CHALMERS

How to adopt the desires and requirements from the Facility Management in the design process with help of BIM

Master of Science Thesis in the Master's Programme Structural Engineering and Building Performance Design

DAVID HOOF

Department of Civil and Environmental Engineering
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Concrete structures
CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The greatest cost of a building throughout the total service life of the building is not the investment cost associated with the erection of the building but the facility management costs related to the operation of the building. Since these costs are dominant it is of high importance that they are taken into account and limited before the erection of the new facility starts.

This thesis has by interviews investigated what the facility managers thinks about their situation in the building process and how the facility management could have been improved by taking more consideration to the facility management in the planning and design of the building. These interviews has resulted in 10 criteria which the project leader and designer should pay extra attention to in order to fulfil the desires and requirements from the facility manager in the design process.

The research has also given examples of how a tool for BIM, building information modelling could function to take these 10 criteria into account in the design process. The aim of the study was to specify features in a future BIM-tool rather than to evaluate existing ones. Nevertheless, it can be concluded that there is no such BIM-tool on the market today.

It is possible to use these 10 criteria even without working with BIM in the design process. Then the 10 criteria and the requirement and desires from the facility management can be used as a checklist.

The thesis has also shown that the building sector could benefit economical by using lifecycle analysis to a greater extent in order to lower the lifecycle cost of a building. Lifecycle analysis could be used both to distinguish between different concepts and to optimize the chosen concept.

Key words: Facility management, Facility manager, BIM, LCA, LCC, The building process, The facility management phase

Hur man uppfylla förvaltarens önskemål och krav i projekteringen med hjälp av BIM
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SAMMANFATTNING

Den största kostnaden av en byggnads livscykel är inte investeringskostnaden kopplad till själva byggandet av byggnaden utan förvaltningskostnaderna kopplade till driften av byggnaden. Eftersom dessa kostnader är dominerande är det viktiga att ta hänsyn till och begränsa före byggandet av den nya byggnaden startar.

Detta examensarbete har genom intervjuer undersökt vad förvaltare tycker om deras situation i byggprocessen och hur förvaltningen man kunde underlättat för förvaltningen om större hänsyn hade tagits till förvaltningen redan tidigt i projekteringsprocessen. Intervjuerna har resulterat i 10 kriterier som projektledaren och projektörerna skall ta hänsyn till för att uppfylla förvaltarens krav och önskemål.

Undersökningarna har också gett exempel på hur ett verktyg för BIM skulle kunna fungera för att ta hänsyn till dessa 10 kriterier i projekteringen för att underlätta för projektörerna att möta förvaltarens alla krav och önskemål. Målet med undersökningen har även varit att ange hur ett sådant BIM-verktyg skall fungera snarare än att undersöka olika BIM-verktyg men det kan tilläggas att det inte finns något sådant BIM-verktyg på marknaden idag.

Det går även använda dessa 10 kriterier utan ett BIM-verktyg i projekteringen. Då skulle man kunna använda kriterierna som en checklista för att säkerställa att man tänkt på allt förvaltaren önskat.

Examensarbetet har också visat att byggsektorn skulle kunna dra ekonomisk nytta av att använda livscykelanalyser i en vidare utsträckning för att sänka en byggnads livscykelkostnad. Livscykelanalyser skulle kunna användas i större utsträckning både för att skilja mellan olika koncept i projekteringen och för att optimera det valda konceptet.

Nyckelord: Fastighets förvaltning, Förvaltare, BIM, LCA, LCC, Byggprocessen

Contents

Preface

This master thesis has been a part of the on-going research at Chalmers University of Technology of how BIM can be used in the building process. The project has been performed with supervision from Rasmus Rempling at Chalmers University of Technology and Lars Rosell at COWI in Jönköping.

I would like to thank my supervisors Rasmus Rempling and Lars Rosell for helping me during these months for this project. I would also like to thank all interviewees for their time and letting me ask them a lot of questions. This thesis would have been impossible to do without them.

I would also like to thank all co-workers at COWI Jönköping for letting me be a part of their crew for a couple of months when I have been writing my report.

Jönköping November 2011

David Hoof

Notations

BIM – Building Information Model or Building Information Modelling

CAD – Computer Aided Design

FEM – Finite Element Method

LCA – LifeCycle Analysis

LCC – LifeCycle Cost

IFC – Industry Foundation Classes

1 Introduction

1.1 Background

BIM is an expression that is becoming more and more common within the building industry. It is a shortening for “Building information model” or “Building information modelling” depending on if one referrers to the model itself or the modelling process. BIM can be defined in many different ways and the scope of this thesis is not to find the best definition of BIM but to find good applications within the Facility Management sector.

One of the fundamental philosophies with BIM is instead of using traditional 2-dimensional drawings, with associated descriptions, to communicate information from one actor in the building process to another, to use an information model. The information model should not only contain information about how the building will look like but also information like material properties, time, cost, order of assembly etcetera. The idea is to gather all information from all actors in the process at one place, an information database, so the total amount of information always increases trough the process. In that way informational information is available for everybody at the same time and you can if you are new in the project act on the information that is available instead of creating your own, new information. This will make the process more efficient and there will be less risk for mistakes, which results in a better product for the user. So the information in the model is always the same and it is increasing over time and it is used even in the facility management phase. So the key thing is that the information in the database, the “BIM”, will move from one actor to another in the building process and it is vital that this transfer of the model goes smoothly to not lose any information.

To some extent BIM is already in use in Sweden today, but there is a huge potential to use BIM in the future within the whole building process.

The facility management phase is the last and the longest phase of the building process and includes the operation and management of the building.

1.2 Aims

The aim of this thesis is to present 10 criteria to help the designers in the design phase to prepare the building for a better performance in the facility management phase. The criteria should represent the requirements, desires and comments from the facility managers in order to give a useful result. In order to reach this goal the requirements, desires and other comments from the facility managers will be observed and the presentation of these will be a milestone before the final result.

The aim is also to present directives for how each of these 10 criteria can be used in a BIM-model in the design process to create a better performance for the building in the facility management phase. A fundamental question for the thesis is also to find

indicators for these requirements and desires so the BIM-model can make sure that the requirements and desires from the facility manager is assured in the design process. With good performance it means to meet the facility manager's requirements and preferences.

1.3 Method

A research project like this thesis can be carried out in different ways. To get to know the subject better a literature study is preferable to start with. In this part of the research both BIM, with some different aspects, and facility management will be studied.

The next part, to do the main research, can be carried out in different ways. The different approaches can be split into qualitative and quantitative approaches where both have advantages and disadvantages.

There is some clear difference between the different approaches. A qualitative approach goes deeper into a specific case and tries to draw general conclusions from that specific case. A quantitative approach, on the other hand, tries to be general to be able to suit many cases to get a good overview. The different approaches are good for different things. In order to get a good overview, maybe to see how widely spread the use of something is at the market, a quantitative approach can be the best suitable. An example of a quantitative method for this research could be to do a questionnaire with questions about the subject and to give this questionnaire to as many as possible to get a wide picture of today's situation. An example of a qualitative method could be to do a case study of a real project and from this project draw general conclusions for the building sector.

In this specific research both method are applicable and both method can be suitable to carry out with interviews. The research part of the project will be done in Jönköping and since Jönköping is smaller than Gothenburg there are not that many big facility managers and clients in Jönköping which motivate a qualitative approach rather than a quantitative.

The research will focus particularly on some big facility managers, the municipality of Jönköping (Jönköpings kommun), the country council of Jönköping (Jönköpings landsting), HSB, Riksbyggen and Norrporten.

The third part of the research will be to draw general conclusions from the interviews and case studies carried out in main research and to write the report.

1.4 Limitations

This work only look into facility management of buildings and not roads, railways, bridges etcetera. The focus is on big facility managers like municipalities, country councils and big real estate owners.

Another limitation is to not look at BIM software and how they can treat facility management, neither in the design phase nor in the facility management phase. This is though very important for the future application of the result of this thesis but the purpose with this thesis is to confront problem in a more general way than looking at specific software.

2 The building process

The building process can be divided into four different phases, the pre study, the planning and design phase, the erection of the building and the facility management phase, Byggforskningsrådet (1996), Nordstrand (2008). The different phases will be described below in sections 2.1 to 2.4.

2.1 Pre study

The whole building process starts with a need for something new. The client, the one that has the need, has to investigate different options to fulfil its needs. The solution is not always to build something new. Often a project leader is contacted to help the client with the investigation to find some good alternatives for the client to continue the process with. Nordstrand (2008)

Typical questions for the pre study are why, where and how should we build. The pre study takes different suggestions into account and analyzes them to see how they will affect the final solution. The cost is often of big interest for the client to see if the project fits the budget or not, so among all other things that are discussed the cost is always important. Nordstrand (2008)

The goal of the pre study is to take a decision whether it is worth to continue with one or more of the proposals to fulfil the need. It is the client who takes this decision and if it is positive the process goes into the next phase, the planning and design phase. Of course there can be other answers as well like a decision to stop the project or to wait some years for more money. Nordstrand (2008)

2.2 Planning and design phase

In the planning and design phase the goal is to produce all building documents needed to erect the building. The planning starts with specifying all the requirements of the client and almost certainly some investigations have to be done to find these requirements. It is also important to describe all the conditions that may influence the design of the building early to facilitate for the design phase and ensure correct building documents for the procurement. Byggforskningsrådet (1996), Nordstrand (2008)

After the planning the design phase starts in order to design such a building that fulfils all the requirements from the client stated from the planning phase. This work takes a lot of time since all details needs to be thought through and all solutions specified in drawings and descriptions. This drawings and descriptions are called the building documents and this is the documents that the contractor will use in order to erect the building. Byggforskningsrådet (1996), Nordstrand (2008)

Depending on how big the project is and what type of procurement form the client is using the planning and design phase can look a little different buy it is outside the

scope of this thesis to describe this in detail. Byggforskningsrådet (1996), Nordstrand (2008)

The last part of this phase is for the procurement between the client and the contractor. The client uses the building documents to get a cost proposal from the contractor. The client may of course ask more than one contractor to be sure to get the best price. When the contract is signed the erection of the building can start and the building process moves on to the next phase. Byggforskningsrådet (1996), Nordstrand (2008)

2.3 Erection of the building

The erection of the building includes everything from the establishment at the local site to the finished building handed over to the client.

This phase is often divided into many different activities to easier get an overview of the project. Examples of such activities can be “the foundation”, “framework floor 1”, “casting of concrete”, “interior” etc. The establishment at the local site is called “the temporary factory” as every new building project requires a new, unique administration. Nordstrand (2008)

The erection does not only require human resources but also a lot of materials and machines. It is very important that the planning and the logistics at the building site works properly to get the project to run smoothly to be able to finish the building on time according to the time plan. Nordstrand (2008)

When the building is finished and inspected the building is handed over to the client, which now is the owner.

2.4 Facility management phase

In some literature the facility management phase is excluded in the building process as nothing new is built in this phase. But according to Nordstands definition the facility management is the final phase in the building process. This standpoint is also taken in this thesis. Nordstrand (2008)

One big difference between the facility management and the other three phases is that they are all very short compared to the facility management as this phase continues as long as the building exists. Therefore the cost related to the management of the building is very high compared to the investment seen over the whole life cycle of the building. To not only look at the investment cost but the total cost over the buildings lifecycle is called lifecycle cost (LCC) and this is described more in section 3.3.

When the facility manager starts to operate the building there are some different categories of work that needs to be done and considered. Instantaneous the facility needs to be supplied with elements like water, electricity, ventilation, heating and cooling, data communication etcetera. Waste and other rest products also need to be

taken care of. These are often categorised as the operation of the facility. The operation is what is needed to maintain the functionality of the facility and to keep up a satisfaction indoor environment for the tenants. Nordstrand (2008)

In order for the facility manager to keep the value of the facility some maintenance is also necessary. The maintenance can be either acute or planned. The acute maintenance is needed when something unforeseen breaks and the problem needs to be resolved at ones on order to not disturb the tenants or hinder their activity. The facility manager needs to have rational and effective information canals in order to repair the problem as soon as possible. Nordstrand (2008)

There is also preventing maintenance to prevent the acute maintenance as this can cause great damage for the tenant. This preventing maintenance can either be periodic based or condition based maintenance. Periodic based maintenance can be to change a filter every 6 months and condition based maintenance can be to repaint the facade when the colour gets to sun-bleached, see figure 1 below. Nordstrand (2008)

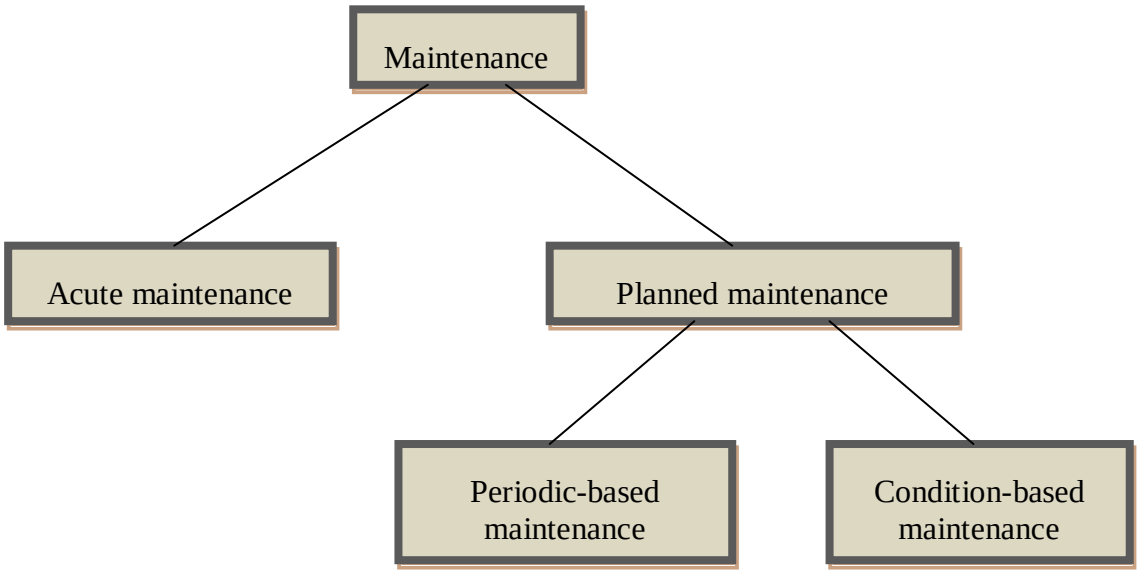

Figure 1. Different kind of maintenance and there relation. Nordstrand (2008)

In order to get an effective and rational maintenance the facility manager often develops maintenance plans with all periodic maintenance. In such plans it is easier to transfer condition based maintenance to periodic maintenance since this is easier to plan. Experience values are good for the manager and when using new materials correct information from the producers is vital. Nordstrand (2008)

Another part that is important for the owner to keep in mind is if changes of the facility are needed in the future. It can be an extension of the footprint of the building or by adding more stories, or a face lift of the facade or rebuilding the entrance etcetera. Modifications might be needed in order to adopt the facility to meet the requirements from new tenants or due to changed activity of the existing. The sort of modifications that can be done is often regulated by the local authorities. When a need

of changed is discovered the building process starts over again but in smaller scale than with a complete new building. Nordstrand (2008)

Often these modifications of the facility are quite small but when the need for modifications are getting big a new option can be worth to consider, demolishing the old building and rebuilding a new one. To demolish a building is connected with a lot of questions like of its own and this is the last step in the facilities lifecycle. Most of the questions are related to reuse and recycle of materials and to take care of the materials in an environmental friendly way. The demolish process includes similar steps like the building process, a pre-study that conclude that demolition is the best solution followed with a planning phase and the demolition itself before the new building can be erected. Nordstrand (2008)

The operation and maintenance described above are with a common name called technical maintenance, traditionally called facility management. During the last decades the facility management has changed a lot from a traditional to a more modern approach, where not only the operation and maintenance is included in the concept. In the wider notation, facility management can include all kinds of staff activities in a facility, like desk services in the entrance, cleaning, mail, security etcetera. It is just the imagination of the facility manager that can limit what services he can offer. The goal for the facility manager is to help the tenants to improve their business through the locals. For a residential facility the goal would be to improve life quality for the tenants. Nordstrand (2008)

In this thesis only technical facility management has been studied to see how the facility management can benefit from a greater role in the planning and design process.

3 ICT in the construction process

ICT, Information and communication technology has been a major contributor to the development within the building sector during the last decades. A significant change was the introduction of 2D-CAD, computer aided design, and now the building industry is facing a new major change with the transition to BIM. To some extent BIM is already in use but the potential with BIM is so much more than we see today.

This chapter fist briefly describes BIM and IFC which are two important concepts for today's development of ICT in the building industry. Secondly, a certain application called lifecycle analysis is explained with its connection to facility management and BIM. The quite new file format for facility managers, Fi2xml, are also described below.

Figure 2 below illustrates how the use of ICT in the building industry has developed. There are some major mile stones like the introduction of CAD, FEM etc. that are illustrated in the figure and some communication routes like the Internet. The next step in the land rising will be for us to have one big island instead of several small ones. This is when we have a common foundation to stand on and this is as showed in the figure when we can use BIM. Wikforss (2003)

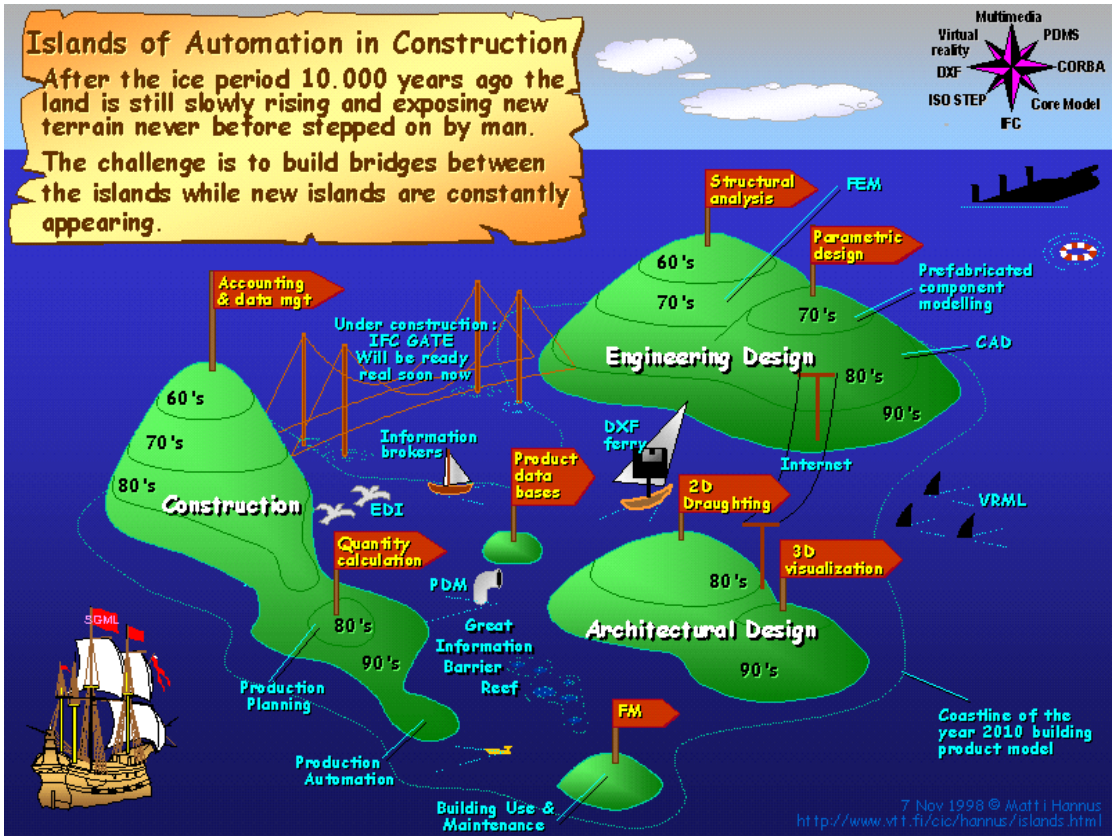

Figure 2. Island of automation in construction. The figure illustrates how the development in the building industry has gone so far and what might be the future. http://cic.vtt.fi/hannus/ *(2011-09-09)*

3.1 BIM

BIM, building information model or building information modelling, depending whether the product or the process is emphasised, denotes the new way of working with information in the building sector. Eastman et al. (2008). There are many different definitions of BIM and the aim of this thesis is not to find the most correct definition of BIM, but to describe the basic concept and the use of BIM in the building process.

The new thing with BIM is not necessarily the information itself. The information is the same as before, but it might be more information in the projects compared to before, but the major change is that it is a new way of working with the information and new tools to assess the information. With a BIM tool it is possible to gather information from different phases in the building process in the same model. A schematic model of how a BIM model works is presented in figure 3 below.

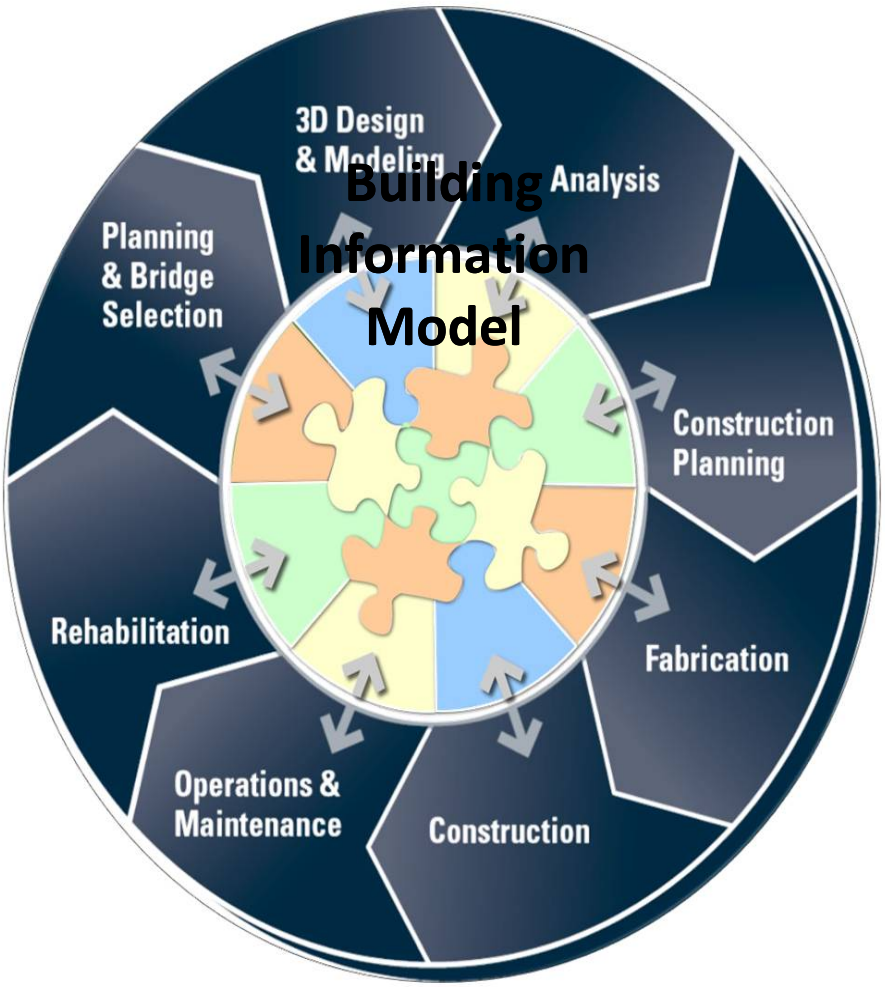

Figure 3. A schematic figure of a Building Information Model. http://www.bentley.com/en-US/Solutions/Bridges/brim.htm [Accessed at 2011-10-04]

All different disciplines can access the information, the core in the figure. They can not only access but also make changes and add their specific information. The BIM model should also contain information about all these different parts that is represented in the outer circle in the figure. The arrows indicate that different software can extract information from the model and the information can be visible in these different software. So the model with all its information is not developed in one single software but in many different.

From the figure it is also visible that a BIM model is much more than just a 3D-model as 3D-design & modelling is just one part of the outer circle.

With BIM it should be a constant flow of information throughout the building process from the pre study to the facility management phase, without any interruptions. Olofsson et al (2010). The figure 4 below shows a comparison between the car industry with a central management through the whole process and the building industry with local management of the information in the different stages of the process. The figure shows how the information and adding value increases through the process. The building process illustrates a traditional process without BIM and the car industry in this figure also represents how the information flow could be in the building industry with the use of BIM. The conclusion to this part is that when using BIM the building industry the information flow in the building industry would be like the information flow in the car industry. The process will then have fewer interruptions and less risk for loosing important information. 5D initiative (2011)

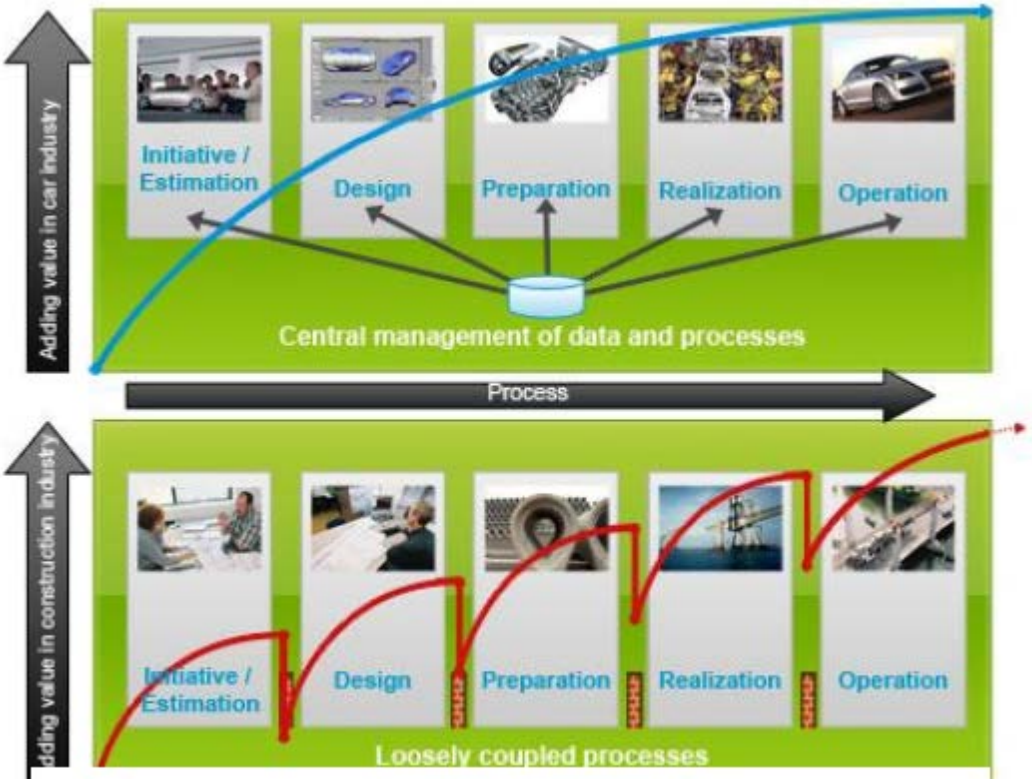

Figure 4. A comparison of the adding value between the car and building industry. http://www.5d-initiative.eu/motivation_why.php *[Accessed at 2011-09-19]*

With BIM technology it is possible to build an exact virtual model of the building long before the erection of building starts. The model contains exact geometry of the building and all relevant information needed for the remaining phases of the building process. Vozzola et al (2009). As mentioned before, it is not the information itself that is new but the tools to use the information when all information is gather at the same place, in a BIM model. With this model a lot of simulations and investigations can be performed already in the design phase and potential problems can be solved. This can be production related problems as well as problems related to the final use of the building. Example of production related problems can be "clash checks" where installations from different disciplines as electrics, ventilation etcetera can synchronize there models to see if their installations collide with each other. Example of benefits with the final usage of the building can be ventilation simulations, 3D visualisations etcetera. Eastman et al. (2008).

Sometimes BIM is mixed up with 3D-CAD but there are some major differences between the two concepts even though a BIM model contains a 3D-model of the building. A BIM-model is so much more than just a 3D-model and the BIM process is not just 3D-modeling, even if the 3D-modeling is an important part of the BIM-process. A 3D drawing only contains graphical objects as lines, circles etc. while a BIM model contains parametric object instead, like beams, walls, roof etc. These objects contain information about what kind of object it is and how this object may be used in relation to other objects and changed according to its parameters. Eastman et al. (2008). (Azhar, 2008). An example of this is a wall and a window. The window can be attached to the wall and if the wall is moved the window moves to. The wall understands that there needs to be an opening in the wall when the window is attached to wall and the size of the opening is the same as the window plus some extra space if that is required by this certain window. Parameters for the window could be height, width, numbers of glass, extra space needed for the opening in the wall, service life, periodic maintenance etcetera. Weygant, R. (2011)

A BIM model is capable of including much more information than a general CAD-drawing. It can be information about the different materials used in the model, like the window in the example above, production time for different parts, recourses needed for assembling the building element at the building site, cost estimations and much more. This is with this information we can do different analysis early in the building process. (Azhar et al, 2008).

BIM is still in a developing process and a lot of further research needs to be done before we can see all benefits with BIM. BIM, to some extent, is sometimes used in Sweden in the building process and mostly in the pre-construction phases. According to two master´s theses carried out at Chalmers University of Technology 2010 the building industry in Sweden are benefiting of BIM to some extent but there are still big potentials in the future. Hassan, H A. and Wondimu, P A. (2010), Ogbeide, E. (2010).

Azhar et al. 2008 has stated the following usage for BIM. Azhar et al, (2008). p. 438

- *Visualization*: 3D renderings can be easily generated in-house with little additional effort.

- *Fabrication/shop drawings*: it is easy to generate shop drawings for various building systems, e.g, the sheet metal ductwork shop drawing can be quickly produced once the model is complete.

- *Code reviews:* fire departments and other officials may use these models for building projects review.

- *Forensic analysis*: a building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.

- *Facilities management*: facilities management departments can use BIM for renovations, space planning, and maintenance operations.

- *Cost estimating:* BIM software(s) have built-in cost estimating features. Material quantities are automatically extracted and changed when any changes are made in the model.

- *Construction sequencing:* a building information model can be effectively used to create material ordering, fabrication, and delivery schedules for all building components.

- *Conflict, interference and collision detection*: because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences. This process can verify that piping does not intersect with steel beams, ducts or walls as shown in Figure 3.

3.2 IFC

IFC, industry foundation classes, is an object-based standard for file format for data models like BIM models used within the building sector. The standard is independent of software producer. It was developed by International Alliance for Interoperability, IAI, now known as BuildingSMART, in 1994. The project started by 12 companies in the USA and now BuildingSMART has local sub-organisations around the world. The aim with the project was to find a standard of how to exchange information about building elements regardless of computer software. BuildingSMART (2011) Wikforss (2003)

The IFC format includes information about the different building elements over the whole building lifecycle, from the pre study to the facility management phase. Eastman et al. (2008)

The IFC standard is build up by four different hierarchy layers see figure 5. Eastman et al. (2008) Wikforss (2003)

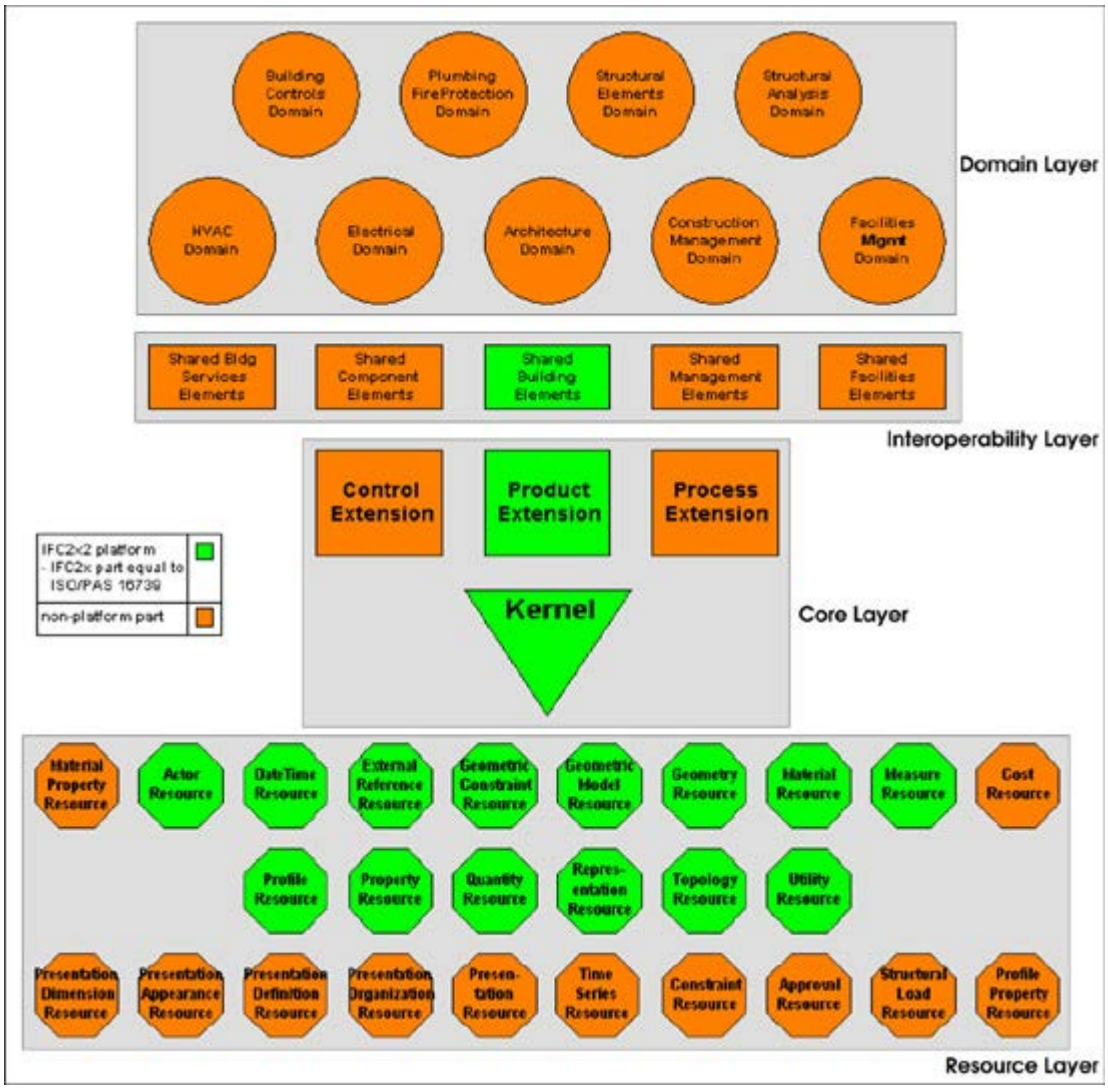

Figure 5. The four different hierarchy layers in IFC standard. http://blog.civilengineergroup.com/ifc-building-model.html (2011-09-09)

The four different layers are the Domain layer, the interoperability layer, the core layer and the resource layer. The modules at a certain layer may only refer to modules at the same level or at a lower level. Wikforss (2003)

The resource layer includes independent resources like measurement, geometries, identification, classifications, costs, materials etc. These recourses are referred from the core layer. Wikforss (2003)

As heard in the name, the core layer contains the core of the model. Here are all the foundation concepts as objects, attributes and relations located. Wikforss (2003)

Classifications like roof, floor, walls, etc. are located within the interoperability layer in the shared elements folder. This layer also contains modules for communication with the domain modules. Wikforss (2003)

The different domains for different disciplines are located in the domain models layer. Wikforss (2003)

Today almost all BIM-software supports IFC. There are also many IFC-viewers for visualisation of the BIM-model. This is very beneficial as people without any BIM-software also can take part of the 3D-model since most of these IFC-viewers are free for downloading. Eastman et al. (2008).

3.3 Lifecycle analysis and lifecycle cost

Cost is always an important aspect when it comes to new buildings and there are different ways to compare the cost for different alternatives of a building already in the planning and design phase. The easiest and most common one is to compare the production cost for different alternatives and try to set this one to a minimum in belief to get the cheapest alternative. But the cheapest production cost might not lead to lowest cost for the owner, consider the total service life of the building. Instead a higher production cost might result in lower total cost consider the buildings total service life. Schade (2007)

LCA stands for lifecycle analysis and LCC for lifecycle cost and it can be very beneficial for the owner of the new building to consider the total lifecycle of the building when evaluating different alternatives in the planning and design phase. Blom (2010)

In a lifecycle analysis all costs for the building within its lifecycle are included and they are summed up with certain methods to give both an equivalent investment cost and a yearly periodical cost. Then these costs are compared to find the cheapest alternative for the owner. For clients who also are responsible for the facility management of the building this can save a lot of money. For public owned companies and organisations this savings will be beneficial for the whole society. Blom (2010). Just to get a feeling of how big the costs are in the facility management face investigations has shown that an office building after 25 years has cost three times more during those 25 years than the initial cost. Schade (2007)

Figure 6 below shows how two of this methods work. Either all costs are summed up to an investment cost, the middle figure, or to a yearly cost, the lower figure. Blom (2010).

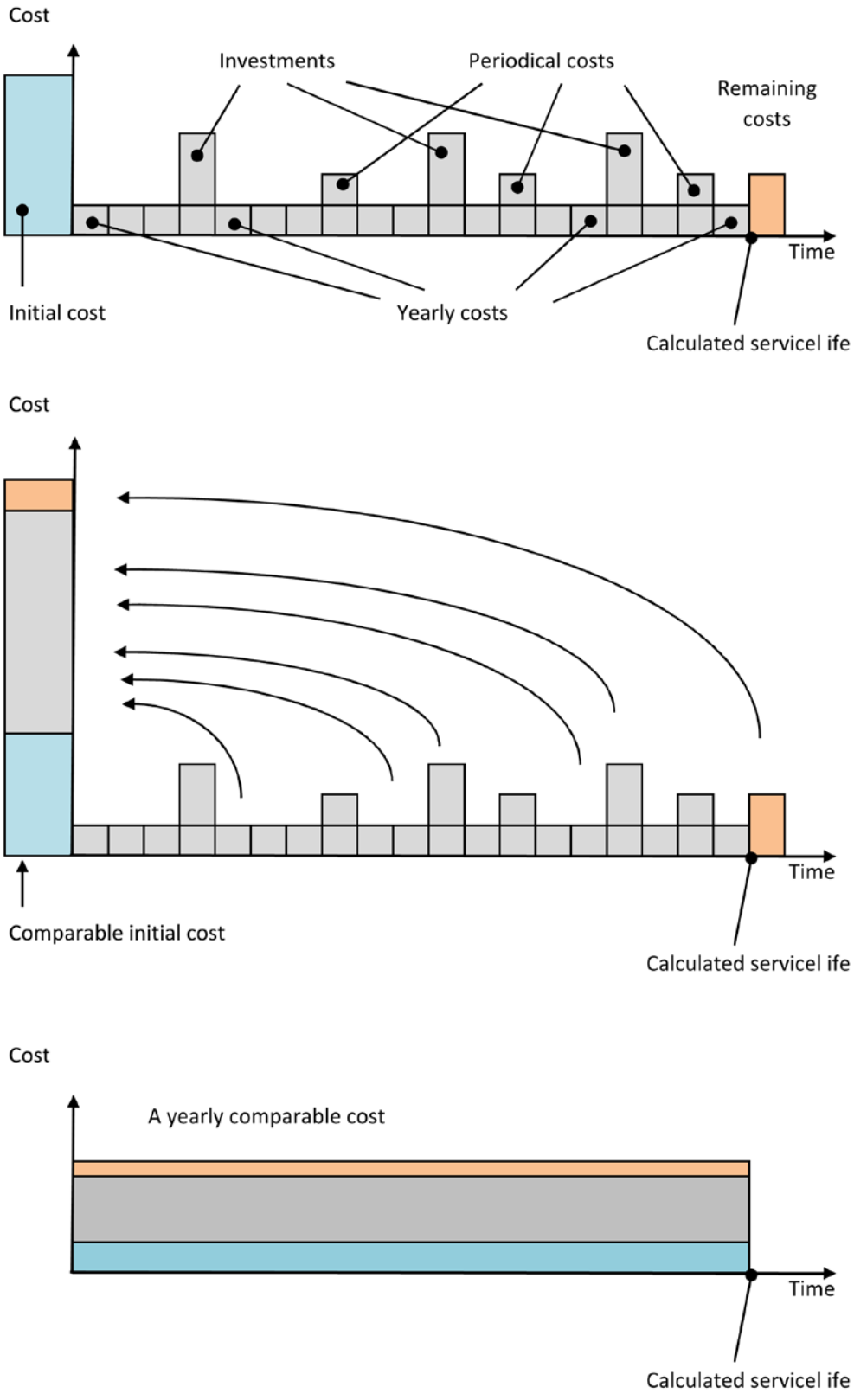

Figure 6. Lifecycle cost recalculated as a comparable investment cost and a yearly cost.

It is possible to perform this kind of lifecycle analysis by hand but it is very time consuming since a building is a very complex system with a lot of different objects and materials. Kaya, C. Fu. S. Aouad, M. K. G. (2007). It would be very beneficial for the design process to have tools for this in the BIM-environment.

One reason why production costs are used instead of lifecycle costs is that it is quite complicated to do the lifecycle analysis giving the lifecycle costs. One main reason for this is the lack of industrialisation within the building process i.e. the complexity of each building. This makes the collection of data time consuming and expensive for each project even though there are standards of how to do this. Regional databases with historical are not often available which otherwise would have done the work easier. If more clients would ask for lifecycle costs this will change and designers will be more used to do lifecycle analysis and databases with historical data will be built up. This will make the lifecycle analysis more reliable and even more useful for the clients. Schade (2007)

To use lifecycle analysis as a decision making tool in the early stages of a building project requires reliable and accessible information all through the project. Braganca (2007). Lifecycle analysis are most effect full if they are carried out early in the process since already when 1% of the total costs of the project are spent, about 70% of the lifecycle cost is decided. This shows that even if lifecycle analysis will give a result later in the process things are more complicated to change since a lot of decisions that influence the lifecycle costs are already taken. (InPro, 2010)

As written in previous sections the use of BIM in the design process will change the way of working with information in the early stages of the project. More information will be available earlier compared to a design carried out with traditional design tools and this makes BIM suitable for lifecycle analysis. Braganca (2007) Blom (2010)

So, lifecycle analysis is a powerful tool and together with BIM it is much more useful in the design process than before. Kaya, C. Fu. S. Aouad, M. K. G. (2007). The result of a more frequent use of lifecycle analysis will be lower lifecycle costs for the owner. Blom (2010)

3.4 Fi2

Even in the facility management phase of the building process the need of ICT-tools are important. A problem for the sector has been that different facility manager uses different programs and file formats so the requirements for what information and how they want it has been different. Förreningen för förvaltningsinformation (2011)

Fi2 is a standard for communication of all kind of information concerning buildings in the facility management phase. It can be areas, rents, building elements with their properties, need for maintenance etc. With Fi2 information can easily be exchanged, even if the information comes from different computer software. The organisation “Förreningen för förvaltningsinformation” which is the initiator to Fi2 expresses it like “Fi2 is the language that makes it possible for different systems within the facility management sector to communicate”. Förreningen för förvaltningsinformation (2011)

Since Fi2 is a common standard with more and more users in Sweden, the thinking is that designers and contractors in the future will know how they should deliver the information to the facility managers. By this more information from the design phase and the production of the building will be available for the facility managers and facilitate their work. Förreningen för förvaltningsinformation (2011). The result of this thesis can be a help for the building sector to know what kind of information the facility management demand.

Another advantage with using an open standard for the information is that the information is not bound to certain software and changing software will be much easier for the user. Förreningen för förvaltningsinformation (2011)

Whit Fi2 it is possible to export relevant information from the built environment to the facility management database with Fi2 like the figure 7 shows below. The build environment is a realisation of the BIM-model so this is a tool how the information from the BIM-model can be exported to the facility management database. This can be a first step to BIM in the facility management. Förreningen för förvaltningsinformation (2011)

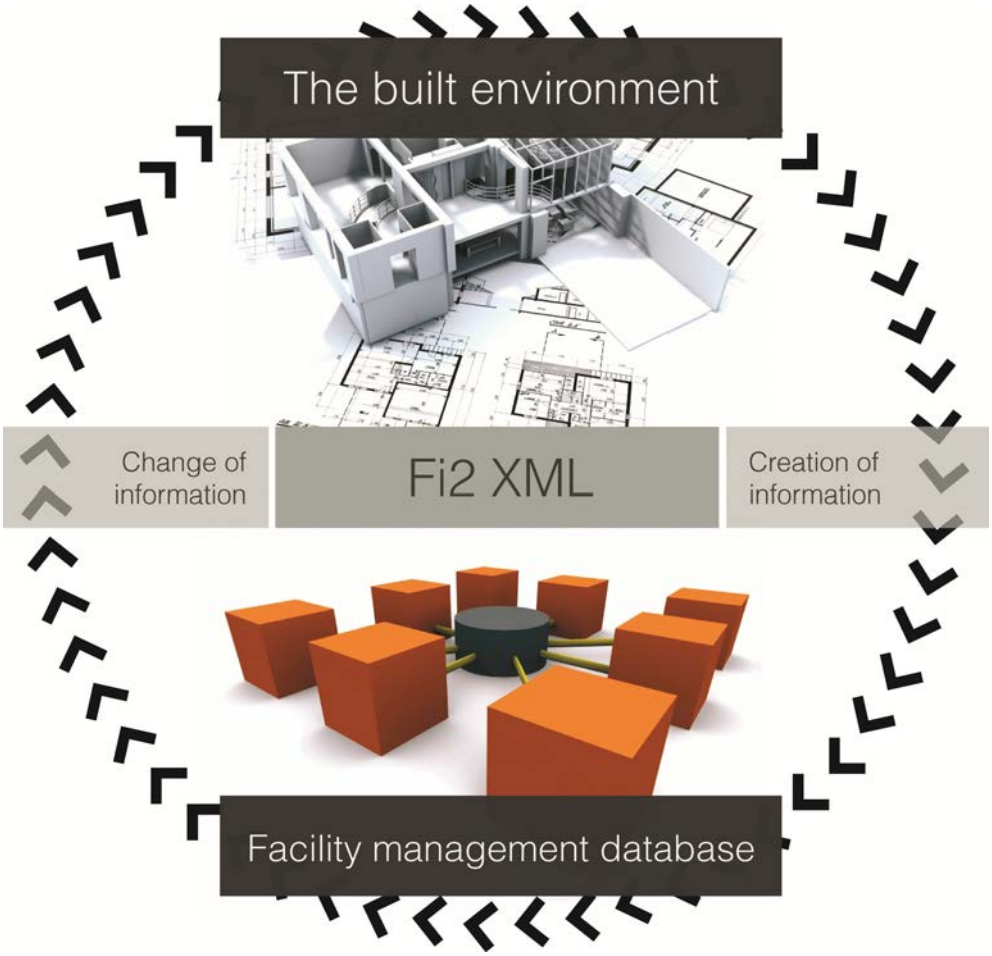

Figure 7. Information cycle. Förreningen för förvaltningsinformation (2011)

As shown in figure 7 the change of information in the facility management database should also result in a change of the build environment so the build environment and the facility management database agree. If the build environment in figure 7 also can represent a BIM-model it would be possible to make changes in the BIM-model by using the software connecting to the facility management database as shown in figure 8. In this process experience gained in the facility management phase can also go back to the BIM-process to develop both the process itself and the buildings in the future.

An illustration of a facility management database itself, the Fi2 database, is presented below in figure 8. Here different software can communicate with the information and use the information that they need.

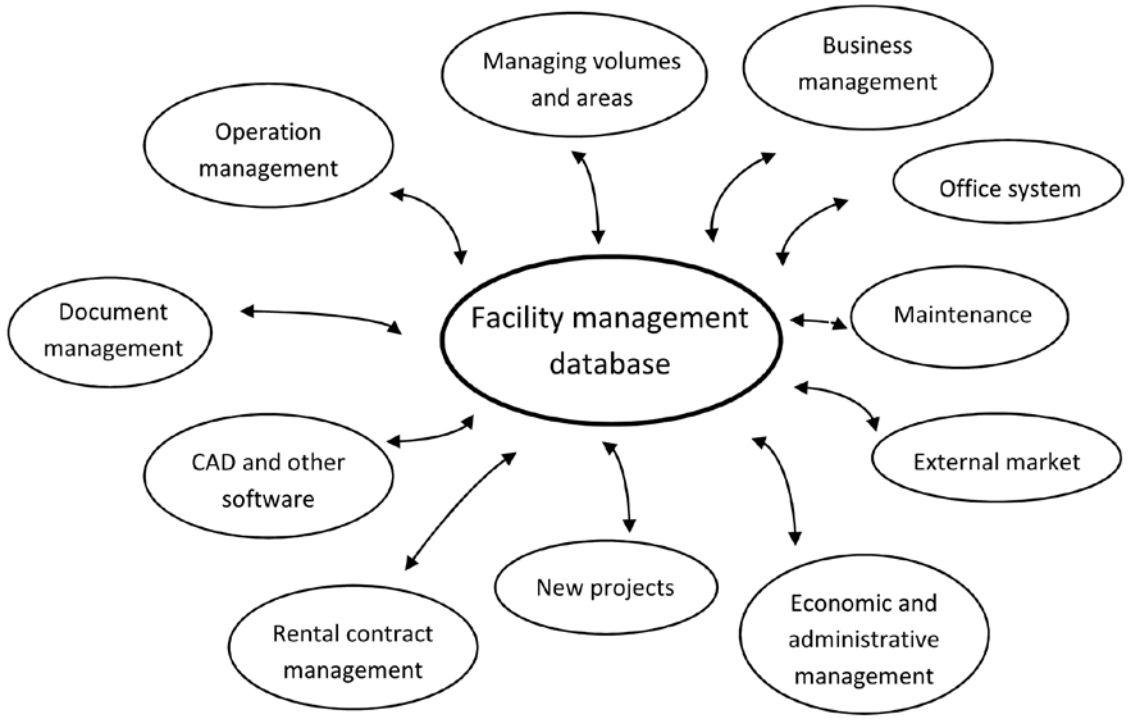

Figure 8. The facility management database.

4 Result

The method chosen for the thesis, a literature study followed by qualitative interviews, has increased the knowledge about the building industry and especially about the facility management phase. This gained knowledge is concluded and presented in this chapter. It is important to emphasize that the output from the result is not only the interviewees' personal opinions but a merged product from knowledge gained in interviews but as well from the literature study and the supervision meetings.

4.1 Research procedure

As mention in the introduction in section 1.3 this project started with a literature study to get more knowledge about the subjects. Mostly facility management, BIM, LCA, LCC and their links to each other were studied. The results of this part of the project are presented briefly in chapter 2 and 3. Scientific articles as well as books and web sites have been used for this part and chapters 2 and 3 give the background to the rest of the report.

The interviews for this research have been performed in Jönköping and they form the basis for the conclusions drawn in the thesis. How the interviews have been performed is described in section 4.1.1 below.

The last part has been to compile the impressions and opinions from the interviews and to draw general conclusions about different criteria that are important to take into account in the design process in order to get a good performance of the building in the facility management phase.

4.1.1 Interviews

The interviews have been performed in Jönköping during the July to October 2011. They have been of a qualitative nature rather than quantitative as a lot of opened questions have been asked. The interviewee has been able to interpret the question as he or she like and give his or her opinion. Since all interviews develop unique different follow-up questions have been asked to different interviewee. The standard questions are presented in appendix 1. Kvale and Brinkmann present the following six criteria for a good interview Kvale, Brinkmann (2009) p. 180:

- The extent of spontaneous, rich, specific and relevant answers from the interviewees.
- The extent of short interview questions and long interview responses.
- The degree to which the interviewer follows up and clarifies the meaning of the relevant aspects of responses.

- The interview is interpreted mostly during the interview.

- The interviewer is trying to validate its interpretations of the interviewee's responses during the interview.

- The interview is self-communicating. It is a story in itself that hardly requires much extra descriptions and explanations.

There are many different types of persons that have been interviewed and they represent different professions from the building sector but the thing they have in common is that they all somehow work with facility management. The majority of the interviewee is facility managers but also higher chiefs and organisation staff have been interviewed. Some interviews have been performed by phone.

The aims with the interviews are to get an overview of the sector and to draw general conclusions from different person's opinions not to present the opinions themselves.

The persons that have been interviewed are Torbjörn Isacsson, Susanne Kelly and Henrik Lalander at Jönköpings municipality, Martin Flodin, Göran Lindsjö, Ronny Leibäck, Lars-Göran Renblad, Ulf Sjöberg and Maria Andersson at Jönköping Country Council, Bo Johansson at Referat and Föreningen för förvaltningsinformation, Bo Tyrefors at Föreningen för förvaltningsinformation, Tommy Sandahl at Riksbyggen, Jan-Erik Andersson at HSB, Hans Larsson at Norrporten, Linus Malmgren at LTH, Magnus Jönsson at MKB, Anders Johansson as lical politician in Jönköping.

During the interviews notes have been taken and after each interview a have a memo been recorded with a summary of the interview. This has been done to be sure to memorise as much as possible from the interview. Sometimes additional questions have been asked at a second interview or by phone.

4.2 Preliminary result

From the interviews a lot of knowledge was gained and many aspects of facility management were raised. In order to present 10 criteria with important aspects concerning facility management the material from the interviews needed to be processed.

From the interviews about 70 unique requirements, desires and other comments concerning the facility management were observed and specified. This was a milestone in the process to find the 10 criteria to improve the facility management. Some of them were very clearly defined from the interviewee and some were a result of a good discussion during the interview. During the process with all interviews these desires were organised in different criteria and as more and more desires were observed the number of criteria grew. When all interviews were done the following requirements, desires and comments were observed, presented in table 1. Each requirement, desire or comment have been classified with preferably 1 criterion, but sometimes even 2 criteria as shown below.

Table 1. Requirements, desires and comments from facility managers

	Requirements, desires and comments from the facility managers	Criterion
1	Easy to change light bulbs	1
2	Easy to check fire alarms	1
3	Easy to change ventilation filters	1
4	There shall be ladders to the attic	1
5	There shall be prepared to make it easy to clean gutters, downpipes, roof tiles etc.	1
6	There shall be accessibility of all facades, so no closed courtyards without arrival of sky lift or small excavators.	1 and 11
7	How do we know which materials that are hazardous is 10 years.	2
8	Where in our facilities do we have hazardous materials?	2
9	Where do we have e.g. this kind of pump? Or other technical apparatus	2
10	Are all materials environmental friendly, even if that might be more expensive	2
11	Are the content of all materials attached?	2
12	How many m2 of e.g. roof tiles do we have? Facade? Ceiling, etc.? Basis for price quotations and procurements	2 and 8
13	Is the demolition considered? Can we re-use / recycle anything or does everything goes to landfill?	3
14	Good not having aluminium doors in the entrance to the stairway as they get skew easily	4
15	Is evacuation in case of fire simulated?	5
16	Are the accessibility for disabled people simulated	6
17	Good to have the same light bulb in different light fixtures	7
18	Use the same type of new washing machines that existing for the residents to know the new ones	7
19	Have the same technical devices and systems that previously because then the operators don't not have to take new training	7
20	Are all rooms and area right defined?	8
21	Are all volumes right defined?	8
22	Is the building flexible, i.e. can walls be moved if the need from the costumer is changed?	8
23	How much rentable space do we have?	8
24	Is it possible to load the slab with a sky lift in order to reach the ceiling, windows etc.?	9
25	Is it possible to change the lamp fixture?	10
26	Is it possible to change the ventilation units in the attic? Are the doors big enough?	10
27	Not to build in key media supply systems impossible to inspect	10
28	Important with sectioning of the median supply systems in order to troubleshoot in case of leakages and stop	10

29	Important with two service lines of electricity in order to ensure operation at power failure (for hospitals)	10
30	Important to prepare for future big maintenance of the building, such as changing sewage and water pipes.	10
31	Are the quality good enough at technical apparatuses such as elevators etc.	10
32	Do we have strong enough elevators / floors / wide doors to bring in new technical equipment when replacing old	10 and 9
33	Will it be as safe workplace for the maintenance people?	11
34	Will it be a good working environment? Accessibility to coffee rooms? Do the locals have windows etc.?	11
35	Is it easy to sort and throw away garbage for residents?	11
36	Is it easy for the garbage truck to collect garbage?	11
37	Are the doors wide enough to get throw the "machinery" needed, e.g.. cleaning trolley, floor cleaning machine	11
38	You should be able to move snow with a tractor not by hand, ex. not for the narrow sidewalks	11
39	Is the roof over the basement stairs so you do not have to shovel the snow by hand in these	11
40	Is cleaning trolley and the cleaning utility room easily accessible from the ground floor or by elevator?	11
41	Can we get in sweeper and tractor and other machines in the garage?	11
42	Is the good accessibility to and in operation rooms?	11
43	Are the facility managements locals good placed geographically?	11
44	Is there enough storage for utensils close to the needs? E.g. mowing, clearing flowerbeds, snow removal	11
45	Are all skills sitting close together? Good to minimize waste of time and increase communication and feedback	11 and 16
46	Can we avoid the flat roofs with internal drainage and other risk constructions	12
47	Is the roof permanent against sun-light and physical damages?	12
48	How much energy will the building use?	13
49	Have we optimized the ratio of heat consumption vs. insulation in a lifecycle perspective?	13
50	We have done a LCC calculation of the ventilation system?	13
51	Is that much glass in the facade "needed" or can we decrease that to reduce the U-value?	13 and 14
52	Dirt should not be drawn in to the building from the house. Important with at least 2 wiping zones	14
53	Are the materials in public spaces (such as stairwells) easy to clean? Not too dark, not too light and not too much friction	14
54	Are the toilets wall mounted in order to facilitate cleaning?	14
55	Important to have a floor drain in the garage.	14
56	It is good accessed to clean windows? Can they open inwards into the stairwell? Do we have to use sky lifts?	14

57	Important to have areas to place the snow in winter time	15
58	Important with good relation documents from all disciplines.	16
59	Important that the activity knows what they get so they are satisfied and you do not need to rebuild the building at ones.	16
60	May the facility manager be involved in determining things such window since they maintain the facility later on	16
61	If the facility manager can be known by the tenants this is experienced as good for the tenants	16
62	Will the activities feel comfortable and as home in the buildings?	16
63	Have we made demands for the facility management in the building documents? It is important to include the facility management in the way of thinking throughout the whole building process	16
64	Are there communication routines between the facility management and the construction project management?	16
65	Does the experience from existing projects come to use in the new projects? Are there routines for this?	16
66	Can we make LCA and LCC calculations to compare different options in the early stages?	16 and 13
67	Does the heating system require a lot of maintenance? e.g. Pellets do, but a hat exchanger or district heating doesn't	17
68	We have chosen low maintenance bushes and plants?	17
69	Important with weed-free soil	17

Table 1 above was mainly used in order to process the result but it can also be used as a checklist for the designer in the design phase in order remember to consider and raise the issue about the facility management.

Each of the desires above was also connected to a possible indicator. An indicator can e.g. be a door or opening width, a ceiling height or a yes/no answer to a certain question. The reason for connecting the requirements, desires and comments to indicators is to be able to measure if the certain requirement is fulfilled or not in order to future BIM-tool to do this evaluation automatically already in the conceptual design phase. An extension of the table 1, Requirements, desires and comments from facility managers are presented in appendix 2. In this table there are also added some extra explanations to explain some of the requirements, desires and comments. Added to the table are also if a classification if a 3D-model and a BIM-model is beneficial or a requirement to investigate the certain requirement, desirer or comment. This additional information has been an important tool for processing the result.

As seen in table 1 above the requirements, desires and comments were preliminary sorted in 17 different criteria. These criteria are presented in table 2 below. In this table are also the benefits of a 3D-model and a BIM-model included in order to see how this can be used for the different criteria.

Table 2. Organisation and classification of the 17 criteria according to the requirements, desires and comments from the facility managers

Criterion		Possible indicators/ good questions to ask and aspects to consider	3D	BIM
1	Accessibility for maintenance	Ceiling height, door width, the possibility to get a ladder inside the room. Possibility to change lamp bulbs, test fire alarms, clean drainage systems etc.	Makes it easier	Can detect the problem regions
2	Material specification, content and where to find them in the building	Has material specification been attached? What is hazardous in 10 years? How can we localize these materials if we need to?	Doesn't help much	Can do this automatically
3	Materials, choice and amount	How much material will we use and how big is the waste? Is the waste recyclable or is it landfill?	Doesn't help much	Can specify materials required
4	Materials, choice according to service life	Service life, cleaning ability and replacing cost	Doesn't help much	Can be a tool for a good choice
5	Evacuation in case of fire	Door width and number of evacuation routes	Makes it easier	Can simulate this
6	Accessibility for disabled people	Door width and level changes	Makes it easier	Can simulate this
7	Appliances, technical equipment, fixtures	Is the production specification attached and is a familiar brand/system used as before in the building?	Doesn't help much	Makes it easier
8	Defined volumes and areas	Are they all correct defined?	Makes it easier	Can do this automatically
9	Design and allowable loads	Which loads have been the design loads and which loads are likely to occur in the service life of the building?	Doesn't help much	Different load cases can be simulated in BIM
10	On site-built systems, the ability to maintain, repair, replacement and troubleshooting	Door width, load carrying capacity of the slab, and the possibility to get out the old equipment and in with the new ones. Have we prepared for future maintenance like exchanging sewage pipes?	Makes it easier	Makes it easier

11	Geographical location of the administration and good work environment for operators	In order to receive material etc. Is there enough storage for utensils close to the needs? Location of garbage room.	Doesn't help much	Can simulate this
12	Hazardous structures	Can we avoid flat roofs with internal drainage and other risk structures?	Makes it easier	If a structure is forbidden BIM can high light this in the software
13	Energy consumption	Insulation thickness, kW/m2/year	Doesn't help much	Can simulate this
14	Cleaning ability, reducing the need for cleaning	Number of wiping zones, Wall mounted toilets? Cleaning ability? Easy to access with cleaning machines	Doesn't help much	Can simulate this
15	Removal of snow	Can we remove all snow with machines like a tractor? Do we have space to place the snow or do we have to remove it?	Makes it easier	Can simulate this
16	Routines communication within the organization	Does the final user really know how the facility will look like and function at an early stage in the process? Does the facility manager take part in the planning and design phase in order to specify its requirements? Will experiences from earlier project benefit this project?	Doesn't help much	There can be a macro or a check list in the software that forces the designer to check the facilities performance according to the facility management.
17	Need for oversight and maintenance of systems	Are these windows/bushes /plants/heating system etc. maintenance-free or how much maintenance does they need?	Doesn't help much	Can find this data

To have 17 criteria is a bit too much from a scientific point of view and around 10 is recommended. In order to meet this recommendation the following reorganization of the criteria were done presented as number 1 to 10 below. The final 10 criteria are also presented more in detail in table 3 in section 4.2.

1. Need of and accessibility for maintenance
2. Materials and technical equipment
3. Accessibility and evacuation
4. Defined volumes and areas
5. Design and allowable loads
6. Good work environment for facility managers and geographical location of the facility management premises and equipment
7. Hazardous structures
8. Energy consumption
9. Cleaning ability and snow removal
10. Routines for communication within the organisation

4.3 Final result

In this section is the final result from the thesis presented in form of the final 10 criteria but also other important aspect for improving the facility management and how BIM can be used in this process.

4.3.1 The final 10 criteria

The final 10 criteria are presented in an extended version in table 3 bellow. Each criterion is presented with additional information and relevant questions and comments for the designer to consider. How BIM can be used to improve each criterion in the design phase is also presented in the table.

Table 3. The final 10 criteria

1. Need of and accessibility for maintenance
Additional explanation This criterion firstly includes the amount of maintenance needed for a specific technical equipment/aperture or technical solution. Can it be worth to have a more expensive alternative if less maintenance is required? It also includes the accessibility for the facility manager to fix and repair all kinds of issues. It should not be a hazard to fix small issues like changing light bulbs, test fire alarms, ventilation filters, clean roof drainage systems etc. All rooms and facades in the facility should be easy accessible with equipment needed for both acute and periodic maintenance. Is there a possibility that any special equipment is required in this certain part of the facility?

Relevant questions/comments

Things to consider getting a good performance can be amount of maintenance needed for different alternatives. Is there an alternative that is "maintenance-free"? Will this be cheaper or more expansive? Example of areas to consider is the heating system, ventilations system, flowers and plants.

Indicators for the accessibility can be ceiling height, door width, the possibility to get a ladder inside a room.

If we have a facility with a closed courtyard without connection to the street, how do we get equipment needed into this area if e.g. maintenance is needed at the faced or the ground material needs to be changed?

Benefits of BIM

The benefits with BIM can be great in this criterion. The BIM tool can find and compare maintenance levels of different alternatives to determine the best solution.

A BIM tool could also detect areas where access for maintenance can be a problem, through the indicators, and highlight them for the designer so the designer has an opportunity to fix the problem.

2. Materials and technical equipment

Additional explanation

This criterion includes all questions about the choice of materials and technical equipment. There are many different motives for choosing a specific material or technical equipment and the fact that designers/building entrepreneurs and facility managers as different perspective these choices done early in the process might not be the best in the long run according to the facility management. This includes the service life of the materials, the importance that they, with all its components, are classified as environmental friendly and that the facility manager is used to manage this certain material or product.

It also includes the problems related to a re-building and demolition of the facility. Are some materials able to re-use and recycle or not.

Another area covered in this criterion is the installations and technical equipment that are "build in" into the facility like sewage pipes, ventilation units at the roofs, heating system etc. Are the effects considered when some of these needs to be replaced and is it possible to prepare for this already in the design phase?

Relevant questions/comments

An obvious question is if all materials are environmental friendly and the answer to that one is easy and often a requirement from the owner. But how do we know which materials that is hazardous in 10 years? How can this materials be located if that is needed and how much of the certain material is there in the facilities? Are all material specification been attached? Is it at a similar way possible to find special technical aperture in the facilities if a certain device needs to be changed?

How much material will be use during production and how big will the waste be? Can the waste be lesser? Is the waste in case of demolition recyclable or is it classified as landfill?

Have the service life of the materials been considered together with the replacing cost. Are the chosen materials easy to maintain and clean?

Are similar products, systems and solutions used as in previous project so the facility

manager are familiar with them and are all product specification passed on to the facility manager? Example of this can be to use the same brand of certain machines and devices as the facility manager are used to as the need of specific spare parts are less and both the manager and the users are familiar with using this specific brand. It can be desirable to use lamp fixtures that use the same light bulbs as this also facilitates for the facility manager. Is it possible to change the lamp fixture itself it that is needed?
Are the doors and openings big enough to make it possible to get out the old equipment and in with the new ones? Have we prepared for future maintenance like exchanging sewage pipes? Are the media suppliers sectioned as the facility manager wants to and are they possible to inspect?

Benefits of BIM

A BIM-tool has the potential to do a lot of this automatically especially detecting hazard materials and specific devises and equipment if they are a part of the BIM-model. It can also calculate the material consumption and which materials that is possible to re-use and recycle.
At a rebuilding of a facility a BIM-tool could check new machines and technical devises to see if they are similar to the old ones and highlight this for the designer.

3. Accessibility and evacuation

Additional explanation

In this criterion are all kinds of accessibility and evacuation of the building included. Firstly it is requirement that the building is accessible for people with special aids, like wheelchairs and walkers. Secondly this criterion also includes evacuation routes in case of fire, both for people with and without aids.

Relevant questions/comments

Important aspects are doors and openings widths and the widths of corridors. For accessibility the changing in level are also important to consider making it possible for them to access everywhere.
How many evacuation routes do we have?

Benefits of BIM

With BIM a lot of these problems can be solved with help of simulations within the BIM-tool.

4. Defined volumes and areas

Additional explanation

A correct definition of all areas and volumes are very important in order to have a rational management of the facilities. This includes having correct volumes defined for heating and ventilation of the facility. It includes having the areas correct defined in order to have correct rentable area and a correct basis for service and maintenance.

Relevant questions/comments

Are all rooms correct defined with correct area and volume description? Is it possible to find total area of a certain covering material? This can be a certain wall paper, ceiling and roof material etc.
Is the floor plan flexible with light internal walls or is it very complicated to move them if the need of the building will change?

Benefits of BIM

BIM can calculate a lot of areas and volumes automatically and it can be very beneficial to use a 3D model to make sure all areas and volumes are included.

5. Design and allowable loads

Additional explanation

When new load combinations appear in the service life of the facility can it can very good to have the design load combination in order to make calculations for the new cases.

Relevant questions/comments

What is the design load combination? Can the calculations be attached in order to facilitate for the facility manager at an eventual rebuilding. What is the design snow load before the roof needs to be shovelled? Is it possible to load the courtyard with a sky lift to maintain the façade?

Benefits of BIM

With a BIM-tool it would be possible to simulate different load cases and to move the load to check different utility ratios.

6. Good work environment for facility managers and geographical location of the facility management premises and equipment

Additional explanation

This criterion includes the importance of a good and safe working environment for the facility managers. Bad working environment is often a result of a bad planning in the design phase and an oversight of the facilities manager's needs.

It also includes the geographically location of the facility managers premises and equipment like cleaning equipment, garden tools, snow removing tools and the department of the facility managers at a bigger facility.

The government in Sweden has through the Swedish work environment authority specified a lot of law concerning the work environment but there might sometimes be a need to put in some extra effort to reach a really good work environment since the laws can be quite general and possible to interpretable in different ways.

Relevant questions/comments

Are there enough storage facilities for cleaning utilities, garden tools, snow removing tools etc. in close relation to where they will be used? Is the facility manager satisfied with its location? Are there possibilities to easy receive goods if that is needed?

Is there good accessibility to and in all technical rooms to perform a good work there? Is it possible to access all rooms that need cleaning with the cleaning trolley and cleaning machines through the elevator?

Is it possible for the tractor and other machines to access the garage to facilitate the work there for facility managers?

With a good working environment is also meant the facilities for the working staff, is there enough widows and can the staff feel comfortable?

It is also important how the facilities are geographically placed in relation to each other. If the garbage house are not easy accessible tenants sometimes starts to leave garbage just outside the entrance doors. This causes extra work for the facility managers.

If the roofs need to be cleared from snow in the winter, is it possible for the facility managers to access the roof find the hatch to place the safety line?

Benefits of BIM

With BIM the accessibility can be simulated for cleaning trolleys and cleaning machines and it can also be easier with a 3D-model in the BIM-tool to get a good overview if the facility managers situation.

7. Hazardous structures

Additional explanation

It is often unpopular for the facility manager to manage hazardous structures as they often are related to problems and requires more attention of the manager. What might be classified as hazardous might differ from one facility manager to another.

Relevant questions/comments

Can we avoid flat roofs with very small slopes? Can we avoid internal drainage systems and other risk structures?

Is it possible to get a longer warranty of the hazardous structure as the manufacturer often says that it is safe?

Is the roof structure permanent against sun-light and physical damage? Will we harm the covering material if we remove the snow from the roof in the winter?

Benefits of BIM

If a structure is forbidden by the facility manager BIM can high light this in the software and it can ask for another technical solution.

8. Energy consumption

Additional explanation

There are regulations in Sweden that forces the owner to limit the energy use of their buildings but it can be economical for the owner not only to fulfil these requirements but to take one step further to decrease the energy consumption even more.

Relevant questions/comments

Is the ratio between insulation thickness and heat consumption optimised in a lifecycle perspective? Is it possible to reduce the U-value in other ways, like reduce the amount of glass in the façade?

Is it performed a lifecycle analysis of the ventilation system?

It is important to lifecycle analysis in an early stage before it is too late to make changes of the facility.

Benefits of BIM

The energy consumption can be simulated with BIM and it is possible to compare different solutions to see the benefits of certain changes.

9. Cleaning ability and snow removal

Additional explanation

One important aspect of cleaning is to reduce the need of cleaning. This can be done in different ways for different kinds of buildings. Another important aspect is to make the cleaning easy by the choice of materials so they are easy to clean and not get dirty too easy.

This criterion also includes the removal of snow in the winter. On part is to remove it so the users don't drag it into the house and another is to have rational methods to remove the snow from outdoor public places.

Relevant questions/comments

Are the floor materials easy to clean? This includes both the colour of the material and the friction caused by the mop when cleaning.

A good way to reduce the amount of dirt coming in to the building is to have at least 2 wiping zones at the entrance. One preferable at the outside and one at the inside of the door.

How will the windows be cleaned? Can they be opened to the inside or can we reach the façade with a sky lift? Are all windows considered, even roof windows and the windows in the stairwells?

Is it possible to use machines to remove the snow in the winter or is it required to do it by hand? Is there enough storage space of snow in the winter close to the facility or is the snow required to be removed from the area?

Is there a floor drain in the garage? This is important in the winter when a lot snow is drawn into the garage.

Benefits of BIM

With a BIM-tool a lot of this can be simulated to see the which cleaning that is required and where the snow can be moved in the winter etc.

10. Routines for communication within the organisation

Additional explanation

No organisation is perfect so there will always be potential of doing things better in order to optimize the facility. Are there communication routines within the organisation to take use of the experiences of the facility manager in new building projects? It is also important with routines for making clear demands concerning the facility management early in the project before the procurement.

This criterion also includes the routines for the final user and tenant to look at the project in an early stage to see if they are satisfied or in something needs to be changed. It is most important that they really get what they need. A good facility management comes at a second place after the activity of the final user. It is also important to create a good and nice environment for the final user of the building.

Relevant questions/comments

Are there routines for communication between different departments within the organisation? Is the facility manager invited to take part at an early stage in the design phase in order to specify its requirements? Are the demands from the facility manager a part of the procurement? Is the facility manager invited to take part in important decision concerning materials and technical equipment that the facility manager will manage later on?

Does the final user really know how the facility will look like and function at an early stage in the process?

Are relation documents required after the erection of the building from all disciplines to benefit the management of the facility?

Can the facility manager be known by the tenants? This make them feel more comfortable and at home.

Benefits of BIM

There can be a macro or a check list in the software that forces the designer to check the facilities performance according to the facility management.

This are the 10 criteria that according to this project the designer needs to consider in order to fulfil the desires and requirements from the facility manager. Table 3 can also be used as a check list for the project leader and the designer to remember and consider the facility management in the design and planning phase since there are a lot of relevant questions and comments. It can also be used for the facility manager that is involved at early stages to remember all important aspects of the facility and to use other facility managers' experiences to improve their own product. The facility management of a certain facility can be very complex and therefor can it be very hard for a facility manager to have all competence needed to take part in the design process at early stages and there this 10 criteria can help as well.

Some of the criteria mentioned above are treated in different literature, especially criterion 6, the part about a good working environment and criterion 9, the part about cleaning and cleaning ability. Finding these literatures, Linn (1997) and Linn (1999), were a confirmation that these criteria are very important.

4.3.2 BIM-tools for the facility management phase

During this thesis the desire for a certain BIM-tool to analyse how the building will perform in the facility management phase has grown. How this tool would work technically is outside the scope of this thesis but the purpose with the tool will be presented here.

Since it is very complicated to evaluate different options at an early stage in the conceptual design phase the BIM-tool could be a help, in the conceptual design phase, to compare different options by calculation a lifecycle cost so the designer can compare different alternatives from an economic point of view. Here the 10 criteria can show guidelines for areas the BIM-tool needs to consider. The BIM-tool would calculate the facility management cost and together with the initial cost the lifecycle cost. This application with lifecycle cost could also be used as the project progresses to be able to do intelligent choices.

Another application of the BIM-tool would be to perform a check, by for example running a macro, to see the real performance of the facility in the facility management phase. This macro would check if the requirements stated for the project are fulfilled and if they are not the BIM-tool will highlight the unfulfilled aspects for the designer. An example for this could be that a requirement from the facility manager is that the lamps at a higher ceiling height than 3,5 meters should be able to lower down or there should be possible to enter the room with a sky lift. Then the BIM-tool finds all lamp armatures and checks the ceiling heights to find those with a ceiling height higher than the stated. Then it will check if the lamp armature is possible to lower and if not the software will highlight the armature for the designer and ask why that is not able to lower or if it is possible to get a sky lift in the room.

Another thing the BIM-tool might ask the designer after a such a check can be if the designer has consider the option of choosing anther window if there is a window with a less lifecycle cost than the one proposed by the designer. This option might be more expansive as investment but if the lifecycle cost is less the option will be cheaper in the long run.

The BIM-tool should not only check the lamps and windows but all other things according to the criteria in the final result in section 4.3.1.

Example of other things that the BIM-tool possibly could highlight for the designer can be the choice of materials according to both service life and maintenance, the size of the facility managers premises, actions to reduce the energy and media consumption to find the most economical solution, if the evacuation routes are satisfactory, if all the areas are defined correctly etc.

To reduce the computer resources needed to run this macro and preform this check there should be different alternatives available to skip some of the 10 criteria or just to check 1 if that is desirable. With this function the BIM-tool will be more rational and user friendly for the designer.

The BIM-tool should also be able to categorise which actions to improve the facility management that are more and less economic beneficial for the owner so he or she gets a reliable help when choosing between different possible options.

The BIM-tool should not be a burden for the project leader and the designer but a great aid for the design process. It is important to emphasize that it might be difficult even for the facility manager to consider all aspects of the facility management and to do the best choices in all different cases concerning all 10 criteria, so the BIM-tool can be a help even for the facility manager that takes part in the design process.

It is also important to mention that these kinds of checks need to be performed many times throughout the design phase. If they are only used in the end of the design phase, when the designer thinks he or she is ready and only has to check the performance in the facility management phase, the result of the check won't have any big influence since it will be too late to make any big changes if that in needed. That is why the BIM-tool and the checklist with the 10 criteria, presented above, should be used along the whole planning and design phase.

During the whole research project, and especially when it comes to computer tools like BIM-tools, it has also been obvious that it is very important with reliable and transparent information throughout the building process. With reliable information it is meant that it is very important that all involved in a project can trust that the information available is correct otherwise the result of the different checks preformed will be unreliable.

It is also very important with transparent information. The meaning with transparent information is that the information is available for all actors in the building process, all the time, throughout the whole project. Than different actors can act on information someone else has created. Otherwise all actors have to create all information themselves. This is one of the key thoughts with BIM, to store all the information at one central place instead of each actor having their own storage of information as described in section 3.1. By this all actors will always have access to the latest information.

These two, together with a good communication, is the key factors that are needed for an improved building process and this is not possible to evaluate in a computer simulation. This is fundamental for the whole process. The communication is

important between all actors in the building process and if there is one single action that should be done to increase the facility managers' opportunities to get their desires fulfilled in the design process it is an increased communication between the designer and facility manager. This is covered in criterion 10 in the result above.

4.3.3 Economic benefits

As mention earlier, in section 3.3, the costs for the facility management are often very high in a lifecycle perspective and a great incentive for raising the issue about facility management is of course the economic benefits that the owner can gain of it. Since it has been outside the scope of this thesis to measure the economic benefits of a more rational facility management any exact numbers cannot be presented. But that it is possible for the owner to earn money in this area is a clear fact, as described in section 3.3. Below, in diagram 1, are two cases presented and how the cost will move from the facility management costs to the initial costs from the first to the second case but also how the lifecycle costs will decrease for the owner in case 2. The first three piles indicates a normal case without any extra consideration about facility management and lifecycle costs in the design phase and the other three piles shows a modified case where the facility management costs are decreased with 10% because of intelligent choices according to the facility management at the expense of 10% higher initial costs. But since the facility management costs are much higher the lifecycle cost will decrease in the second case. But as mention earlier, this is just a principle of how the lifecycle costs can be lowered and not any exact numbers of how much it will decrease.

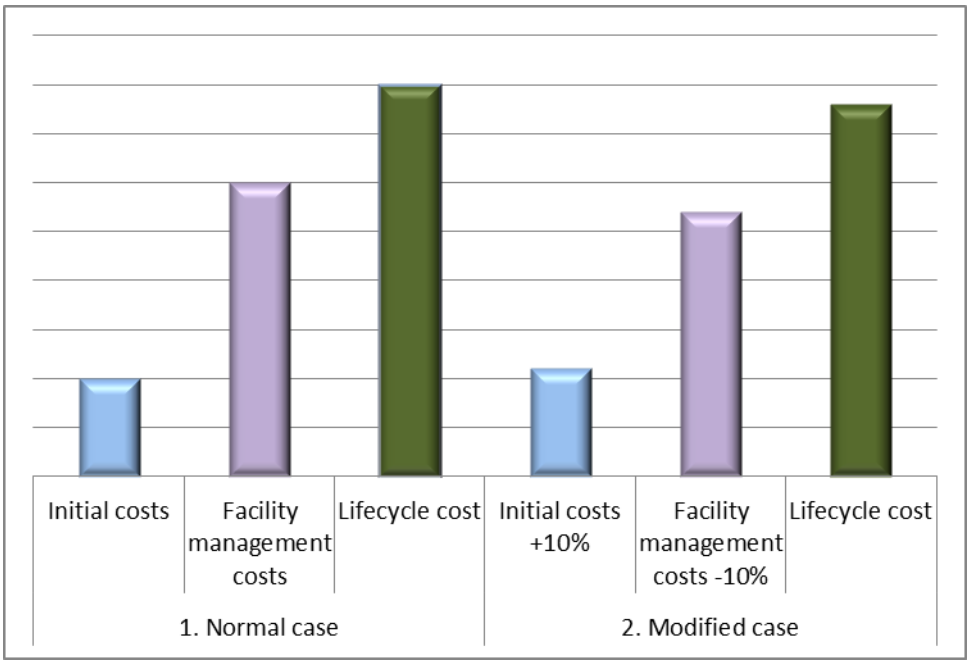

Diagram 1. Lifecycle cost for two different cases. One "normal case" and one "modified case" with lower facility management costs and higher initial costs but with a lower lifecycle cost. This is just a principle of how the lifecycle costs can be lowered and not any exact numbers of how much it will decrease.

From the diagram above it is obvious that the facility management costs influences the lifecycle costs more than the initial costs. To do a lifecycle analysis in the design phase can therefore be very valuable for the owner since it often is possible to lower the lifecycle cost of the building. And with this tool it will be possible to see how different choices will affect the result in the design phase.

The lifecycle analysis could also be used for evaluating different alternatives in a conceptual design phase if the lifecycle costs are important for the owner. So the lifecycle analysis can be used at several times throughout the design process.

When working with lifecycle analysis it is as well as with other BIM-tools very important that the information is correct and available for everyone. The different cost that will be summarised to the lifecycle cost must be based on experience and be applicable in each case.

This project has shown that different owners manage their facilities in different ways and that there is a different between how much the focus is at facility management in early stages of the building process. It is not possible to draw any general conclusions of which types of facility managers that take more and less consideration to the facility management in the planning and design phase due to the method chosen. It would have been possible if a quantitative method would have been used. The qualitative method rather gives result what aspects that are important to facility managers than the possibility to draw general conclusions between different kinds of facility managers. To be able to draw conclusions if there is any difference for example between public owned and private owned facility managers more both public and private owned facility managers would be needed to interview. But it is obvious that in some organisations the facility management are higher valued than in other. The general conclusion about this is that organisations where the facility managers and the responsible project leaders for the new projects are working close to each other there is a tendency that these organisations to a greater extent consider the facility management in the planning and design phase. Some explanations to this are that there is a greater “we-feeling” at the company/organisation and not a “we and them felling”. If there is a “we and them feeling” it is easy for the project leader to have the attitude like “that can they (the facility management) solve later”, “we have always done it like this and that is good” and “they haven’t said anything about this so it must be good”. If they are working closer together from the different departments this can be improved since the communication between the organisations will be improved.

Another hindrance for taking the facility management in consideration in an early stage of the building process is the limited budget. The project leader at the company/organisation often has one budget for the initial costs, shown in figure 6 above, but no economic incentives for lowering the facility management costs since that doesn’t affects the project leaders budget. This together with a “we and them felling” that decrease knowledge about what the other department really are doing and what they want decreases the possibility for the facility management to be a part of the planning and design process. So when different options are compared at early stages there is no reason for the project leader to choose anything else than the alternative with the cheapest initial costs, and this is nothing to blame the project leader for but more an organisational issue.

5 Conclusion

5.1 General conclusion

The aim for this master thesis was to present 10 criteria to help the designers in the design phase of a building to make the building perform better in the facility management phase. These 10 criteria are presented in table 3 in section 4.3.1 and they can be a great help, both for the designer and for the facility manager, that take place in the design process since the facility management of a building is a very complex activity.

These 10 criteria represent the requirements, desires and other comments from several interviews performed during the research process. All interviewees are somehow related to facility management. The research has shown that all studied companies and organisations to some extent work with facility management in early stages of the building process but it can differ a lot from one actor to another and all interviewees agree that it is of high importance that the facility management is considered early in the building process. The mention motives for this are both economical and with consideration to a good and safe working environment for the facility managers.

The result of this thesis shows that even if the building sector has improved the last decades by taking the facility management into account there are still potentials to improve this process and there are a lot of money to save in this area, both for private companies and for public owned organisations and by extension the whole society.

The part of the result with the 10 criteria that symbolise the potential for facility management can also be used as a checklist for the designers in the planning and design phase to ensure that the issue about facility management is raised at early stages in the building process. If the designer has these 10 criteria as an aid during the planning and design of a new facility the basis for a better performance in the facility management phase is greater.

Today there is no BIM-tool that can consider all the aspects of the 10 criteria presented above but such a tool would really be beneficial for the facility management since the facility most likely would perform better in the facility management phase.

The thesis has also showed that the extent of lifecycle analysis could preferably increase at early stages in the design process. The lifecycle analysis has 2 main uses; firstly to help the designer to choose between different concepts in the conceptual design phase and secondly to validate how changes at the chosen concept affects the lifecycle cost in order to find a rational and effective final option.

If one thing would be done as a first step to improve the facility management that would be to let the responsible for the facility management active is a part of the planning and design phase and for the designers to active listen to their opinions. By this action the communication would increase and a lot of the requirements from the other criteria could be solved automatically. Hopefully this will also help the designers to think more about the lifecycle perspective since this often is more significant to the facility manager than the designer.

5.2 Future studies

The result from this thesis leaves a lot of options for future studies some at a master thesis level and some at higher level. There would be very interesting to do case studies to follow up the cost from the pre-study in to the facility management. But since this runs over a long period of time that would be impossible to cover that in a master thesis and maybe even in a PhD-study. It would be possible though to take the 10 criteria presented in section 4.3.1 and study the planning and design phase to see if these issues are considered. That could be covered in a master thesis.

Another option is to really dig in to one or two criteria to find really good indicators and how this can be checked automatically in a BIM-tool.

Further studies can also cover how different company/organisations consider the facility management in early stages in the building process, to see if there is any differences between different companies and organisations, and which method that might be most beneficial for the owner.

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7 Appendixes

Appendix 1: Basic questions for the interviews

Appendix 2: Requirements, desires and comments from facility managers

Appendix 1, Basic questions for the interviews

What are a good/a bad facility management according to your opinion?

Do you think you have the right possibilities to perform a good facility management?

How could your costs be lowered by a better design phase? Would this lead to a lower lifecycle cost of the building?

Can you give some example of good solutions that makes your work easy and smooth?

Appendix 2, Requirements, desires and comments from facility managers

	Requirements, desires and comments from the facility managers	Criterion	Indicators	Unit	Extra explanation	Can 3D facilitate?	Is 3D a demand	Can BIM facilitate?	Is BIM a demand
1	Easy to change light bulbs	1	Ceiling height	m		Yes		Yes	
2	Easy to check fire alarms	1	Ceiling height	m		Yes		Yes	
3	Easy to change ventilation filters	1				Yes		Yes	
4	There shall be ladders to the attic	1	Integrated ladder in the hatch?	Yes/No				Yes	
5	There shall be prepared to make it easy to clean gutters, downpipes, roof tiles etc.	1			Roof ladders, roof doors etc				
6	Does the heating system require a lot of maintenance? e.g. Pellets do, but a hat exchanger or district heating doesn't	1	Hours of operation/week	Hours				Yes	
7	We have chosen low maintenance bushes and plants?	1	Hours of operation/week	Hours				Yes	
8	Important weed-free soil	1							
9	There shall be accessibility of all facades, so no closed courtyards without arrival of sky lift or small excavators.	1			Door widths, opening heights	Yes		Yes	
10	How do we know which materials that are hazardous is 10 years.	2		Yes/No	To be able to search for materials in a data base				Yes
11	Is the demolition considered? Can we re-use / recycle anything or does everything goes to landfill?	2		Yes/No				Yes	Yes
12	Where in our facilities do we have hazardous materials?	2			Article number etc.				
13	Where do we have e.g. this kind of pump? Or other technical apparatus	2	Article number and how many	Number of, m, m2, m3	Article number etc.			Yes	
14	Are all materials environmental friendly, even if that might be more expensive	2	Approved by e.g. "Sunda hus"	Yes/No				Yes	
15	Are the content of all materials attached?	2	Attached content?	Yes/No				Yes	

16	Good not having aluminium doors in the entrance to the stairway as they get skew easily	2	Choose of material	Yes/No				Yes	
17	Good to have the same light bulb in different light fixtures	2		Yes/No				Yes	
18	Use the same type of new washing machines that existing for the residents to know the new ones	2		Yes/No					
19	Have the same technical devices and systems that previously because then the operators don't not have to take new training	2		Yes/No					
20	Is it possible to change the lamp fixture itself?	2	Ceiling height	m		Yes		Yes	
21	Is it possible to change the ventilation units in the attic? Are the doors big enough?	2	Door width	m		Yes		Yes	
22	Not to build in key media supply systems impossible to inspect	2		Yes/No		Yes		Yes	
23	Important with sectioning of the median supply systems in order to troubleshoot in case of leakages and stop	2	m2 (or. m) /section	m		Yes		Yes	
24	Important with two service lines of electricity in order to ensure operation at power failure (for hospitals)	2	Number of electrical supplies	Number of					
25	Important to prepare for future big maintenance of the building, such as changing sewage and water pipes.	2	Easy changeable	Yes/No					
26	Are the quality good enough at technical apparatuses such as elevators etc.	2	LCC	SEK				Yes	
	Do we have strong enough elevators / floors to bring in new technical equipment when replacing old	5	Are the design loads attached?	kN/m2				Yes	
27	Do we have wide/high enough doors/openings to bring in new technical equipment when replacing old	2	Opening height/width	m				Yes	

28	How many m2 of e.g. roof tiles do we have? Facade? Ceiling, etc? Basis for price quotations and procurements	4	Are all areas correct described?	Yes/No				Yes	
29	Is evacuation in case of fire simulated?	3	Door and corridor widths	m				Yes	
30	Are the accessibility for disabled people simulated	3	Door and corridor widths	m				Yes	
31	Are all rooms and area right defined?	4	Are all areas correct described?	Yes/No		Yes		Yes	
32	Are all volumes right defined?	4	Are all volumes correct defined?	Yes/No		Yes		Yes	
33	Is the building flexible, i.e. can walls be moved if the need from the costumer is changed?	4		Yes/No	The super structure	Yes		Yes	
34	How much rentable space do we have?	4	Rentable area	m2		Yes		Yes	
35	Is it possible to load the slab with a sky lift in order to reach the ceiling, windows etc?	5	Are the design loads attached?	Yes/No	or kN/m2			Yes	
36	Will it be as safe workplace for the maintenance people?	6			Might be possible to check with the union				
37	Will it be a good working environment? Accessibility to coffee rooms? Do the locals have windows etc.?	6		Yes/No	Might be possible to check with the union	Yes		Yes	
38	Is it easy to sort and throw away garbage for residents?	6	Distance: Entrance - garbage room	m		Yes		Yes	
39	Is it easy for the garbage truck to collect garbage?	6	Distance: Street - garbage room	m		Yes		Yes	
40	Are the doors wide enough to get throw the "machinery" needed, e.g.. cleaning trolley, floor cleaning machine	6	Door width	m		Yes		Yes	
41	You should be able to move snow with a tractor not by hand, ex. not for the narrow sidewalks	6	Width of e.g. sidewalks	m		Yes		Yes	
42	Is the roof over the basement stairs so you do not have to shovel the snow by hand in these	6		Yes/No		Yes		Yes	

43	Is cleaning trolley and the cleaning utility room easily accessible from the ground floor or by elevator?	6		Yes/No		Yes		Yes	
44	Can we get in sweeper and tractor and other machines in the garage?	6	Opening height	m		Yes		Yes	
45	Is the good accessibility to and in operation rooms?	6		m2	m2 in the operation room	Yes		Yes	
46	Are the facility managements locals good placed geographically?	6		Yes/No	In order to receive material etc.	Yes		Yes	
47	Is there enough storage for utensils close to the needs? E.g. mowing, clearing flowerbeds, snow removal	6	Distance to closest storage	m		Yes		Yes	
48	Are all skills sitting close together? Good to minimize waste of time and increase communication and feedback	6,10	Number of office buildings	Number of		Yes		Yes	
49	Can we avoid the flat roofs with internal drainage and other risk constructions	7	Roof angle	°	Internal drainage Yes/No	Yes		Yes	
50	Is the roof permanent against sun-light and physical damages?	7	warranty time of the roof	Year				Yes	
51	How much energy will the building use?	8	Energy consumptions	kWh/m2/year					Yes
52	Have we optimized the ratio of heat consumption vs. insulation in a lifecycle perspective?	8	LCC	SEK					Yes
53	We have done a LCC calculation of the ventilation system?	8	LCC	SEK					Yes
54	Can we make LCA and LCC calculations to compare different options in the early stages?	8		Yes/No					Yes
55	Is that much glass in the facade "needed" or can we decrease that to reduce the U-value?	8	Energy consumptions	kWh/m2/year				Yes	
56	Are the materials in public spaces (such as stairwells) easy to clean? Not too dark, not too light and not too much friction	9			Cleaning ability				Yes

57	Dirt should not be drawn in to the building from the house. Important with at least 2 wiping zones	9	Number of wiping zones	Number of		Yes		Yes	
58	Are the toilets wall mounted in order to facilitate cleaning?	9	Wall mounted toilets?	Yes/No	Might not be important in residential buildings	Yes		Yes	
59	Important to have a floor drain in the garage.	9		Yes/No					
60	It is good accessed to clean windows? Can they open inwards into the stairwell? Do we have to use sky lifts?	9	Are all glass areas accessible?	Yes/No	e.g. opening windows	Yes		Yes	
61	Important to have areas to place the snow in winter time	9	How big area to place the snow	m2		Yes		Yes	
62	Important with good relation documents from all disciplines.	10	Are relation documents required?	Yes/No	from all disciplines				
63	Important that the activity knows what they get so they are satisfied and you do not need to rebuild the building at ones.	10			3D can help a lot	Yes		Yes	
64	May the facility manager be involved in determining things such window since they maintain the facility later on	10			Communication within the organisation			Yes	
65	If the facility manager can be known by the tenants this is experienced as good for the tenants	10			i.e. you recognize the facility manager				
66	Will the activities feel comfortable and as home in the buildings?	10			Also important with a "nice" house not only functionality				
67	Have we made demands for the facility management in the building documents? It is important to include the facility management in the way of thinking throughout the whole building process	10		Yes/No					

68	Are there communication routines between the facility management and the construction project management?	10		Yes/No					
69	Does the experience from existing projects come to use in the new projects? Are there routines for this?	10		Yes/No					