational phase.

- *Do you consider it more likely that a building owner would agree to construct a BIM model if it was usable during the operational phase of the project?*

Yes, however the owners need to understand what benefits it can bring but as the FM market in Iceland is an unknown size in Iceland so their view on the usability of the model is perhaps unknown, they are also unfamiliar with the method. But the foreign owners are definitely willing to fund BIM as knowledge on the method is better understood.

- *What problems/conflicts are can be foreseen if designers increase their workload to produce and manage information in BIM models that can be used in facilities management?*

There isn´t any big problems in implementing the COBie method and delivering a model usable for facility management. The only thing that is lacking is the interest from the client. Other obstacles can be easily overcome in the process.

- *How will implementing a method of collecting and managing data (COBie) influence design cost?*

This will not have any big influence in the building cost and if you take into account that the design cost of a building is around 10% of the building cost and the building cost is around 10% of the buildings LCC then the increased expenditure of using BIM is very low.

- *Do you believe that it is added value to building owner to have a BIM model that can be used for operation and maintenance?*

Yes it has to be.

- *Have you/your firm had any experience in working with a BIM model that would be used during operational phase of building?*

No the models that we have produced have only been during design-build phases.

- *Is there a demand for BIM models usable during the operational phase?*

No not really the main reason is that the knowledge on BIM in the facility management industry is lacking.

Verkís

Founded in 1932 verkís is the oldest consulting firm in Iceland they provide comprehensive services in all fields of engineering and related disciplines.

Interviewee:
Stefán Friðleifsson, structural engineer and project manager.

- *Do you use a structured method of capturing and storing information during Design and Build phase of projects?*

No, none other than on the bases of the work description provided by the owner, defining what information shall be provided by the contractors which we then accept. Other than that we don't store that information the contractor does and then hands over the building handbook during construction handover.

- *What is your knowledge on the COBie Standard and are you aware of how it is evolving.*

No not on this specific standard.

- *What limitations/challenges do the designers expect implementing COBie?*

Standardization in general of work description would be greatly beneficial. There will be some challenges to be overcome as this is standard is new and in development. Information tend to get lost in translation between the native design software and the IFC file.

- *Do Consultants think that main contractors are ready to collect data in a structured digital format and insert it to the BIM model?*

That depends on the contractors those that have technical departments are more capable of inserting the information than smaller contractors as those that have had the chance of working on a BIM project before but they will depending on the projects that will be designed in BIM. It will however take some training.

- *Do you think it would add value to a BIM model if it is constructed with information enabling it to be used during the operational phase of the project?*

That has to be as he is buying the models from us it has to add value that he can use them during the operational phase.

- *Would you be willing to offer a BIM model with facility management information to clients*

Yes always, if there is a market for the BIM method we would like to offer it.

- *Would you consider it more likely that a building owner would agree to construct a BIM model if it was usable during the operational phase of the project?*

Yes definitely.

- *What problems/conflicts are can be foreseen if designers increase their workload to produce and manage information in BIM models that can be used in facilities management?*

You can always anticipate some small conflicts between the different stakeholders that work on delivering information to the model. The contractor, owner and different consults all have their different view on the project and they all require that the information is valid and at the right time for their use of it.

The technical issues are minimum and can be solvable.

- *What can be done to counter those problems/conflicts?*

There needs to be a pilot project to see how this works either from within the office or in collaboration with contractor and owner, the process of implementing the information needs to be defined and then we can request the information to be delivered in the way we can insert them directly into the model.

- *How will implementing a method of collecting and managing data (COBie) influence design cost?*

It will not be a significant cost increase on the whole construction cost but it would increase the design cost. It however depends on the definition from the client and what part of the project we will manage. However taking into account Buildings LCC vs. design cost the benefits are clear.

- *Do Consultants believe that it is added value to building owner to have a BIM model that can be used for operation and maintenance?*

Yes that must be.

- *Have you/your firm had any experience in working with a BIM model that would be used during operational phase of building?*

No not personally but we have been working on projects in Norway where our clients have used the models to make decisions about the project layout with the users depending on the model, so there they used the users/operators of the facility to assist the designer in decision making which was very helpful.

- *Is there a demand for BIM models usable during the operational phase?*

Yes there should be, there are many large facility owners on the market and they would appreciate all tools that could help them in operation.

EFLA

EFLA is a general engineering and consulting company with international activities and consultancy. They operate in different field's energy, industry, buildings, transportation, environment and project management.

Interviewee:
Arinbjörn Friðriksson, Director of building department.

- *Do you use a structured method of capturing and storing information during Design and Build phase of projects?*

Yes we use structured methods of collecting and storing information, it is important when designing a facility to work in a structured way so pre-design, design and detail design is done in the right steps and that certain stages are completed before moving to the next stage. These stages are often not defined well enough here in Iceland and that can stand in the way of clear decision making in the design process.

- *What is your knowledge on the COBie Standard and are you aware of how it is evolving.*

None.

- *What limitations/challenges do the designers expect implementing COBie?*

We have been involved in pre-designing a project in BIM where information where implemented in the model e.g. information on all spaces was inserted. So we know it is logical to work in this manner with large construction projects. The system is relatively new so there will always be somewhere needed to work around issues but that is with all new systems. The main obstacle is the making the decision "are you gone stay behind or are you gone lead the way".

- *Do Consultants think that main contractors are ready to collect data in a structured digital format?*

Icelandic contractors are well equipped and can deliver what you ask of them, but the question is rather how are you going to define what you want and then you need to make it clear how you want it delivered otherwise the contractor won´t deliver. Demands and requirements needs to be clear from the owner especially now when the method is new.

- *Do you think it would add value to a BIM model if it is constructed with information enabling it to be used during the operational phase of the project?*

Yes there is no doubt, but there must be that it is the same actor that builds the facility and the one that operates it otherwise he won´t see the benefits.

- *Would you consider it more likely that a building owner would agree to construct a BIM model if it was usable during the operational phase of the project?*

Yes but the idea has to be sold to the owners and then it depends on the individual/organization how acceptable they are to new ideas. And if you look at buildings LCC you see that the biggest cost is in the operational phase of the structure and if you look at the method in that view then the benefits are obvious.

- *What problems/conflicts are can be foreseen if designers increase their workload to produce and manage information in BIM models that can be used in facilities management?*

No, not really but the project participants have to agree on what system would be used and to coordinate the work. There could be some issues with the human factor people often set themselves oppose to changes and that would be a something that would be solved.

- *What are the limitations of producing a BIM model usable in the operational phase?*

The method is so new that I would be surprised if any model would be fully developed as is with most other software we use today so further development is needed.

- *How will implementing a method of collecting and managing data (COBie) influence design cost?*

Everything new will increase the base cost and therefore it is often public actors that lead implementation of new methods because they have a longer vision. So the cost will rise but possibly you could see how that cost would be gained back in the first project. Those that look at buildings LCC are more likely to lead the change to BIM.

- *Do Consultants believe that it is added value to building owner to have a BIM model that can be used for operation and maintenance?*

Yes definitely.

- *Have you/your firm had any experience in working with a BIM model that would be used during operational phase of building?*

Yes we pre-designed Landspítalinn hospital.

- *Is there a demand for BIM models usable during the operational phase?*

There is still no understanding from the owners on facility management and the operational stage the focus is still too much on the building phase of the construction. Owners of large facilities need to put more focus on the cost of operations even though it can add cost in the building phase.