The flow of information in the building process: Implementing the field of fire protection in Building Information Modeling

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I PREFACE

The study of Building Construction and Architecture at the Norwegian University of Life Sciences (UMB) has given a broad understanding of the construction and planning of buildings. Through “Gründerskolen”, a summer program in venture and entrepreneurship, an interest for innovative thinking was aroused. This made the choice of a masterthesis within innovation and the introduction of Building Information Modeling to the building and construction industry, come natural.

Combining the background from UMB with the new knowledge I have gained through my experience at Multiconsult, has given me a understanding of traditional planning, and to see the benefits of introducing new technology and the Building Information Modeling-mentality into the conservative building and construction industry.

Through my work I have had the pleasure to meet great people who have guided me along the way. I would like to thank Thor Ørjan Holt, my mentor at Multiconsult, as well as Egil Kvamme, Lars Christian Christensen who has helped me with the Fire Safety issues and challenges concerning Building Information Modeling.

Åsmund Kveim Lie (Nosyko), Magnus Killingland (Multiconsult), Odd Goderstad (Graphisoft), Eilif Hjelseth and Thomas Thiis from UMB, has also been of great support.

Skøyen, May 2009

Cathrine Mørch

II PROBLEM DEFINITION

The papers' goal is to explore how using the Building Information Modeling (BIM)-technology can increase the efficiency of information flow ,and contribute to an improved implementation of fire protection considerations in the building process.

The assignment embraces the following elements:

- *Map the flow of information in the traditional building process*
- *Suggest a information model for the BIM building process*
- *Look at the opportunities and challenges in the information logistics between the architect, the engineer and the software by using BIM*
- *Develop IDMs for fire considerations in the early phase of the building process*
- *Show how model code checkers can, in principle, be utilized to check if different fire protection regulations are maintained in a building model*
- *Suggest how different software can replace the traditional fire concept given by the fire protection engineer*

III EXECUTIVE SUMMARY

The purpose of this paper is to evalute how the fire protection engineers' (FPE) work can be integrated when using Building Information Modeling (BIM) in the project-phase of a construction.

The building and construction industry is the world's largest industry with regards to revenues. Sources claim that 40% of the flaws detected after erection, can be traced back to poor communication in the planning of a construction. As the complexity of buildings increase, the need for a more streamlined information flow between stakeholders is clear. In the eyes of the industry, the introduction to BIM is step in the right direction. The strategic goal of one of the main builders in Norway, Statsbygg, is to utilize BIM in all projects by 2010. Benchmarking today's use of BIM in the Norwegian industry, this is a stretch target.

This paper gives a short overview of the traditional building process and a brief history behind, and potential of BIM, trying to establish a common platform for the two philosophies. It also details the work of the FPE in the building process, to see how their roles can better be incorporated in the before mentioned process. Today the importance of many disciplines are underlined using BIM, the role of the FPE is however, not one of these.

This paper is a case study based on Statsbygg's construction project for the University of Stavanger; a pioneer project utilizing BIM in all phases of the building's life-cycle. It focuses on how the role of the FPE was, and better could be, included by using BIM, based on the key learnings for other professions in this specific project.

The introduction to BIM involves a development of new software, which has to be implemented to get a full use of the potential of BIM. One of the big challenges for the FPE in the traditional building process is assuring that the fire concept is widely known through the whole building process. In BIM, all the information is stored in *one* model, making the fire concept more available to all phases of a project and the flow of information more seamless and efficient. Several applications that could be useful for the implementation of fire safety considerations in BIM, is suggested.

This paper focus on the process map of the FPEs' work and which possibilites and challenges implementing their work to BIM would bring. This initial test show that a far more extensive database of property sets and functional parts, as well as a standardized system to structure the information is needed to utilize the full potential of BIM. This paper concludes that the underlying data that exists today is insufficient, especially on the field of considering fire safety.

Interviews and tests has shown that the knowledge of BIM in the construction industry is low, making the stakeholders willing to comprehend this new technology is going to be one of the main challenges in the future. Restrictions regarding the technology must be fixed and the level of competence has to be raised before BIM can be used as a adequate tool in the planning, execution and management of a building.

IV TABLE OF CONTENT

1 INTRODUCTION

During a building process the load of information gets more and more comprehensive as the project evolves. New rules and regulations make it more important than ever before that the information reaches the right receiver. This, simultaneously with the fact that the building industry is costly with many flaws and a high potential of innovation and efficiency improvements, makes the introduction to Building Information Modeling (BIM) highly suitable. The case in this paper is based on Norwegian standards, but all principles are adaptable to any other location.

The building and construction industry has a 50 billion US dollar turnover in Norway, of which 5% is spent to improve flaws and defects in buildings. The working-hours spent on doing this was, in 2001, estimated to be 1, 7 billion. (Ingvaldsen, 2001). According to Jøns Sjøgren, the same information is produced 7 times in the traditional way of projecting. (Sjøgren, 2009).He also indicates that 20%-30% of costs in a building process is related to poor communication and divided processes among the involved parts. Eilif Hjelseth supplements Sjøgrens view on the building process, with his statement on how 40% of all building flaws can be traced back to the planning of the building. (Hjelseth, 2009). All these declarations trigger the desire for new innovative thinking and technology.

A large share of the high expenses related to the industry is due to limited flow of information between stakeholders involved in the project. The gap, between those who still utilize paper and pen to the engineers considered to be in forefront technologically, is big. Different formats, software and tradition of communication makes the exchange of information inefficient between stakeholders, and in some cases non-existing. (Skjelstad, 2009).

By improving the interaction between the parts in the project through using the concept of BIM, with the open IFC-standard based on the mentality of interoperability among the various software utilized, the costs and flaws seen in the industry have a potential of being reduced considerably. (Jøns Sjøgren, 2009). The IFC-standard makes it possible to gather all the information in *one* model, making it more convenient to get access to information needed whenever wanted.

Norways biggest builder, Statsbygg, astounded a whole industry when they in a press release announced that BIM would be their main way of planning from 2010;

”Statsbygg plans to use digital Building Information Models based on open international standards. Statsbygg has as a goal to use BIM through the whole life-cycle of their buildings. In 2007 at least 5 project should be accomplished with the utilization of BIM. By 2010 BIM should be used as the main principle in all of Statsbyggs’ buildings and projects.” [1] (Statsbygg, 2007) (Author translation.)

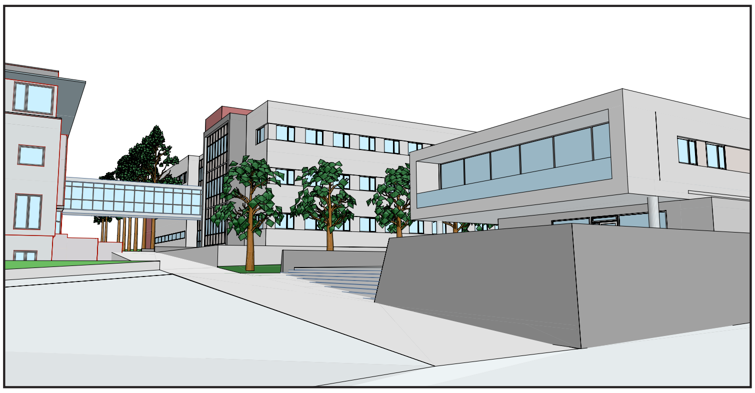


Figure 1 - *The University of Stavanger.*
Illustration from Multiconsult

It is critical for the building process to have a clear evaluation of the challenges and possibilities related to the introduction of BIM. By looking at what obstacles one can encounter between the Fire Protection Engineer (FPE) and the architect in a project, this paper clarifies the roles and responsibilities that follows the fire protection considerations in a building process. The improvement potential of using BIM is huge, and by looking at how fire protection considerations can be implemented in BIM, this paper can be a step towards an improved and more efficient building process.

Multiconsult recently won a competitive tendering launched by Statsbygg, including the planning of two buildings belonging to the University of Stavanger (Figure 1). Statsbygg demanded a use of BIM in the projection and the product, making this project historic in a Norwegian point of view. Multiconsult is one of the leading Norwegian companies regarding BIM, and they expressed recently that BIM is one of their three priority areas in 2009. (Multiconsult, 2009.)

1. “ *Statsbygg satser på bruk av digitale bygningsinformasjonsmodeller (BIM) basert på åpne internasjonale standarder. Statsbygg har som mål å benytte BIM i hele livsløpet av sine bygg. I 2007 skal minst fem prosjekter bruke BIM. I løpet av 2010 skal BIM benyttes som hovedregel i alle Statsbyggs bygg og byggeprosesser*.” (Norwegian quotation.)

1.1 Limitation

To be able to get to the dept of how BIM can make the information from the FPE more available in the building process, a limitation of the paper was necessary.

The premises from the FPE is delivered in the preproject of a building process, which makes this phase most interesting regarding the goal of the paper. Before the preproject, there are no fire considerations to consider beyond the framework conditions such as the regulations given by the governmentn such as The Planning and Building Act (PBL) and the Technical Regulations under the Planning and Building (TEK).

To get a better insight in how the information flow is, regarding the fire documentation of a building, there are in the analysis been done a evaluation of the traditional building process compared to BIM, in the preproject of a buidling process.

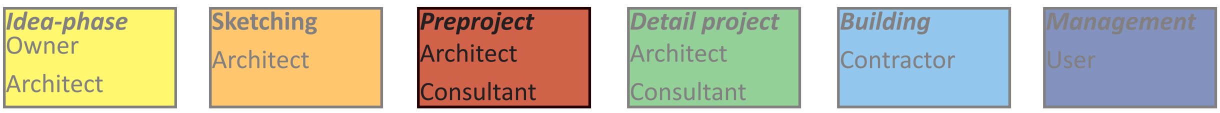


Figure 2 - *The different phases of a building process*

1.2 Method

As the BIM mentality and technology was new to the undersigned, I have had to use some time to get into the terminology and the theory of BIM. To get a synopsis of BIM, I have done a massive search of literature and attended a workshop, arranged by BuildingSMART and different actors in the Norwegian building and construction industry.

Regarding the fire protection considerations in building projects, the information has been available through interviewing relevant people in Multiconsult, Link-Signatur and the Acency for Planning and Building Services (PBE) in Oslo. Through a cooperation with Graphisoft and Nosyko, I got the help I needed regarding the IFC-software I have discussed in the paper. Åsmund Kveim Lie gave me a quick introduction to dRofus, and its possibilities regarding fire protection considerations.

To be able to link my results to a real project, Multiconsult have been helpful to let me sequence the projection meetings in the project; University of Stavanger (UIS). This project has been a case study, where I have emphasized the fire protection considerations in the planning of the project.

2 THE BUILDING PROCESS

The building process is a wide concept. It includes all process' from the idea of a construction to the building is executed. Today the construction industry is standing in front of a possible revolution. The introduction to the BIM mindset and technology is creating a upheaval. (Mohn, 2009).

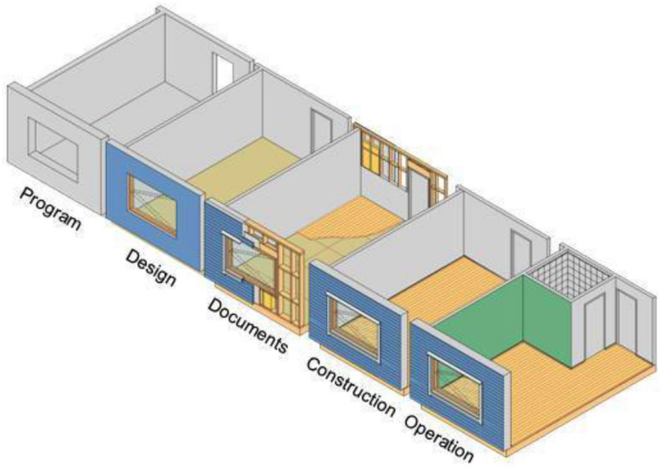


Figure 3 - *Gradually growing information through the building process (IAI 2008.)*

In the traditional building process, the phases that one would have to go through are clearly defined. This benefits some fields, while others has a big potential regarding its efficiency. The biggest challenge in a projection is the logistics and maintenance of information generated in the process (Figure 3). In the next chapter these process' are further looked at.

By developing BIM, the industry has tried to change the traditionally conservative mindset. On the webpage of BuildingSMART they announce that:

"*The use of this standard method is reducing costs, delivery time and environmental impact as well as improving communication, productivity and quality. It enables the building industry to take more and better decisions earlier in the life cycle of a built facility.*" (BuildingSMART, 2008)

BIM is more explicitly described in chapter 2.2.

2.1 THE TRADITIONAL BUILDING PROCESS

2.1.1 THE STRUCTURE

The building process can be described as the life-cycle of a building. This life-cycle holds all the process' that leads us to or are a presumption to complete a project. (Eikeland, 1998). The figure (4) shows how the life-cycle can be represented as a linear process with sequential activities. In the reality the building process is much more complicated. Due to technological developments, changes in the legislations and a constant focus on business improvements, the procedures in the building industry vary from enterprise to enterprise and place to place.

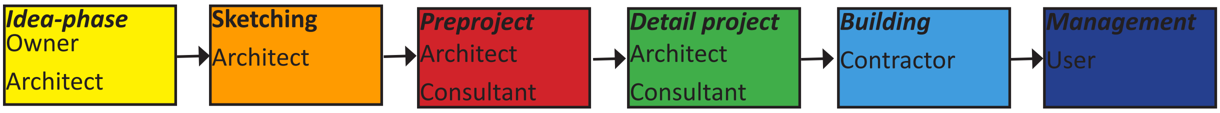


Figure 4 - *The traditional building process*

With "sequential acitivites" it is implicit given that when one phase is passed, it is difficult to go back and change what is already appointed. A process like this does not exploit the full potential of what opportunities new technology has to offer. With new technology one can perform "loops" in the process, which makes the flow of information better between the phases and stakeholders involved. (Figure 5) An example is while the project is developing, in the preproject, it would be desirable to look up previous, relevant information and considerations that has led the consultant to a specific solution. (Haugen, N.D.)

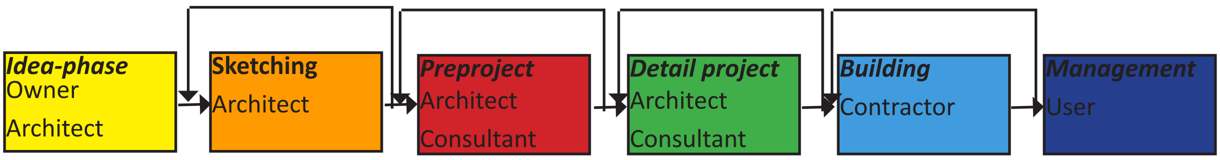


Figure 5 - *Loops in the building process*

There is no precise way of completing a building process, but there are some procedures that are more efficient than others. (Haugen, N.D). However the traditional way of organizing the production of a building, with the terminated phases, tasks and participators is slowly fading away as the industry is changing into using new enterprises and becoming more flexible regarding the utilization of new technology. Regardless of which process is chosen, the shared goal for the whole industry is to "*produce good quality buildings and constructions, architectural, functional, technical, environmental and operational - within agreed time and costs*",[1] as Tore I. Haugen describes the building process in his note on "The Building Process - challenges in a changing environment"[2].

In the first phase of a project, which is part of the programming. The involved parts in the planning get together to analyze and identify the needs and possibilities of what is wanted built. In this phase the owner has the opportunity to specify what requirements he has, and express his goals and visions for the building. This phase defines the future problems, and all the information that has any consequence for the future projection should be detected and considered. This leads to a gradually growing knowledge in the project, and generates a more reliable foundation for decision making. This is a knowledge that is shared by Jeffrey Wixs understanding of how the BIM mindset is. The level of knowledge increases as more information is put into the project. (Wix, unknown). The process of how the information is generated and communicated is shown in figure 6.

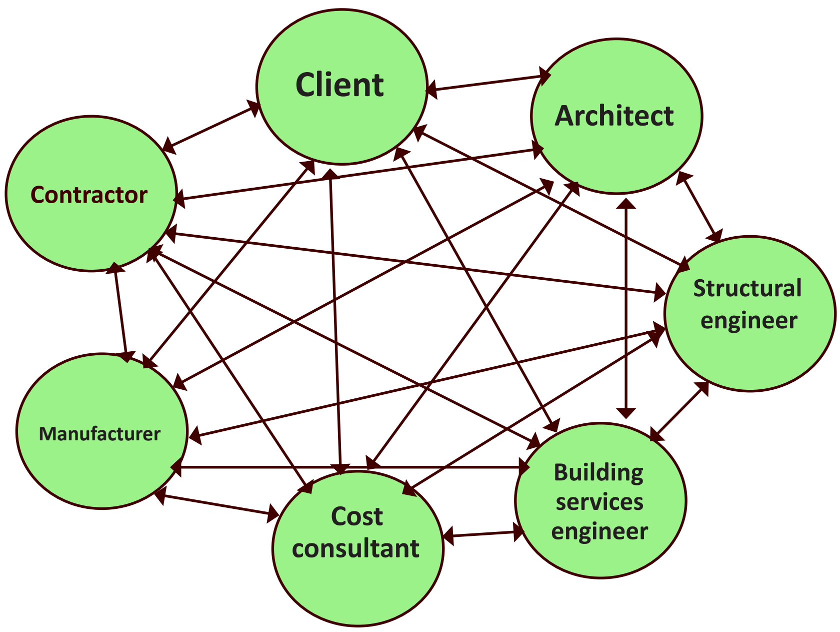


Figure 6 - "*Tangled web of communication*" (Europa INNOVA)

1. "Produsere bygninger av god arketektonisk, funksjonell, teknisk, miljø og operativ kvalitet - innen avtalt tid og kostnad."
2. "Byggeprosessen - utfordringer i omgivelser i endring."

The product from the programming is a draft of what is desired from the owner. This draft is often referred to as the “Building Program”. The draft is a review of what is desired, this includes a plan for the needs and possibilities for the building and all other relevant information from the parties involved. (Byggforsk, 1999). Making the building program the basis for the physical object, designed by the architect.

In the sketching-phase, the physical solutions for the project is defined, based on the specification of requirement that are generated in the parallel programming-phase. This means that the design is already set by the architect and the builder by the time the engineer gets it, which leaves the engineers with a limited possibility to makes changes regarding the design. (Skjelstad, 2009). This missing interaction and cooperation between stakeholders often leads to inefficient and costly buildings, as the constructions, energy consumptions and regards due to fire protection is not considered in a sufficient extent by the architect, before the design is finished.

When the engineers finds the design difficult to accomplish, due to structural problems or on other fields, the design have to be reviewed and changed by the architect. This is cannot be looked upon as a “loop” in the process, but rather that the process would have to start over again. This significates that the architect have to change his design based on the feedback he gets from the engineers, and then sends the “new” design to the engineers back and forth until the design is of a sufficient level from a structural/fire safety etc. point of view. The process is based on iterations.

When the engineers start adding their knowledge based on the architects model, the project is in the “preproject”-phase. The engineers receive a sketch of the design from the architect, and then have to add “their” technological expertise into the project. The engineers adjust the information from the architects model into their specific tools and software, to the differences that are made during the entire projection.

At the end of this phase an estimation of the costs of investments and life-cycle should be presented and the details of the project can be planned. The design gets edited and specified. It is now becoming so accurate that the risk of misconceptions should be as little as possible when the drawings reach the building site. This drawing material is also the basis for a competitive tendering, which will determine the choice of contractor being used in the project.

After the building has been built it is ready to be handed over to the owner. The defects and flaws that are detected should be aligned. After the building is handed over, it reaches its last phase of the life-cycle, where it is in its natural state. The formal acquisition usually happens after the contractor has had the responsibility of the facility management of the building, for a period of time, depending on the size of the project, contract among other things.

2.1.2 The participants

The building process involves different stakeholders and they all have their own, particular task during the process. Although they have different interests, they all work in a joint, structured system, with a common intention or goal. (Eikeland, 2001). These participants can be a person, a group of people or in some cases a whole firm. This all depends on what level of details you are at. All the different parties of a project organization are given different tasks and responsibilities, and when the project is at an end, the particular project organization fades out. This is why the organization of a building process is often refered to as temporary. (Eikeland, 2001).

In the earliest phases, it is the builder, the designing team and the parts that are in the projecting that are involved. The parts that are involved in this phase of the project is responsible for describing and the development of the project, and in that way giving a foundation to the process of producing. This is how Anita Moum emphasizes it in her article about ICT and the architectural design process: "*A fundamental pillar of a successful building project is a good design process*." (Moum, 2006.)

Anita Moum (Architect) describes the process of designing as a hierarchy with three different levels.

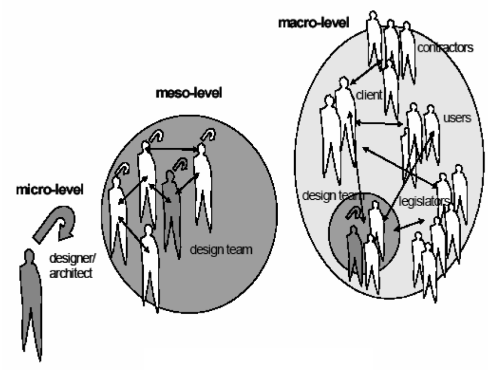


Figure 7 - *The architectural design process (Moum A.)*

The Micro-level: Focuses on the designers own ideas. In a building process, this would be when the architect has to decide which idea he wants to proceed with.
The Meso-level: describes the interaction within the group. As Moum mentions as "*The Design Managemen*t". Which is the collaboration of design and evaluation of the different visions of the building. What should the concept look like?
The Macro-level: the superior level of the projecting, which includes all the stakeholders, manufacturer etc. At this level they determine which concept they should develop further.

The Architect

Usually the architect is involved early in the building process. Before the process of designing starts, the architect has to map the needs and cost limit for the projection. (Lyngtveit, 2008). At this point the projection is in the "idea-phase" of the building process. But as soon as the architect get an overview of what function, design and space requirements the building has, the ideas starts appearing, these ideas get analyzed and sketched. As the projection gets more definite the sketches evolves into real drawings.

“Abstract models (physical models, drawings, 3D-renderings etc.) allow the designer great manipulative and immediately investigative freedom without incurring time or costs, which would have been the fact if the ideas had to be tested directly at the building site.”
(Moum, 2006).

The Engineer

As an overall duty the engineers are responsible for that the building endures the strain it will be exposed to. This is ensured through instructions, experiences, calculations, analyses and simulations. The workload for the engineer depends on the complexity of the building, and the need for information is related to what analysis is required for the specific building. The foundation for what result the engineers get, is the drawings from the architect. The engineer always has to follow the existing standards in their field of expertise.

The interaction between the Architect and the Engineer

When we look at the interaction between the architect and the engineer we are at the “macro-level” as Moum describes (Figure 7). During building meetings in the projection, the architect and engineers have to front challenges connected to changes in design and revision of structural matter amongst other things. Because of this continuous process, the interaction between them is based on iterations. (Baggetorp, 2007.)

One of the main challenges the interaction between the architect and the engineer are facing today is a shortage of time in the projection, this due to the desire of building low price buildings at a high rate. This can lead to a of focus on their own profession and not the interaction between them (Baggetorp, 2007). Making the understanding of each other weaker, which could bring along conflicts and misunderstandings.

2.1.3 *INTERACTION*

How the interaction is between the different parts of a building process can determine how good the flow of information is. There are many involved and the needs and interests varies depending on which phase the project is in. The information can be exchanged in a group of architects, between the architect and engineer and to other parts as the owner, the developer, the public body etc. (Baggetorp, 2007).

During the building process new information is continous produced and gathered, this information makes the basis for decisions that are made later on in the process. In the beginning of the projection the wishes and demands from the developer are the source of information. This combined with the regulations and requirements from the government, makes the starting point of a building project. Different standards, like the Norwegian Standard (NS) and international standards will also be sources of information that will have an influence on the project.

A fundamental part of the FPEs work will be to determine the fire class of the building, to get this he will need to know what kind of activity the building is made for and how many floors it will have. This is information the FPE gets from the architect, and is only one of the basic considerations the FPE does, as the fire safety in buildings is a complex field with many public regulations to take into account. (Kvamme, 2009)

It is not only regulations and standards that form the basis of information. Another important source of information is earlier experiences. (Kvamme, 2009) This information is easily available and can be adapted to new projects. Making decisions based on experience could be problematic regarding the exchange of information later on in the building process. As experience is a parameter that often is left out from the documentation, making it a “hole” in the decision-foundation (Ulfsnes and Danielsen, 2009).

The important is that the work of the FPE gets communicated to the architect, so he implement the fire safety considerations into the design, as early as possible in the projection. By implementing the premises from the FPE, and other premise providers, early in the project, the chance of getting a more optimized building without having to make costly changes in the design, is bigger. Figur 8 shows the connection between the investment costs and the possibility to influence the design during the building process.

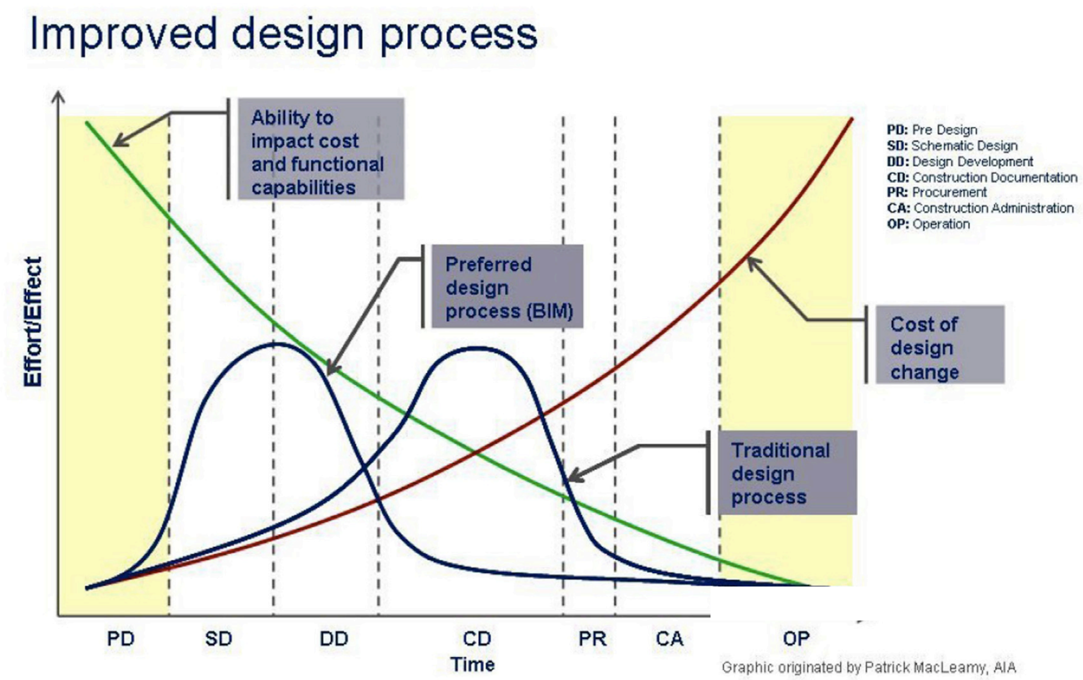


Figure 8 - *The relation between costs and changes in the design through the building process (Patrick MacLeamy, AIA)*

To be able to transfer relevant information to other parts of the projection, information flow is the key word. By utilizing ICT in the building process, the information flow have the opportunity to be more seamless than it traditional has been. (Sjøgren, 2009.)

There have been several attempts to make a joint format which would simplify the exchange of information through ICT. With different applications, the transmission of information has not been how the industry had hoped. The format-problem is one of the reasons that the same information has to be generated over and over again.

In many building projects the distribution of who is responsible for the fire protection abeam professions and phases is diffuse. In these cases the communication and flow of information could be poor, and in some cases the distribution of responsibility is problematic. (Ulfsnes and Danielsen, 2004).

A presumption for a good documentation abeam professions, is that all the involved parts are familiar with the fire safety concept (figure 9) for the specific projection.

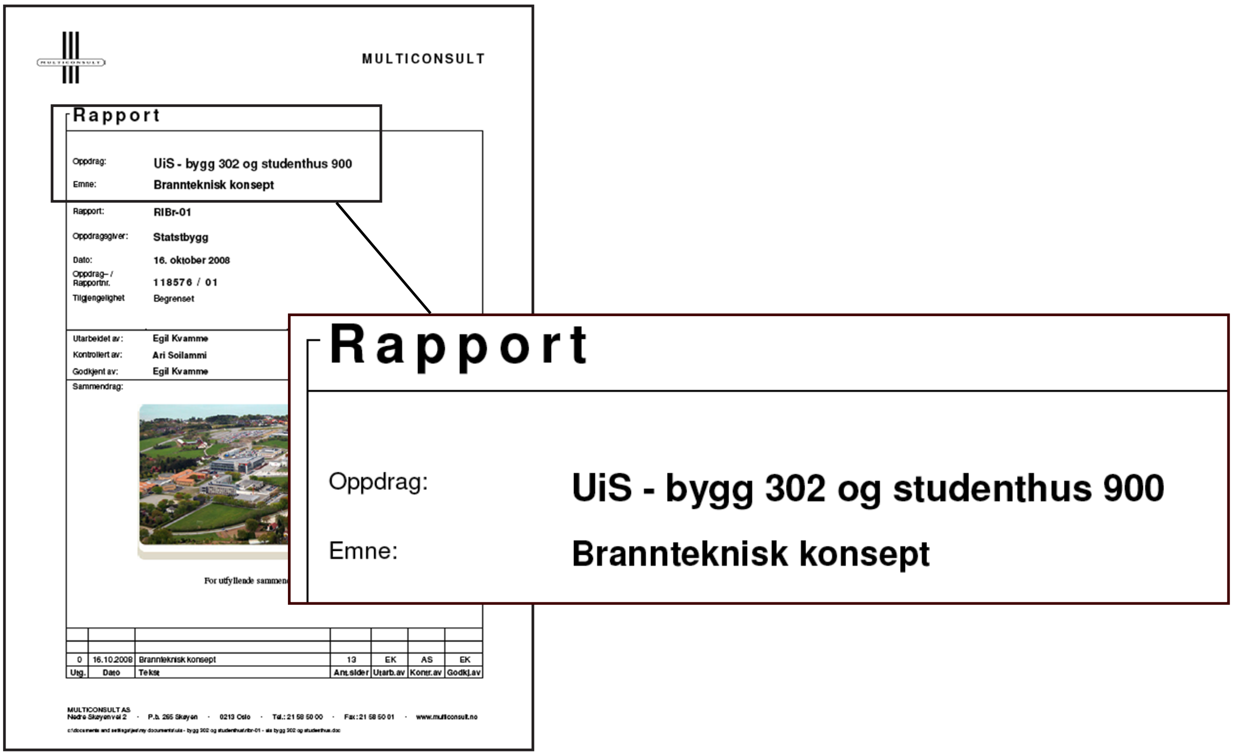


Figure 9 - *Fire concept (Egil Kvamme, Multiconsult.)*

2.1.4 *Quality control*

Before, the local authority was obliged to control all buildings. A change in the regulations in 1986 reduced the compulsory control in to a "entitlement to control" for the authorities. (PBL § 97). The responsible for the control is now those with responsibility for specific fields of a planning. Every field should compose a plan for accomplishing a control for the fields they are responsible for, a "control plan". Stakeholders with responsibility in a planning is now responsible for that the planning and execution, of their field, is performed correctly, and that it exists a trackable control of that the planning is done proper.

This control plan ensures that the regulations and demands from the authorities is obtained, and should be used as a steering document for the whole control of the building. (Jacobsen, 1997.) The control plans should ensure that the details that are controlled at the commissioning of the building, can be tracked back, through the planning documents and to the terms for the building authorization.

The local authorities are obliged to see that the construction work is controlled. Their responsibility is to control that the control plans of the project are done properly, and that they are followed and used through the building process. By assuring that some critical control points are included in the control plan, the building authorities makes sure that the stakeholders performs a sufficient control of their field of action. (Ulfsnes and Danielsen, 2004).

The control can be divided into two principles:

1. *Documented self-control*

2. *Independent control*

The responsible applicant should supervise the control during the building process, he should make sure that the control plan is followed and used as a control of the quality of the work. Like the responsible applicant, the responsible executing should ensure that control plans of their special fields are made and being followed.

The authorities are obliged to supervise that the implementation of the control plans are done sufficiently, and that they have the possibility to demand an independent control if the control plan not is followed correctly. As these plans are, normally, the only interest and responsibility the local authorities have in a building process, their importance is not be underestimated. (Jacobsen, 1997).

2.2 Building Information Modeling (BIM)

2.2.1 The BIM concept

Building Information Modeling (BIM) is a "digital 1:1 modeling" of a building (Statsbygg, 2008). BIM is a two-sided concept which can be used in relation to the "product"; the Building Information Model and the "process"; Building Information Modeling.

Building

Information

Modeling

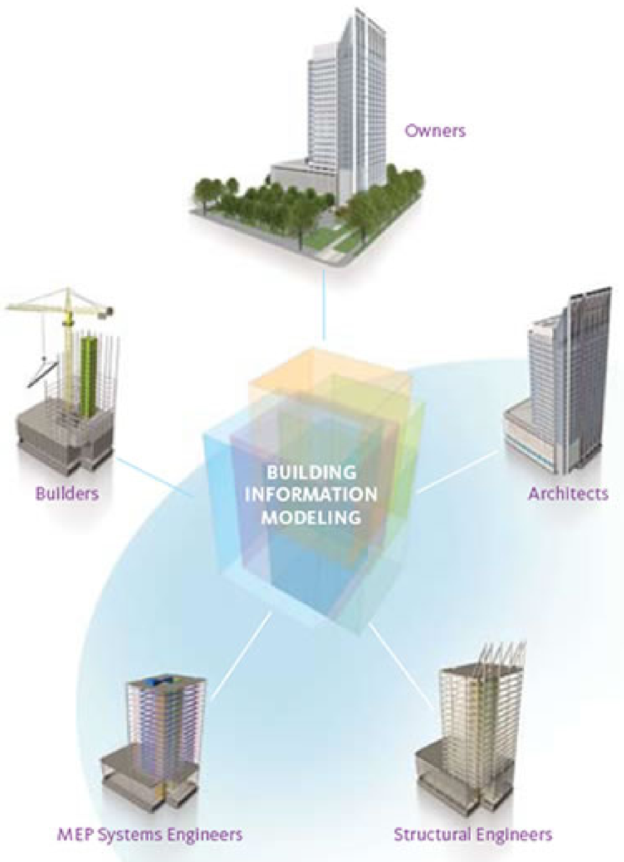


Figure 10 - *The BIM gets enriched as the project evolves (Microsol resources.)*

The I (Information) and the M (Modeling) are to two most important contents in the acronym BIM. The buildings and other constructions, that we want to model are created by putting together objects (e.g. a door, IfcDoor), which can be assigned characteristics (e.g. fire classification EI-60) and have relations between themselves (e.g. this fire door belongs to the wall ABC123 which defines the room A321). When modeling the most important is what information we are talking about (e.g. this is a fire door with the fire classification EI-60), and not how the door visually looks like with lines and symbols on a 2D-drawing.

As the stakeholders adds their knowledge to the BIM, the model gets enriched as figure (10) shows. From the model one can get 2D-drawings, 3D-visualization, 4D- progress, 5D-expenses/progress, 0D-quantitylists and so on.

Before the BIM concept can be fully implemented there are three major elements that have to be in order, often related to as the BIM triangle (Figure 11):

*1.**An open international standard***
(IFC-Industry Foundation Classes – ISO/PAS 16739)
*2.**Consesus on the terminology used***
(IFD- International Framework for Dictionaries – ISO12006-3)
*3.**Connect the BIM to the relevant processes***
(IDM-Information Delivery Manual – ISO/DIS 29481-1)

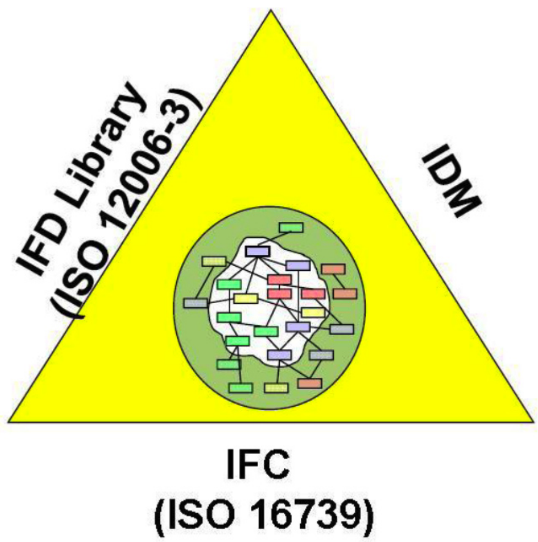


Figure 11 - *The BIM triangle (Sjøgren.)*

2.2.2 The working method

The use of BIM as the method of work is a big step in the development from 2D-drawings. In the previous chapter the BIM concept was described, and we will now take a closer look on how the mindset of BIM is. Figure 12 shows the principle drawing of BIM. The joint model consists of different models from the various professions involved in the building process. By using these models, simulations can be done, drawings can be generated and visualizations can be produced. (Europe INNOVA,2008)

The profession models melted together, makes the joint model, and it is on this model the real benefits are realized. The joint model holds the necessary information from all the different professions (figure 12), and functions as a reserve of information that is enriched meanwhile the building process proceeds. (BuildingSMART, 2008).

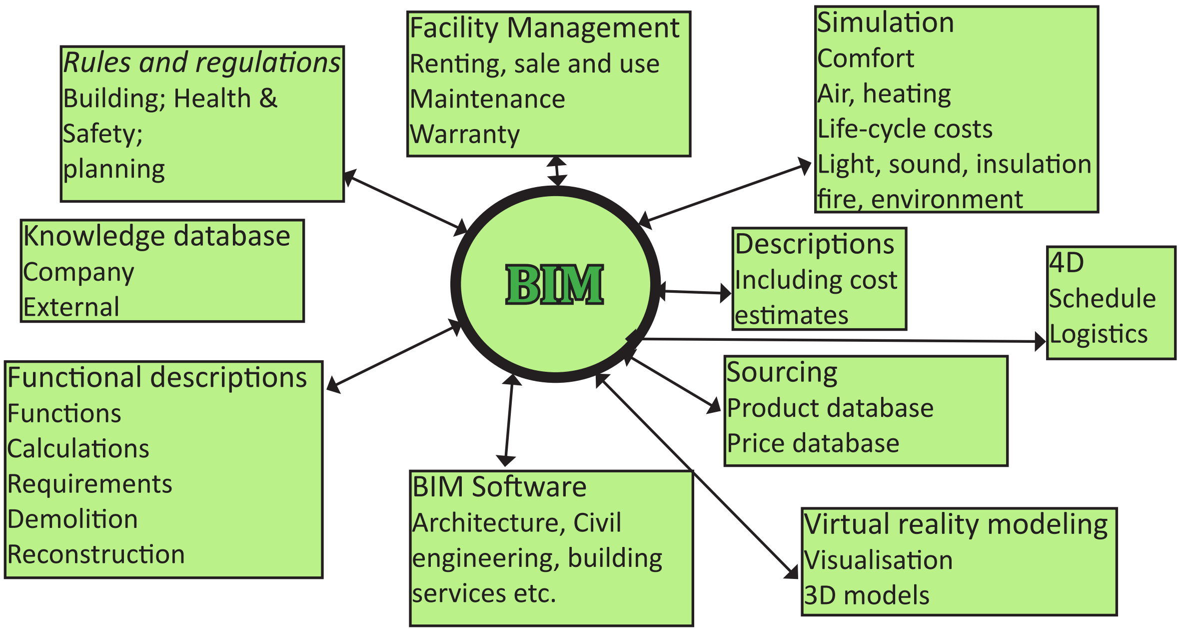


Figure 12 - *A fully functional building information mode*l (Europa INNOVA.)

To avoid complications and clashes between the different fields, one can check the model for collisions. The purpose of doing this is to discover conflicts between components or if objects are placed “on top” of each other in the model. This can easily happen during the modeling and can be hard to detect with a 2D- paper visualisation. Errors like these are important to discover, as they could have a big influence on simulations regarding statics, energy consumptions or a fire analysis. In these controls one can also check if the objects are lacking relations to other objects, e.g. if a beam is “flying”. Chapter 6.2.3 discuss more about how Model Code Checkers (MCC) can be used to control conflicts and flaws in a model, regarding the fire safety aspects and other aspects of a building.

The Europe INNOVA initiative has listed these aspects as the main benefits of using BIM ;

Seamless communication: using a common IT language, project information is shared among projects practitioners and I automatically updated – accuracy and quality are improved.

Visualization: striking walkthrough visualizations help the client understand the design and improve the decision-making.

Automatic rule checking: the proposed project can be checked against local building rules and regulations.

Energy efficiency: energy analysis can be swiftly conducted on the model and design changes incorporated without difficulty.

Cost calculations: analysis of costs keeps the project budget under control.

Clash detection: clashes and errors are discovered early on, not during construction.

Operational efficiency: once the project is completed, the BIM is handed over to the operator who can use it to manage the facility.

Easier decision-making for refurbishment or demolition: the BIM shows what materials were used and the details of the structure, so that responsible cost-effective decisions can be made.

Seamless communication and **Automatic rule checking** would be the two point most relevant to this paper and to the FPE.

By adding 4D to BIM, we are introduced to another form of simulation. The definition of 4D is 3D+the time aspect of a building project. 4D is used to visualize the progress in the project. By connecting the model to a time plan one can get another dimension, 4D. (Europe INNOVA, 2008).

The use of 4D gives a better coordination at the construction site, and makes the interaction between the different professions such as the architect, contractor and engineer better. With a complete 4D model, the logistics at the construction site will be of a better control, and this is something the contractor can take advantage of. It also allows the construction process to be analyzed virtually.

BIM also introduces the construction industry to the term of 5D, which includes the costing facility of BIM. The 5D aspect of the BIM combines the 4D progress with costs, which leads us to the next big advantage of BIM. Production of quantity lists. (Europe INNOVA, 2008)

The possibilities regarding the production of quantity lists are big. As the objects are realistic and connected to an existing database, the costs and quantity of the materials used, will be available directly. The visualization will be realistic and if there is any need for change, it is possible to do without having to start modeling all over. Changing one object will lead to an automatically update of the object-database. The communication and coordination between the professions will profit by the new mindset, and reduce the number of times the same information is produced in a project, as it is already available in the model. (Sjøgren, 2009).

The structural engineer is one of profession who will benefit from having one model, as this eases the work of finding the other professions influence on the structure. The potential of performing simulations, is as mentioned earlier, big with using the BIM mindset. (Det Digitale Byggeri, 2006) This will also benefit the FPE, making it easier to control if the premises are withhold without having to check each 2D-drawing.

In the article "*Barrier against Building Information Modeling*" [1] (Author Translation) by Marit Støre Valen, some disadvantages with the use of BIM is presented. One of the challenges will be the lack of expertise. This will also come in sight when trying to implement this mindset to the conservative industry. Another challenge will be the distribution of ownership to the models, who owns what at what time? This will also be important concerning the distribution of responsibility in the project. Some points out that there will be necessary to introduce new contract with the implementation of BIM. (Statsbygg, 2008). Challenges regarding the introduction to BIM is further looked at in the "discussion" of this paper.

2.2.3 The structure

As mentioned in the chapter describing the traditional building process, this way of building does not support the option to go back in the different phases in a project. This is one of the things that the introduction to BIM has the possibility to change. By using the opportunities that are available in the BIM technology the loops can be performed more seamless, without interferring with uninvolved fields. The process map of BIM, that visualizes the possibility to go back in the phases is shown in figure 5.

By the use of BIM, one has the possibility to consider different solutions several times and to do adjustments in the model before making a decision. By introducing this opportunity the traditional building process, with the sequential phases, is over.

1. "Barrierer mot bruk av bygningsinformasjonsmodeller"

With the development of BIM, the planning- and building process will be compressed into three main phases.

1. *What is being built?*
2. *How should it be built?*
3. *Execution*

In the first phase the building is defined. By the use of advanced software within each profession, it is possible to expand the programming to analysis of the construction, consumption of energy, fire simulations and life-cycle costs etc. All this information can be drawn from *one* information model. This phase is where the FPE delivers his concept. As this is a premise for the project, it is important that it is delivered as early on in the project as possible.

By having *one* joint model, the different parts of the project can get a clear view of the building, which makes the basis for decisions more reliable. BIM is not only a good tool for the professions in a project, but also for the builder and the future users of the building, who can, at an early stage be involved to make the building as optimized as possible.

The next phase is where the project-group decides how the building should be built. The considerations of drawings to estimate the cost of products, is replaced with a virtual building process. Changes of components and adjustments of design and systems, are added to the model, and the virtual building process is continually updated. The 4D- technique makes it possible to plan the building process and illuminate challenges. From the information in the BIM, the construction- and detail- drawings can be generated.

In the phase of the execution, the information gathered in the BIM, is easy available. This information will only be as precise as the information stored in the previous phases. Making the accuracy of what is added to the model important.

The project supervisor distributes the information when needed. All the information is exchange through the BIM, and the project supervisors' role is to coordinate the information exchange between the consultants, architect and the builder.

To get a model with information to function is a challenge. One will have to decompose the traditional way of working, and develop new ways to process data and make different software compatible. This system is today available, but still under development, and new areas of application will be implemented in the years to come. (Hjelseth, 2009.)In the next chapters the process map of BIM is discussed.

2.2.4 Information Delivery Manual (IDM)

By improving the quality of the information and the communication between the different parts of the construction process, BIM can be an improvement in the industry. By making the information available when it is needed and assuring that it is of a satisfactory quality, the traditional building process itself is already improved. For this to happen the industry has to have a common understanding of the processes and what information is relevant - when.

According to BuildingSMART the key tool to benefit from the potential in BIM is to integrate to information with the process. (IAI, 2008.) The Information Delievery Manual (IDM) objective is to provide the reference for process and data required, by defining the processes and the information needed for their execution and the results of that activity. Figure 13 shows the IDMS structure.

The IDM will clearify (BuildingSMART):

- where a process fits and why it is relevant
- who the actors creating, consuming and benefitting from the information are
- what information is created and consumed
- how the information should be supported by software solutions

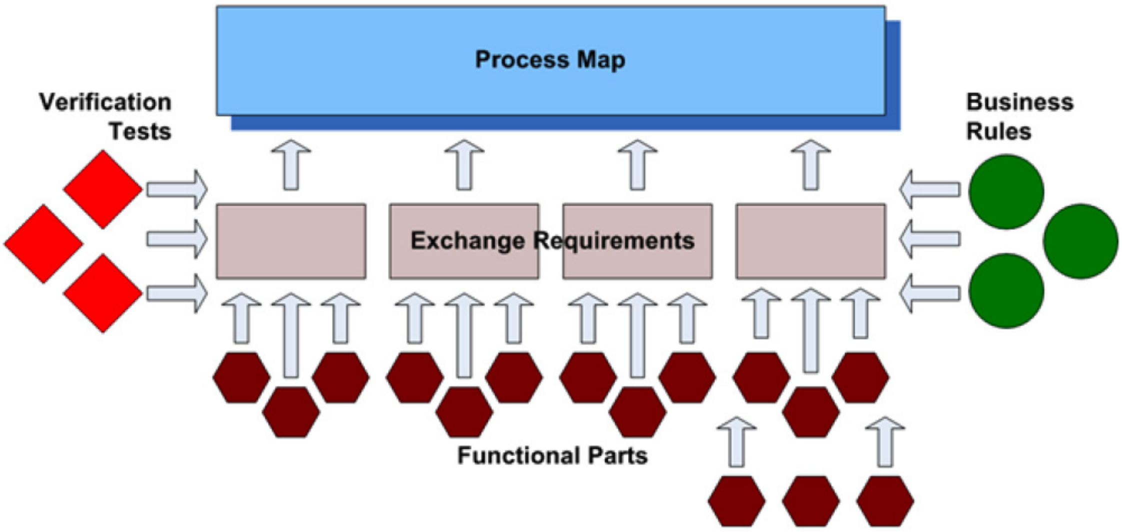


Figure 13 - *Building information models -- Information delivery manual -- Part 1: Methodology and format (ISO/DIS 29481-1)*

An IDM describes what information should be included in an IFC-import. The figure (14) explains how all processes that involve an exchange of information, have their own IDM. Gradually the BIM gets enriched with more and more information from the different parts in the projection, as all this information is not relevant for all parties at all times during the building process., a strain of information is necessary.

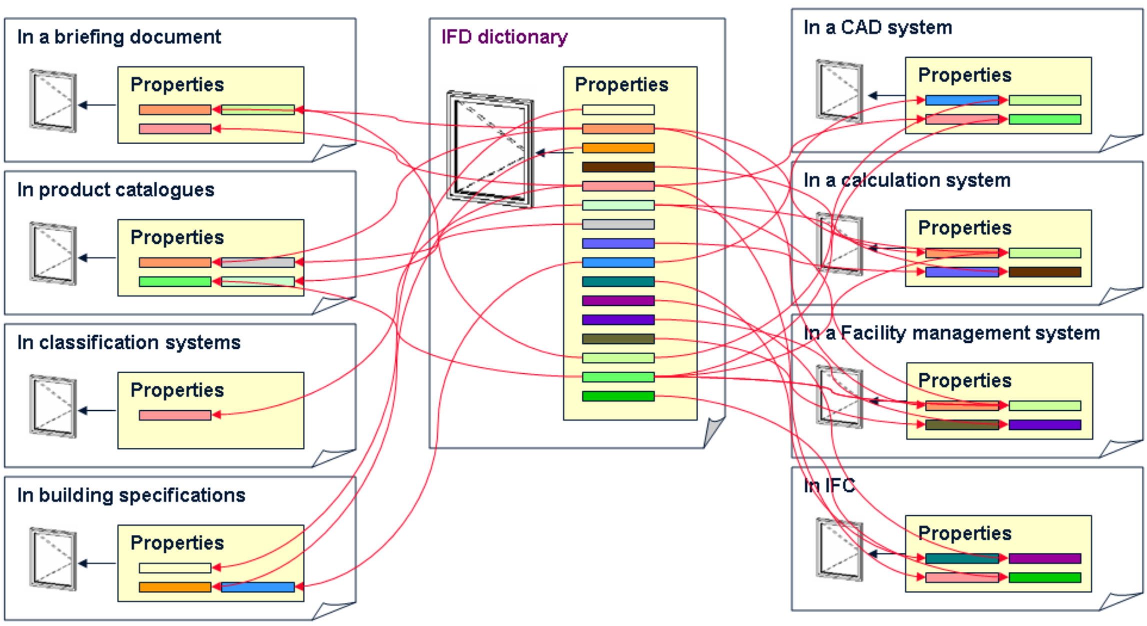


Figure 14 - *IFD as a mapping mechanism (Bjørkhaug)*

Figure 15 is an illustration of the IDM-principle. The figure also illustrates the challenge of using IFC. The trouble of defining what information is relevant at what time. As the circle to the left show all the information that is available in a BIM, whereas the circle to the left is the relevant information available.

According to ISO/DIS 29481-1, the IDM has three fundamental parts and is what we call the IDM structure.

• *The Process Map*
• *Exchange Requirements*
• *Functional Part*

IFC supporting all business requirements at all projects stages

IDM supporting a business requirement at a project stage

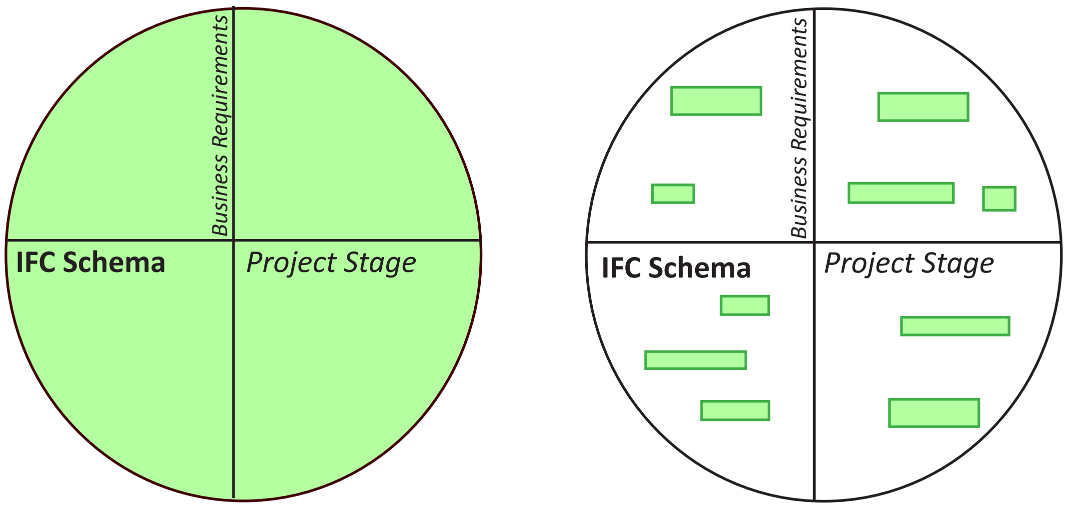


Figure 15 - *Illustration of the IDM-concept (Baggetorp, 2007.)*

These parts are more thoroughly discussed in the chapter on IDM for fire protection of buildings (5.4), where there also is suggested an IDM this topic.

2.2.5 *Industry Foundation Classes (IFC)*

There are many standards in the construction industry, from ISO standards to national standards and guidelines from the government (Figure 16). Some of the standards for sustainability in buildings are, according to the Europe INNOVA initiative s report on "STAND-INN", only just starting to emerge and are no yet widely used. (Europa INNOVA, 2008.) The IFC-standard are the one that has gained a high profile in the construction industry the last couple of years.

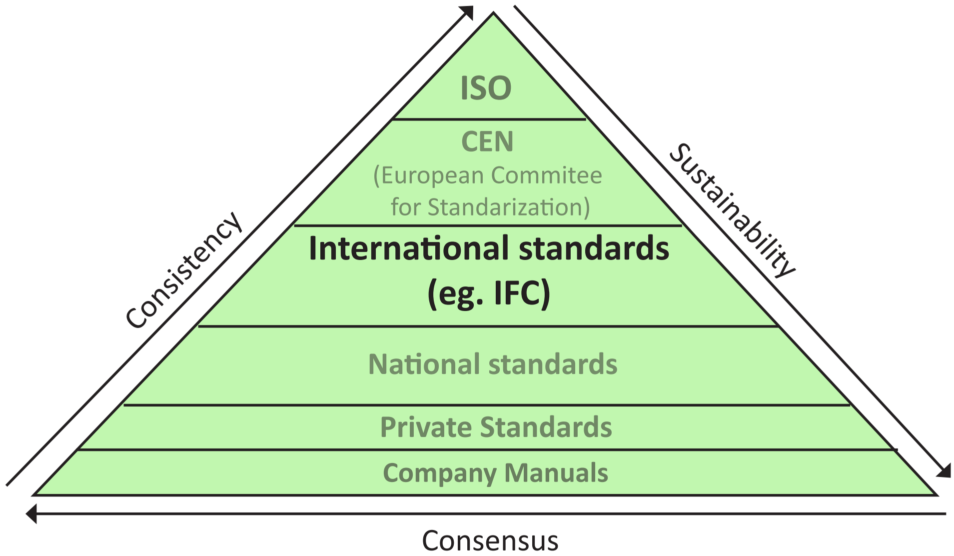


Figure 16 - *International open standards support industry performance improvement (Europe INNOVA)*

The IFC-standard is an open standard which, according to the Europe INNOVA initiative; "*enables interoperability between applications and allows complex information to be shared.*" (Europa INNOVA, 2008.) The IFC definitions are rich, intelligent and covers geometry, spatial relationships, product information, cost etc. They are not a software product themselves, but a free available standard for the developers to use.

IFC is developed for the exchange of information. The format makes it possible for stakeholders to communicate with the joint model, regardless of the software one is working with. The IFC is an objectorienteded model, which makes the basis of the BIM. It models all type of information; parts of the building, geometri, material characteristics, costs etc. This information is gathered in a property set for the element, as shown in chapter 5.3.

The format defines many element classes which represents parts of the building (*IfcBuildingElements, IfcBeam, IfcWallCommon* etc.) These objects are mainly elements used by the architect, and does not pay any attention to the fire protection or other special fields of a building. By introducing property sets developed for other fields such as, fire protection, these element classes kan maintain the qualities that is needed to perform a fire simulation or analysis of a building.

The vision is to get property sets to cover all fields of the building process, and by doing this enable a seamless communication between them. The I*FCBuildingElement* could be the basis of the building, the element that the other fields could refer to in their elementtypes (eg. *IFCFireWall*). Making the *IfcBuildingElement* the "physical" object in a virtual building, but which also represents other functionalities, such as fire resistance, at the same time. (Figure 17).

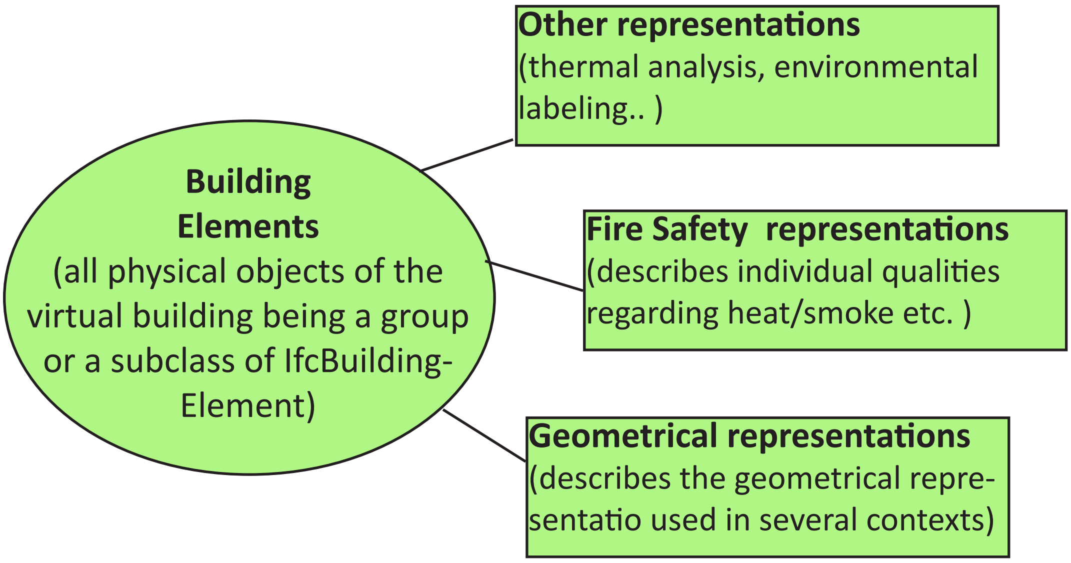


Figure 17 - *Shows how building elements refer to other characteristics in BIM (Europa INNOVA.)*

The IFCs was developed by the IAI (International Alliacne for Interoperability), which rebranded themselves to buildingSMART in 2006, when their first early-work with the new open standard was completed.

The Europe INNOVA initiative describes the introduction to IFC:

"*The combination of building information model and IFC software offers fantastic possibilities. No more tedious reentering of data further along the value chain. No more lengthy cost analysis, expensive design change, reworking because clashes are detected late in the day. No longer a tangled web of communication between the many parties to a construction project – everyone can now share information through the BIM*." (Europa INNOVA, 2008.)

As the Industry Foundation Classes (IFC) format is not yet complete, there will be some defects regarding the software, the development on this field is going fast. Thor Ørjan Holt (Multiconsult) claims that this will not retain the use of BIM, as there are other aspects that will be much more complicated to implement, by the time the mindset is implemented, the IFC-standard will be compatible and reliable.

The development and implementation of the IFC- elements is important to make BIM be more efficient, finding a system to tie the relevant information together should also be a focusing area. Methods of doing this is suggested later in the paper.

2.2.6 International Framework for Dictionaries (IFD)

IFD can be look upon as kind a of dictionary. By having an international “dictionary” (IFD), the converting of BIM can be done between different languages. IFD maps the connection between mechanisms. As an example a door would be “door” in English and translated to “dør” in Norwegian. In relation to BIM this would not be the right way of translating, as “dør” in Norwegian relates to the door and frame, as it in English only referes to the door leaf itself (Figur 18).

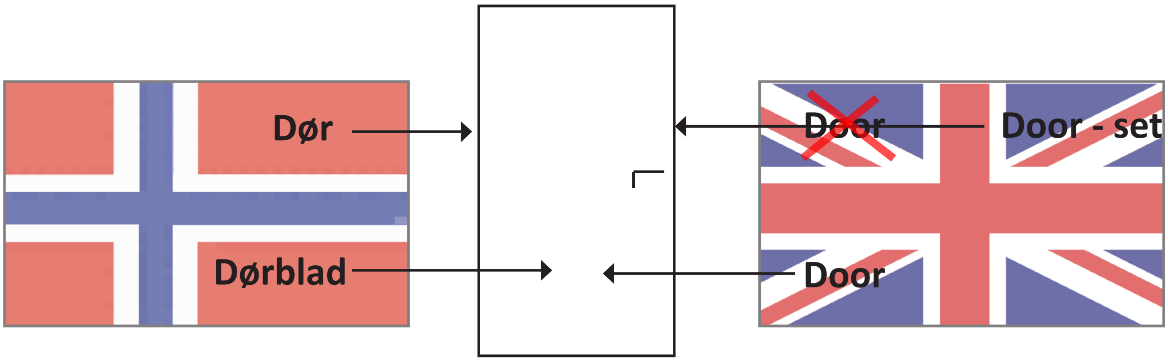


Figure 18 - *Shows the need for an international dictionary (Bjørkhaug, 2007.)*

IFD is an open international library where all building objects used is semantic described and given a unique identification number. By describing the objects semantically the objects signification is stored in each object. Making all information in the IFC-format unique, and we can label it with a Global Unique ID, which can be looked upon as a parallell to the personal identification number humans get when born. By having these GUIDs, the objects is understood independent of which language they are described in. A Greek architect can describe material characteristics and a Norwegian receiver can, without difficulties, understand it, if the GUID is given correctly. Text and descriptions is exchanged between humans, but the GUIDs is used and understood by computers.

GUID can be used to let the different parts of the projection add fire measures to the BIM. This can be done by giving the different fire protection aspects their own GUID, and by doing this link the fire information to the objects in the model.

The IFD can attach the BIM to product-databases such as NOBB (the Norwegian building material database), this can give detailed information of the element, which one traditionally would have to collect manually. This gives the project group the possibility to collect information about real-life products. By using this opportunity, the fire resistance and fuel load of materials could be considered versus costs and other aspects early in the projection. In this way the fire protection considerations would follow the object through the project.

2.2.7 Information management

The information stored in a project could be decomposed to the highest level of detailing, but it is also possible to regard the information in a larger view such as a; complex building, site, region, country and world. The figure (19) under shows the relation between the parties involved in a building process.

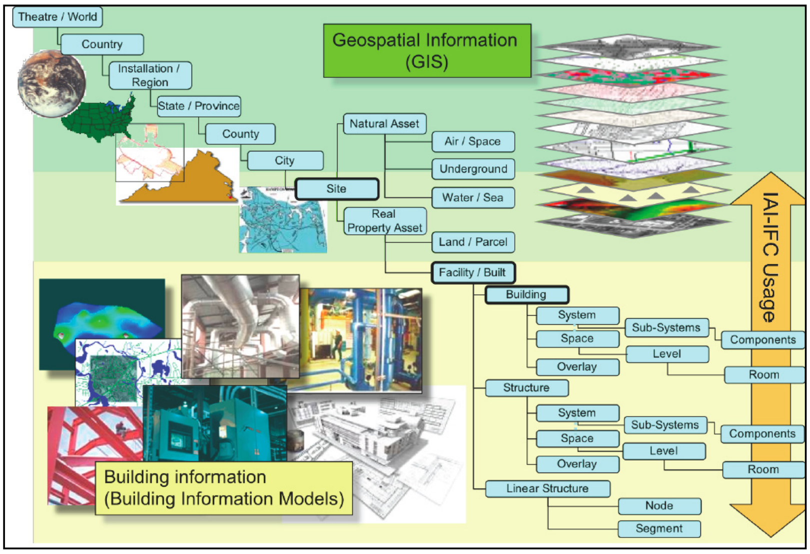


Figure 19 - *The relation between stakeholders in a building process* (National BIM Standard.)

The information in BIM is mainly concentrated in two different parts.

1. The joint model and

2. The profession models. The profession models can be divided into different models for each specific field, as shown in figure 20.

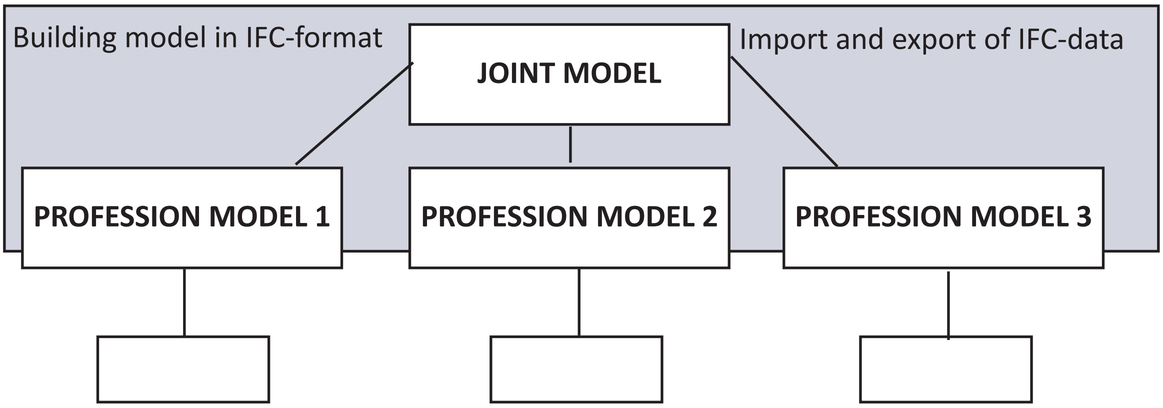


Figure 20 -*The relation between the different models (Statsbygg.)*

1. The joint models' commission is to put together all the different profession models. This gives an overview of the project. The joint model can detect possible collisions between the profession models, control the quality of the documentation that is generated and give a visualization of the project.

The joint model has to be highly accessible, to be able to communicate, control and coordinate the information in the building process. To make this possible the model can be placed on a common server. On this server the models from the different fields can be merged together into the joint model. The project supervisor would have the superior responsibility for the model.

2. The profession models that the BIM is built up from, are from different fields of the building process and made from various software. The models that are used reflect the responsibility of each profession. By looking at how the architect and the FPE work, we can get a clearer view of how the interactions between them is. The model the FPE uses are a model used to do analysis and simulation and a model to generate drawings. The architects' models are aimed at showing the design and function of the building.

To indicate the difference between these models one can look at the different software the professions use. The architect may use ArchiCAD, which is object based software that is made for architects. As the commercial for ArchiCAD says "*It's a program made by and used by architects,*" which describes the software well. As this is a program that cannot do anything else than what the user can; design buildings.

The FPEs task is to ensure that the fire safety in the buildings is maintained. By using simulators and programs to run analysis of the architect model, the FPE gets information about how the building will perform during a fire. The level of detailing in these models is different, and it is important that the right information is delivered in an import. IFC compatible simulation programs are available, which eases the FPEs workload, as they do not have to create a new model when needed to run a simulation. (Kvamme, 2009). These softwares are discussed in chapter 5.

2.2.8 Interaction

Working with a BIM requires a change in mentality for the parties involved. The general mindset, way of communicating, as well as the role pattern that exists today has to change. All stakeholders in a project have to determine that BIM is the method, and that information should be shared openly. Instead of working in the linear manner described earlier in the paper, the information has to flow interoperable and towards a common goal. The Europe INNOVA initiative reports that "*work processes have to become more transparent and communa*l." (Europe INNOVA.)

The major part of the information is initially defined in the design of the building. According to "the BIM Handbook", the architect payment schedule is 15% for schematic design, 30% for design development and 55% for construction documents. (Eastman et al., 2004). This distribution of payments reflects the traditional way of producing construction drawings. By introducing BIM, the amount of time required for a production of construction documents is reduced. (Eastman et. al, 2008).

Building projects begins at different information development levels, including definitions of the buildings function, style and construction. In the mentality of BIM the model should be enriched by all the parties in the building project. The parts of the model that are relevant for a specific profession are imported into an application that is custom-made for the tasks this field demands.

One of the challenges for the flow of information is therefore that the architects' model not necessarily is at the same accuracy that the engineers would be in need of. The reason for this is that the primary tasks for the architect is to design the building and that this often take place in the early stages of the project, when the level of information is low. Whereas the FPE has to wait for the design to be more complete, this to get a simulation as "real-life" as possible. The architects software is often of a lower level of accuracy, and does not, at this stage, include a fully complete database of necessary attributes concerning the fire protection of buildings. (Lyngtveit, 2008).

It is important that the different software specializes themselves in their specific fields. As this is one of the criterias of getting a optimized building. (Andersen, 2009.) The challenge will then be how the information flows between the different applications with different levels of accuracy.

Up until now most engineers has chosen to model everything over again, even though the possibility for an import has been available. The architect-model has, in best case, been imported and used as a "background", a reference-model. The reason for that the engineer chose to rebuild the model is that it has been more time-consuming to debug an inaccurate model, than build it all over with the architects' model as "background". (Kvamme, 2009.) The engineer is responsible for the documentation he produces, and wants to be in control of what he is doing, and therefore also control that the model is correct. This leads to a more complex problem, how to import a model of a low level of accuracy into a program which requires a high level of precision? And how can one fast and simple "fix" the model, and in the same time have full control?

To run an analysis the need for accuracy is high. By have a small error in the model, the analysis may not be accomplished, or the result might be useless. As one of the architects in Link-Signatur explains:

"The architects often utilize some of their own libraries, which they have created themselves and that are not compatible with the open standard IFC. This could be a small detail as a door sill, which the architect software does not have a satisfying object of. The Architect will then have to create their own object, by extruding and drawing, in which they utilize where needed. This door sill will not appear in a IFC-file, as it is not included in the export of the model. This could be crucial for a possible analysis, as this would be an error in the model. In a fire or energy analysis, this door sill will function as an open space and let through both heat and smoke. This will off course be unfortunate for the analysis, which will end up being completely useless."
(Skjelstad, 2009.)

On a 2D drawing a small error like this will not necessarily be any problem, as the door sill will not show as it is on a layer "under" the door itself.

In a building process, the interaction between the architect and engineer is somewhat random. Ulfsnes and Danielsen points out the need for revisions and overview of all the information as an important issue in a project. (Ulfsnes and Danielsen, 2004) With a BIM mindset the information will follow another line and one can imagine that the information will flow in "loops". (Hjelseth, 2009). The BIM will constantly be modified and enriched. For this to happen the information has to go from the architect to the engineer and back to the architect as the figure (21) shows.

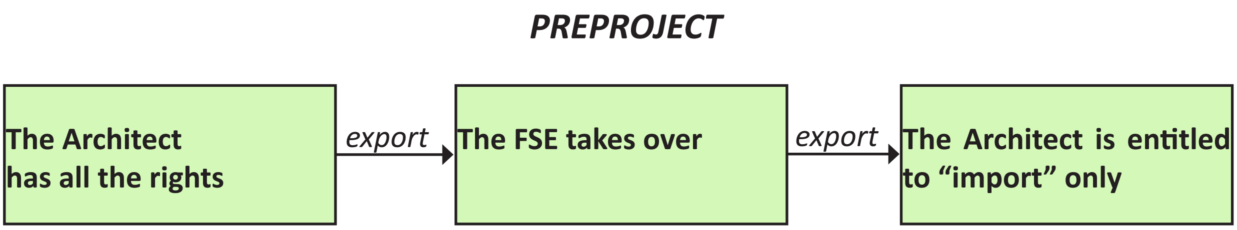


Figure 21 - *The exchange of information between the Architect and the FSE (Eberg et al. 2006)*

2.3 Building models

2.3.1 From 2D-drawings to 3D-models

The development of computer software within the construction industry has been formidable. The evolution of drawing tools (CAD, Computer Aided Design) has been one of the main developments. The way the drawings have been delivered has changed, due to the change of equipment used.

The first way of using CAD was as a digital drawing-board, this way of drawing is still made use of and will probably not be fully replaced in some time. (Lyngtveit, 2008). The digital drawing-board signifies a way of drawing with a mouse and a keyboard. The advantage compared to traditional drawings, by hand, is that the computer has many facilities which simplify the work. These facilities might be as simple as a copy- og a mirror-function or components that are available in a large library that makes the design faster to finish. These components are easy to find and makes the process of drawing faster as it is a big extent of re-use of these components. (Goderstad, 2009.)

A disadvantage of using 2D-drawings is that it can lead to misunderstandings and interpretations because of its lack of details. The drawings does not contain anything else than the visual building as lines and strokes (Haug, 2007). This is not efficient, as you are in need of documentation in addition to the drawings. In a computer system based on objects (BIM), the wall will not only exist as lines and strokes, but it will be an object that holds some of the information that was added as documentation in the traditional way of building. Some of the documentation will probably be found as it is today, as not all information is adequate to place in a BIM.

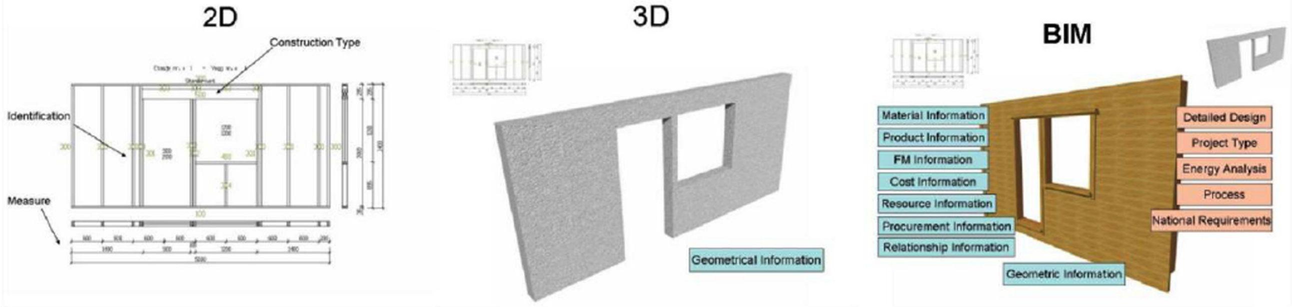


Figure 22 - *An example of wall in 2D, 3D and BIM (Hjelseth, 2009.)*

From 2D the development has gone towards using 3D. (Figure 22.) The Danish “Det Digitale Byggeri” divides 3D modeling into three levels; 3D- CAD, 3D-CAD based on objects and Building Information Models. This represent the different levels of complexitivity in the modeling.

3D- CAD

This is the most simple 3D modeling. The model is built up of lines, point or “solid” parts. A model of a wall could exist of two sheets which are placed next to each other. The model is a geometric building model, but the part have no qualities attached other than geometry and position. They can be utilized to solve geometric problems, visualizations, simulations and to gather information about the space and volume in the model. The limitations are connected to the communication between applications, it can be difficult to maintain the information the way it was intended.

Object based 3D- CAD

In object-orientated modeling, the model consist of objects, such as walls, windows and doors. The object contains geometry and characteristics. These characteristics are connected to the real building components characteristics.

Just like the 3D- CAD, the “3D- CAD based on objects” can solve geometric problems. In addition it is “intelligent” in the way that the window “understands” that it should be placed in the wall. (Det Digitale Brygger & bips, 2006). Most of the CAD software also has the possibility to generate quantity lists.

Building Information Model

This is the most comprehensive way of modeling buildings. It includes more information than the 3D- object model, this information can be descriptions of the building, economy and time plans(4D). All the involved parts of the building process enrich the model with their specific information through the whole project.

The components in the model possess the capacities and characteristics that the real components have. In addition the components hold information about the relation between themselves. The model generates the traditional drawing by choosing which cross-section one wants from the model. having the opportunity to turn information, properties, on and off, the export/ import only includes the information needed.

2.3.2 Drawings, models and descriptions

By using a model as the working method, the drawings will be the way to illustrate the model. An example is the 2D- floor plan of a building. These can then be generated from a model, and used to show the escape routes, fire hoses and emergency exits in a building.

From this model it is possible to generate the drawings needed with the information needed at a certain time. The different professions have varying level of detailing for different purposes. When utilizing BIM, the information is at all time available and one can choose what information should be included and in what scale the drawing should be in.

The design from the architect could be used to visualize and present the project. The drawings should then be of a level of detailing that give the viewers a picture of how the product will be like when finished. The drawings of the construction will make the foundation for the production drawings and documentation that is needed for the contractor to execute the project.

In this paper the main focus will be concentrated on the fire cafety concept that the FPE produces, in addition to this concept, the FPE also makes simulations and analysis regarding the spread of fire, development of smoke and how people behave in a given fire. The level of descriptions and simulations all depends on the contract practice and the complexness of the building, these are elements important to include in a BIM. (Sjøgren, 2009).

2.3.3 The level of detailing

The same information is, as mentioned, produced several times during a project. With the introduction to BIM this will be unnecessary. If this time consuming production of information can be reduced oncewith one, BIM will give an advantage compared with the traditional way of building. This chapter will describe how the model gets enriched with information through the building process.

A collaboration between the University of Aalborg, Rambøll, Arkitema and NCC (Det Digitale Brygger & bips, 2007), describes seven levels of the model. The levels show the contents of information and the extent of concretizing. By using BIM as the working method, the model will be enriched through the building project, and in the end, have the opportunity to, consist of the information needed to construct an optimized building. A joint understanding of the models content at the different levels is crucial, and the various levels could be attached to the different phases and form the basis of the contracts involved in the project.

The transition from one level to another is indistinct. The different level of information shows how detailed the model is and how specific the objects in the model are. This signifies that the level of information represents the content of information in the model at a given time.

Figure 23 is an illustration of the level of information. The number of objects increases as the project evolves. These objects are also enriched and the level of information increases as the building process advances.

Traditionally the level of detailing on the drawings determined which phase the building process is in, now the model will be the determining element.

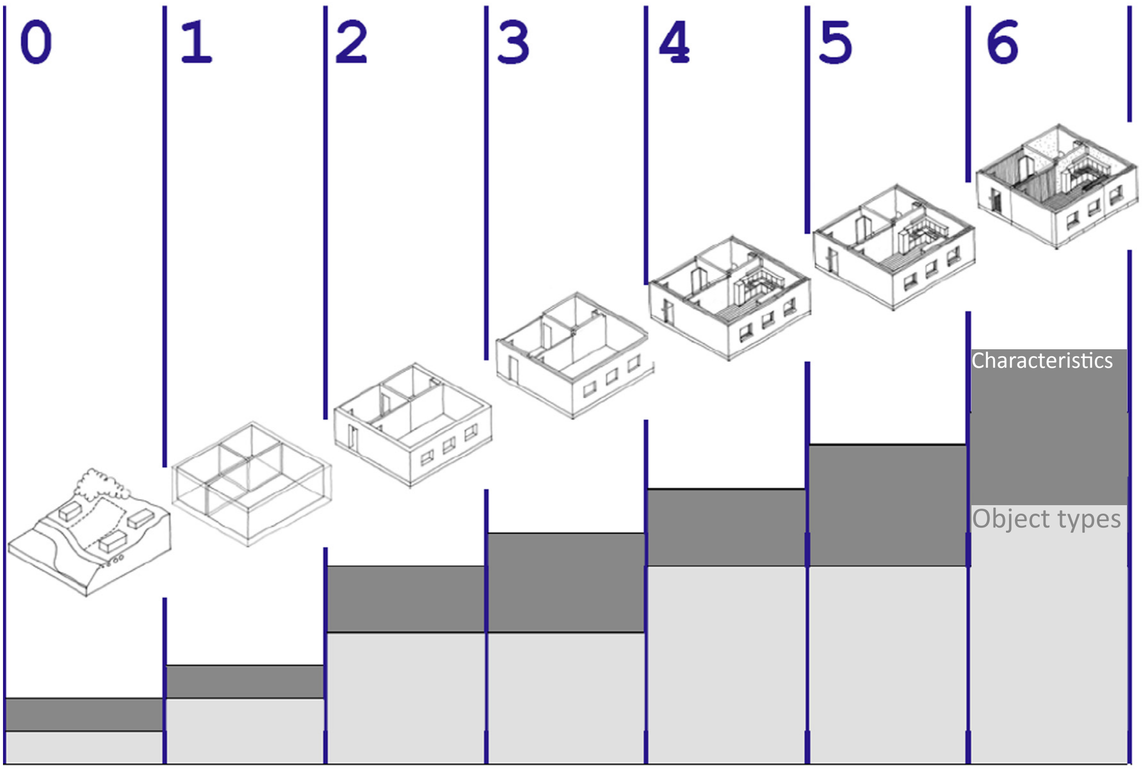


Figure 23 - *The figure shows how a building gets enriched and the content of information increases during the project (Det Digitale Byggeri & bips 2006)*

The fire protection aspect of a building will follow all the different levels in the figure, as it is a premise provider to the rest of the projection, and will affect all the different stages in the building process. The fire concept should be implemented as early as possible, but has traditionally not been introduced to the project-group before level 2.

2.3.4 Software

With the introduction to digital information modeling, a wide spread selection of software is available to be able to maintain each specific field of expertise in the building process. The architect has several CAD-software available to create a design. With BIM, and the applications the CAD-software now are offering, the architects work has become much more than just designing. The software gives the opportunity to add characteristics to the objects in the model, such as ArchiCAD, which is something that BIM can take an advantage of.

Engineers has utilized software for years to perform analysis' and simulation', these have become more an more compound in line with the increased demands of documentation. The difference now, with the introduction to BIM, is that the engineers can import and export model between the fields. This eases their work, by not having to model the design over everytime they are in need of an analysis.

Fire Dynamics Simulation (FDS), is one of the software that the FPE utilizes in his field of fire protection engineering. This is software carries out smoke spread analysis. The software has many common aspects to architecture- and structural engineering software. The FPEs needs to have the basic geometry and topology of a building, which includes information on the size and shape of rooms, opening, exits from a space and where the exit leads. (Spearpoint, 2006.) In addition to this the FPE need to determine the fires that are likely to occur. This is a parallell analysis, based on the fuel load, use and how combustible the fuel load is etc. (Kvamme, 2009.) The software is programmed to perform a simulation based on which fuel loads the building consist of. An example is how a fire would perform differently in a library compared to an empty warehouse with the same shape. (Kvamme, 2009.)

With the introduction to BIM, new interoperable software are developed. Both dRofus, a room and equipment database, and Solibri, a model code checker (MCC) are new applications developed with the evolution of BIM. How these software can be utilized to make the implement and ease the FPEs work, is discussed in the chapter 6.

3 Fire protection engineering

The FPE usually delivers a report (the fire concept) that includes the requirements regarding the fire protection from the authorities, and instructions how to fulfill these requirements in a given building. This report shows how the fire prevention is, where the escape routes are etc.

This fire concept is the basis for a more detailed projection. (Egil Kvamme, 2009). An assumption is therefore that the users of this report reads and comprehends the performance prevision and the presumptions that are taken into consideration before making the decisions that they do. The engineer that are in responsibility for the detailprojection shall describe solutions that fulfill the performance criterion in a fire prevention concept. If the descriptions differ from the fire concept, is this to be considered as derogation and should be documented and worked up as a part of the fire documentation, which is the basis for the supervision in the operating phase. (Ulfsnes and Danielsen, 2004).

The FPE has the possibility to use a template from TEK, but when the solutions differ from TEK it is needed to document the solution chosen, this is vital for that the building satifies the requests from the government. The lack of this documentation does not automatically mean that the building is not of a satisfying standard, but it could signify that the process has been somewhat random and based upon experiences which may not be transferred to the next level in the projection. (Ulfsnes and Danielsen, 2004).

The choice of contract practice will always have an influence on how the fire considerations are ensured. In many projects there is confusion of who is responsible for the fire protection in the different professions and in between the projection and the execution. (Ulfsnes and Danielsen, 2004). The lack of clarified responsibility of the fire considerations can lead to misunderstandings and a weak communication between the different parts, concerning the fire safety in buildings.

As the delivery of fire protection documentation, from the projection group to the managers of the daily management is not clearly defined, the delivery varies from project to project. It is therefore important, according to Ulfsnes report on how the fire considerations can be protected through a building process, that the developer realizes this, and get the fire protection documentation regulated by contract. In this way the developer receives the necessary drawings and documentation when the building is at the completion stage. (Ulfsnes and Danielsen, 2004.)

An introduction to BIM might be one way of getting the premises from the FPE more visible. How this can be done is discussed in chapter 5.4.4.

3.1 Ensuring the fire safety

In this chapter the methods of how the fire safety is ensured in the traditional building process, are summarized. Typical problems are also described.

The ensuring of fire safety in buildings can fail in any part of the building process. (Andersen, 2009). This results in that the fire protection measures does not follow the project from the planning, and that the choice of solutions for does not correspond with the execution of the building. Hans Andersen from the Agency of Planning and Building Services (PBE) points out some of the mistakes that he has experienced during his time as a supervisor for the authorities: (Andersen, 2009.)

- The performance criterion are wrong, and the documents has a insufficient detail planning for the fire protection measures
- Some projects possess little or no documentation of fire resistance
- The supervision reveals flaws and defects in the control system of the involved parts, but has difficulties of discovering defects in the planning and execution of the project.

3.2 The fire protection engineer (FPE)

The FPE is responsible for the development of the fire concept of a building. This concept should be the foundation for the detailplanning, and give premises to the architect. Experience shows that the design often undergoes changes during a project, and unless the FPE has an agreement of pursuing his/hers work, these changes are not to be consulted to the FPE, and the fire concept stays unchanges even though the design is modified. (Kvamme, 2009)

The FPE might only be part of the beginning of the planning, and could at the best be contacted to approve the solutions with nonconformities. Using the FPE to control the fire solutions that are selected are not normal procedure. (Kvamme, 2009.) According to Ulfsnes and Danielsens report, there are many projects with nonconformithies from TEK, but the extent of documentation varies. (Ulfsnes and Danielsen, 2004.)

A presumption in building matters, is that the performance provision is followed, and that nonconformitys is documented to show that TEK is satisfied. If the FPE is engaged to make check points to the other professions who are involved with the fire safety of a building, an assurance of quality would be much easier to control and nonconformithies are more likely to be discovered. (Ulfsnes and Danielsen, 2004.) The problem now is that the FSE is not involved in the project after the fire concept is developed and delivered.

The undefined role of FPE is often a problem in the building process (Andersen 2009). The fact that many projects have a fixed price, makes the work of the FPE more limited. As the development of a fire concept often is based on a fixed price, the following-up of the concept would be at a payment by the hour. Some building projects are not willing to engage a fire consultant at these terms, which limits the quality and control of that the fire concept is implemented in the whole process. (Ulfsnes and Danielsen, 2009).

In complex buildings, many different elements influences the fire considerations. E.g by utilizing a sprinkler system the performance criterions could be reduced regarding some building components. According to TEK the performance criterion regarding structures and restrictive fire cells, are some of the components that could be reduced with the utilization of sprinkler system. Traditional the procedure with sprinkler system has been to rate the building one level lower than original, with the introduction to sprinkler systems. (Kvamme, 2009.) By referring to the reliability data of the sprinkler system without any further documentation, the demands are fulfilled according to the “traditional way of planning”. This way of doing things is unsatisfying, one should always consider the consequences. (Ulfsnes and Danielsen, 2004.)

3.3 Documentation of fire safety in buildings

As mentioned, there are many different ways to fulfill the demands from TEK, and REN is one of the suggestions to satisfy them. Often the FPE does not choose to succeed REN, this does not signify that the demands are not fulfilled, but rather that the solutions that is selected have to be documented in a way that the authorities can see that they fulfill the demands from TEK. (Ulfsnes and Danielsen, 2004.)

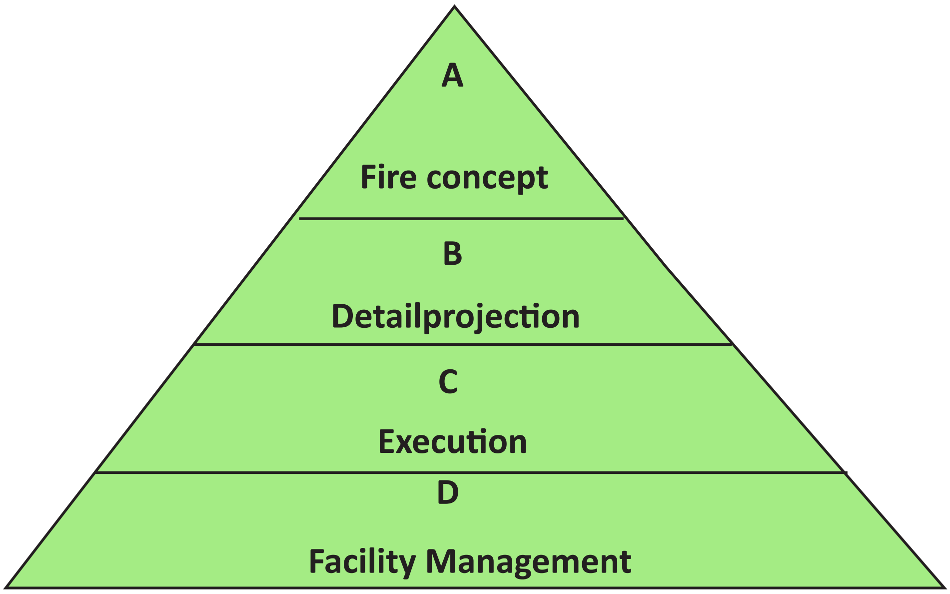


Figure 24 - *The flow of documentation of fire safety through the project (Byggforskserien, 626.102)*

This shows that the solutions that are chosen are not always connected to the fire concept delivered in an early phase of a projection. Some of the examples of why the solutions that are chosen differ from the fire safety concept can be: (Ulfsnes and Danielsen, 2004.)

- The foundation for the detailplanning is lacking
- The executing part is not aware of the foundation
- The needs of the building has changed and the new solutions are not communicated to the FPE
- inexpensive solutions are chosen, compared to choosing solutions that are more economical on a longer basis
- Flaws in the craftsmanship are made, but is not corrected because of a small change of being discovered

The reason for this to happen can be many, but an insufficient multidisciplinary communication is clearly on of the main causes. (Ulfsnesand Danielsen, 2004). Because of the lack of communication in the projection, the knowledge of what is important to ensure a satisfying fire safety in buildings disappears during the process. There is no joint method of how the projection, solutions, execution and control are accomplished. A common understanding and consensus of how this should be done abeam projects and professions is missing. And this is where an introduction to BIM could be of great value. (Kvamme, 2009.)

The actual risk of being caught and punished for a wrong execution is little, because of the shortage of supervision at the construction site. This leads to a lower limit for choosing solutions that are less expensive and that flaws are not likely to be fixed, as the consequences are small. (Andersen, 2009).

According Ulfsnes and Danielsens report on how the fire safety considerations are maintained in the building process, the problems often appear in the poor documentation of the fire safety conditions, solutions and execution. It is a high diversity between how the different projecting consultants perform their obligation, and there is not necessarily a consistency between the quality of how the documentation is and the qualifications the firm has on the field. A joint understanding of how and what should be be delivered is desired. One of the reasons that the fire protection considerations are poor and unsatisfying, could be the undefined content and processes of the fire safety documentation. If the involved parts in the building process acquainted themselves with the content of the fire safety documentation and found a interdisciplinary agreement on how the processes should be done and what the documentation should contain, the quality control of the projection would be easier. (Haaness, 2009).

Both Andersen ,and Ulfsnes and Danielsen points out the difficulties of tracking the information and the handling of aberrations as problematic. The system is based upon trust and that the information can be tracked through the whole projection of a building. If a detail flaw is discovered in the execution, it should be possible to go back and check the descriptions, the planning and the control of this specific detail. A system to control the handling of aberrations is necessary and should be utilized. Figure 25 shows how the disiplines all should consider the premises from the FPE.

The requirement of today's system is that the parts themselves have the responsibility to accomplish a building process in accordance to PBL. According to Ulfsnes and Danielsen, the problem concerning the fire safety considerations in a project is often the various understanding of what is needed to satisfy the demands from the authorities. The FPE is often left without any particular role after the concept phase, this can result in a detail planning which does not satisfy the performance criterion in the fire protection concept. In small projects where the contractor makes use of certified solutions and licensed fire measures this will not be problematic, but the more complex the building is, the more critical it is that the report and instructions from the FPE is ensured. (Ulfsnes and Danielsen,2004.)

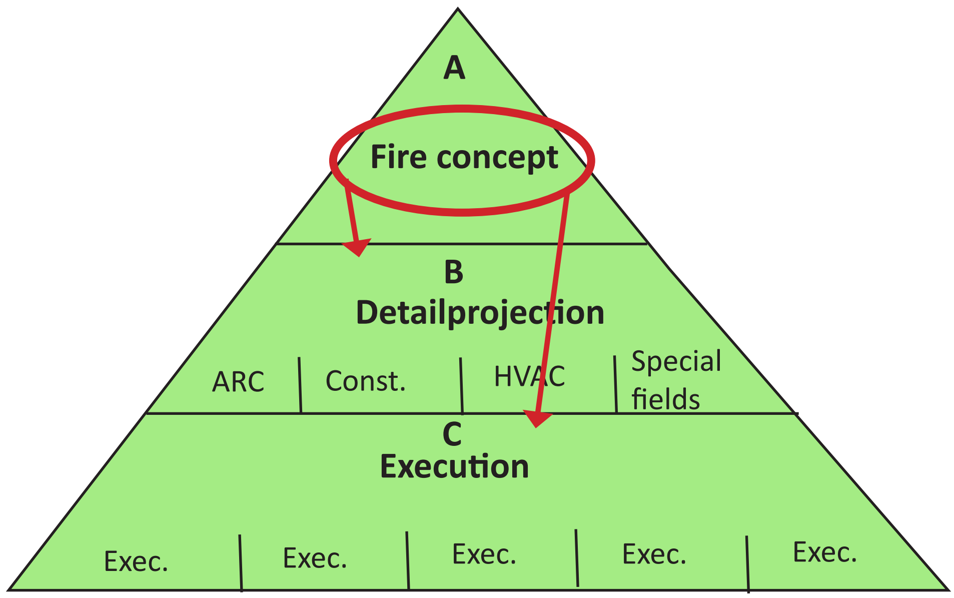


Figure 25 - *Interdisiplinary quality control (Byggforskserien, 321.025)*

3.4 Quality control

The Norwegian Institute for Building Research (Sintef) has published numerous of recommendations on how to plan and execute the fire protection, as well as how to document and control the fire protection of buildings. In addition to these there are several other standards and instructions one can follow; The instructions from PBE, standards from the Association of Consulting Engineers (RIF), technical books and the certificates and approvals from the supplier, is available to meet the demands from the authorities. By having all this information, the administrative part of the planning should not be too confusing. The reason that flaws and misunderstandings are happen could be that the counsels not are prepared by the users themselves or that they might be too comprehensive. (Ulfsnes and Danielsen,2004). This is also one of the main challenges with the introduction to BIM, which is discussed later in this paper.

Along with these standards a description of what “normally” goes wrong in a building process and what should absolutely not go wrong in the certain project, should be added to the control plan documents. This makes it easier to find a sufficient extent of control. According to Sintef, a list of specific check points should so be written, to make the element of danger more clear.

The controlled planning documents as well as controlled drawings should be available at all times. A substantial point in the building process is that the planning and execution takes place according to the controlled documentation. (Ulfsnes and Danielsen, 2004.)

“*The correction and reset of experiences to the planning is maybe the most important link in the treatment of nonconformance. The experiences should be used to continually getting better; to learn from ones mistakes. The corrections should eliminate the flaws and make sure they does not appear again*.” (Ulfsnes and Danielsen, 2004.)

Traditionally the treatment of nonconformance should be collected as a part of the documentation of control at the final inspection of the building. If a building projection is without nonconformities, is this due to a lack of control and documentation, rather than a perfectly performed building process, says Andersen in an interview. (Andersen, 2009.)

The extent of detailplanning considering the fire protection of buildings is not comprehensive enough, and the solutions are traditionally not included other than in the 2D drawings. At the construction site the selected solutions are, often, completely missing. (Hedemann, 2009)

Ulfsnes and Danielsen ask themselves in their report if a fire concept is a suitable foundation for a detailplanning. A presumption would in any case be that the involved parts of a building process are known with the concept, and that in this way get implemented in all the different professions. (Ulfsnes and Danielsen, 2004.)

The most important presumptions must be emphasized. If these presumptions are missed out, decisions in conflict with the concept could be taken. It is also important that the concept is not of a level of complixity, that the different parts of the process does not comprehend. It should become clear what set of rules and regulations the FPE are basing their planning on. (Andersen, 2009).

The result of a poor detailplanning is that the contractors documentation available at the construction site is insufficient. This results in a habit of using solutions that they have used before. These solutions often lack documentation or the documentation is not following the solution all the way to the construction site. (Hedemann, 2009.)

Regarding the control of the planning and execution of buildings, the problems often are related to the checklist that has been developed. According to Hans Andersen these lists generally focus on the things that are visible and easy to discover, and that could involve a complaint from the customer.

The control plan is usually produced at an early stage in the planning, and is often too general and should be supplied with a check list to maintain the level of details. The check lists itselves are also lacking the some of the crucial information about the building components. Even though the lists include many professions, the control of fire prevention measures is limited. In some cases only the fire resistance of the components are included in the check lists. (Ulfsnes and Danielsen 2004)

If there are variations from these lists, they are to be considered as nonconformity and should be documented in a treatment of non nonconformance. Sintefs report emphasizes that they are questioning the use of this documentation, as many projects has surprisingly few conformities. The possibility for that the treatment of conformance is not implemented and used in the extent is should, is something the report looks upon as one of the biggest risks the control of the quality in buildings encounter. "*If the conformance is not documented, how can one learn from ones mistake?*" (Ulfsnes and Danielsen, 2004)

Overall the problems during a building process are generally due to the problem of reaching the right information at the right time. Considering the fire protection of buildings, the implementation of the fire concept would be one of the greatest risks in a project. This is due to the different quality and tradition of the working, the different consultants and professions involved in the building process are used to delivering their information in various ways. (Kvamme, 2009). This is were the BIM could be the solution to the poor interaction between the disciplines.

The flaws in a building process occur in all the different phases of the project. With reference to Hedemann, one of the reasons of these flaws is the lack of qualifications and knowledge, and many of the flaws could have been avoided if the facilities that are available was utilized. (Hedemann, 2009.) A relevant question is if the facilities are known and if the instructions are red. Ulfsnes and Danielsen claims that SAK, which describes the procedural part of a building matter, should be as fundamental as the material instructions (TEK). Which emphasizes the need for change in the field of the FSE.

4 CASE STUDY

4.1 UiS – University of Stavanger

Statsbygg has, as a pioneer in Norway, signalized that BIM is the future in the construction industry. In the tendering text on two new buildings in the University of Stavanger, Statsbygg requires use of BIM the projection of the buildings. This means that the consultants and all other parts of the UiS project communicates through a joint building information model, with the common, open file-standard (IFC).

The desire from Statsbygg is that the BIM follows the building from the idea-phase through the building process until the day-to-day management of the buildings. The architects and the consultants have to deliver according to the routines in Statsbyggs "BIM-Manual". As the BIM follows the project through the idea-phase to the constructors, Statsbygg requires an "as built"- BIM from the contractors when the building is executed.

The UiS project represent a new start of BIM for Statsbygg, as this is the first project that requires a complete BIM projection and execution. By 2010 all Statsbyggs projects requires BIM. (Statsbygg, 2008.)

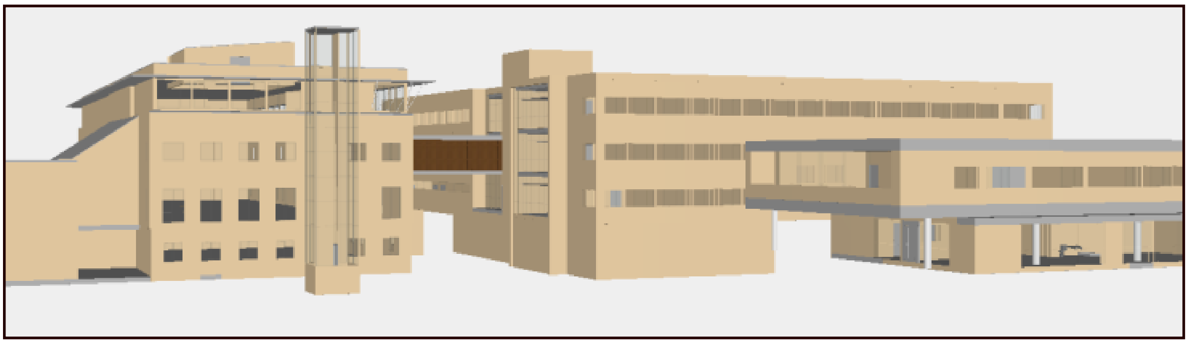


Figure 26 - *University of Stavanger (UiS) (Multiconsult.)*

4.2 Project phases

This case study has followed the University of Stavanger in the preproject. As this is a large project, it will take years before the buildings will be complete executed. It emphasizes the flow of information between the different parts, especially how the FPEs premises are accessable for the project-group, but also the between the different software they use in the different special fields.

The execution and management of the building is also important phases of the buildings lice-cycle, but will not be considered any further in this paper.

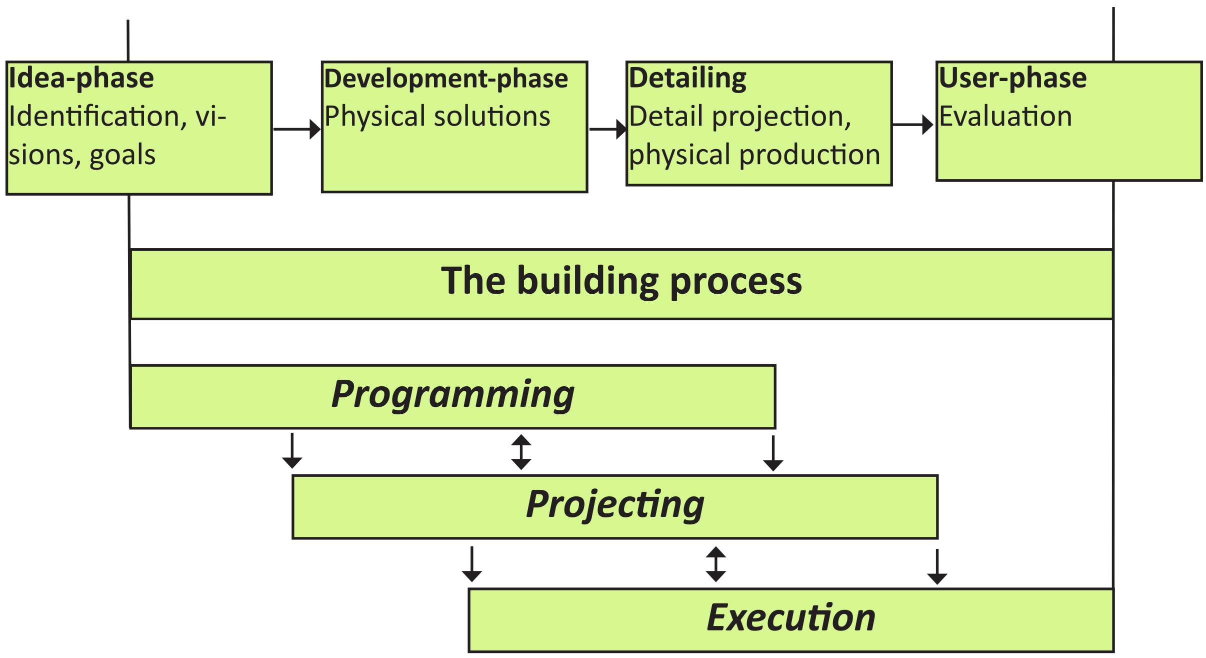


Figure 27 - *The project-phases (Byggforsk, 220.010)*

4.2.1 Frame

The project involves to new buildings, which is built in addition to the exiting buildings of the University of Stavanger.

The two buildings are:

1. *Building 302*: 3 main levels + technical basement. The building is, with a fire-technical view, classified as a "mixed" building. 25 % of the building is of the purpose of education and the rest is offices. The basal area 1100 m2, and the united area is 3600 m2 all together. The load of people is ca. 575.

The risk category of building 302 is 3 for the education-part in the 1. And 2. Floor. The risk category is 2 for the rest of the building. (Kvamme, 2008.) This risk classification is based on norwegian standards. The building is divided into different fire cells, where each classroom, emergency staircase, technical room and floors with offices is separated into fire cells.

2. The Student-House: is a new building with to levels. The use of this building is mixed, as its purpose is for offices, education and assemblies. The basal area is 370 m2, and the united area is 640m2 all together. The number of people is calculated to be ca. 185.

The risk category of the Student-House is 2/3 on the upper level and 2/3/5 on the lower level. Fire class 3. The building is divided into 3 main fire cells; lower level, upper level and the staircase. In addition to this, the technical room and any other possible zones of risks must be separated into their own fire cell.

4.2.2 Objective

The building program of UiS, emphasizes the environmental aspects of the project. The builder, Statsbygg, wanted to build the buildings as environmental friendly as possible, in particular regarding the use of energy in the building. By using BIM and Riuska, Multiconsult and Statsbygg will get a clear view of the energy consumption early on in the project. (Figure 28). Making use of some of the benefits BIM brings. As this was a pioneer project in the use of BIM, the project-group encountered some problems due to the import and export of te models, which is discussed later in the paper.

An objective of having a satisfying indoor-climate is also existing, without having placed any specific goal.

Figure 28 - *RIUSKA is used to analyse the energy consumption in the UiS-project (Killingland 2009.)*

4.2.3 Identification-phase

The project started with a mapping of the requirements of the building. This was the foundation of a sketch with the principles of the building and the needs the builder had. In this phase there were three different parts involved:

1. The group of Program Developers

These are responsible for the programming of the buildings. In the UiS-project, these were the architect and the builder.

2. The Program Develop-collaborator

These are the people that are not involved in the projection, but that are in some way connected to the project. In this case this would be the renter, the students and the people employed at the University. They are the people that are going to use the building, and should therefore have a saying in the projection.

The students had several input on the building, making the design as optimized as possible.

3. Resources

The last group is the people that are not involved in the building itself, but have a broad knowledge on their special fields. These are also free to contribute to the project, to make the building as good as possible. In particular this includes the labor inspection (Health and Safety Executive) and the local government.

In the UiS-project, the Norwegian Association for Disabled (NHF), was contacted in order to evaluate the quality of the building, as the regulations and instructions for Universial Design that are available today are vague and not fully developed.

5 ANALYSIS AND RESULTS

5.1 THE SUPPORT OF ICT IN THE BUILDING PROCESS

The flow of information will vary in extent and need in the different phases of a building project. This paper goes deeper into how the work of the FPE can be eased and what challenges the introduction to BIM will bring. By utilizing the opportunities the introduction of BIM gives, the accomplishment of a building process will, implicit, go through some changes. (Hjelseth, 2009).

One of the objectives of the BIM-technology is to arrange an automated transfer of information between all the links in a building process. Before introducing BIM to the industry, the main components; IFC, IFD and IDM, has to be optimized. The work of accomplishing this will be a constant process, as the demands from the software and stakeholders will keep on coming.

In the traditional way of planning, the communication happens mainly through meetings during the projection, where all the different parts involved has the possibility to express their opinion, based on drawings and paper documents available. As mentioned this kind of building process' is called a linear building process. (Figure 4.) What is likely to happen with the implementation of BIM, is that loops back and forth in the projection will be more common. (Figure 5) This means that the different parts of the projection can work more parallel, compared to how the process is today.

In the traditional way of planning the architect is close to finished with the building design when it is delivered to the engineer. The engineer ads his expertise to the design, changing the architects design as little as possible. This will not always give the best, optimized solution, but has until now been the standard way of planning.

By including the engineers at an earlier stage in the project, the vision is that the design gets more optimized.

5.2 THE TRADITIONAL BUILDING PROCESS VS. BIM

5.2.1 THE TRADITIONAL BUILDING PROCESS

The information in the traditional building process flows from phase to phase, but seldom to the rear. In the preproject many stakeholders is involved, including the FPE, and a large amount of information is generated and exchange. The exchange has traditionally been of 2D-documents, that does not contain much other than information about the shape of the building. All other information is transferred as "documents", notes in which each consultant has to regenerate in their specific profession-model. This coordination is the most challenging part of the traditional building process, as every project is different with different participants and various working traditions.

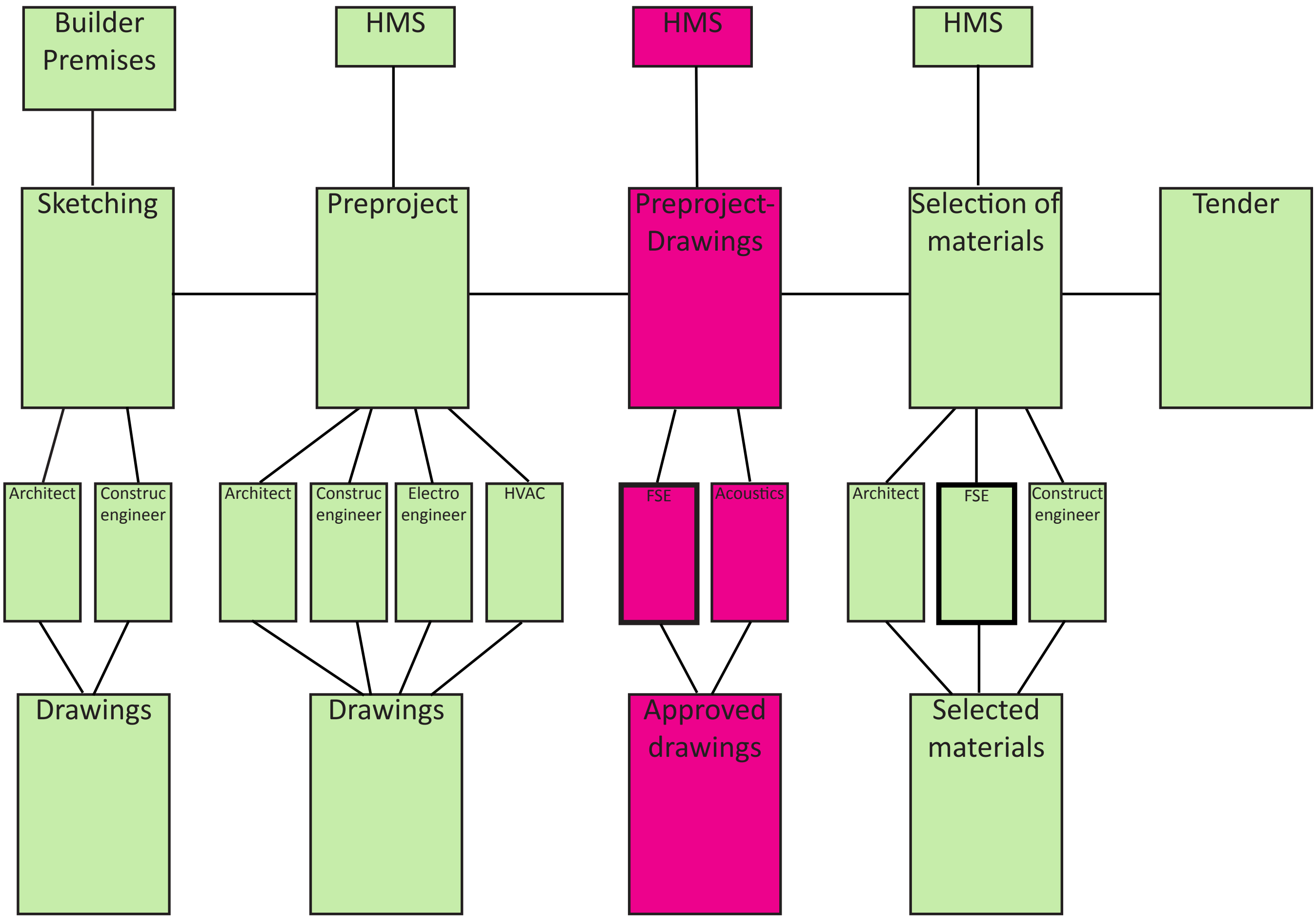


Figure 29 - *The traditional information model of a project*

Clashes between the fields is normal, and the process of checking the different profession-models is time consuming. If a flaw is detected, the project-group would have to go back in the planning and, in worst case scenario, start all over. This is not a desirable process, as it is both costly and inefficient.

The FPE enters the project when the solutions regarding the design is more or less set, he controls that the solutions due to the fire protection of the building is maintained. These are solutions that one wants to decide early, to avoid big, costly changes later on in the project.

Lists of what kind of materials which is wanted in the house, is generated. This is a cooperation between the architect, the acoustic engineer, FPE and the builder amongst others, to maintain the buildings characteristics. The chosen materials gives the basis for a calculation of the building, which could give an estimate of what the building would cost to build.

In figure 29, the traditional flow of information is sketched. The defined phase is clear and the information model makes it difficult and expensive to go back to an earlier phase to make changes in the project-foundation.

5.2.2 THE BIM BUILDING PROCESS- based on the experience from UiS

In the UiS-project, the BIM mentality was supposed to follow the main areas in the projection, such architect, the landscaping architect and consulting engineers (HVAC, construction and electro). The fire concept was therefore not implemented in the BIM, but traditionally delivered from the FPE.

The planning starting with the programming of the buildings. The architect designes the buildings, and exportes the sketches to a IFC-file, making it readable for other IFC-based software. When this is done all the fields of the projects has access to the architects ideas and can give feedback on the design and shape, based on their special field of expertise. By doing it this way, the unveiling of “bad” design was detected earlier than it traditionally would be.

The consultants imports the model from the architect to their tools, by using a specialized IDM that specifies what information the specific software and field have use for. After this, the necessary shaping and dimensioning takes place. The results is sent back to the BIM and the BIM gets enriched with information from all involved stakeholders.(Figure 30.) This leads to an early understanding of the project, and clashes between the fields were avoided in a much higher scale.

The builder, Statsbygg, has through the whole project had the possibility to follow the development through 3D-vizualizations as the project evolved. This has led to a broader understanding between the projection-group and the builder, and has made it easier to account for the nonconformities. This was especially visible during the project meetings, as the BIM was used to visualize the project up to the highest level of detailing.

As the project still is in the preproject-phase, it will take sometime before the real building can begin. The vision for the rest of the planning is to make the calculation of material costs and energy consumptions as accurate and simplified as possible. As the quantity-list can be generated from the BIM directly, it gives a good estimate of the costs of the project. If there are any corrections later on in the project, the BIM will automatically be updated and the calculations could easily be performed.

When the tendering-phase approaches the information needed, is all available in the model. By using 3D- visualizations, the builder can get a good impression of the project.

The illustration under (Figure 30) shows how the flow of information would be in a BIM building process. The consultants all communicates through a joint model, they all have access to the same information. When changes are made, independent of in which field, the BIM is updated and the consultants get access to the change instantly.

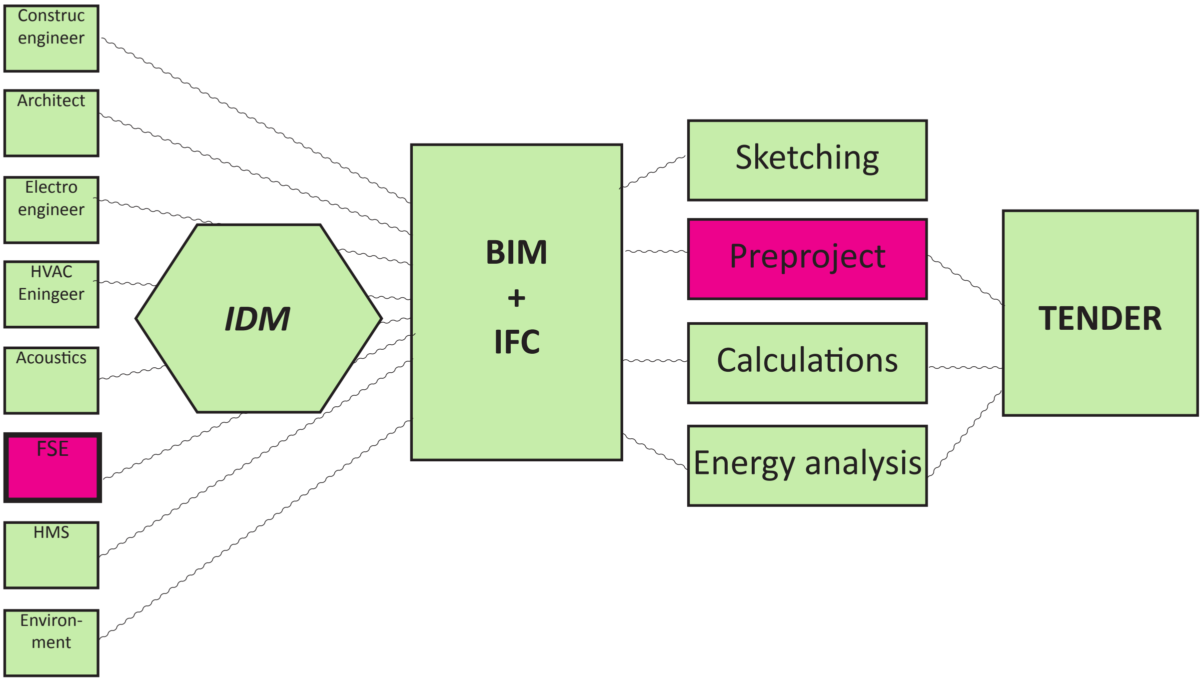


Figure 30 - *The idealized BIM information model*

5.2.3 Attainment of goals and demands

The UiS-project was, from the beginning, meant to have an environmental friendly profile. Some requirements were set, but as the planning started many years ago, the requirements the project group sat was already outdated. The new regulations and instructions make it impossible to build the UiS-project without meeting the original demands. This means that the new building of the University of Stavanger will not be anymore environmental friendly than any other building that is being built today. In one way this is not according to how the project originally was planned, but on the other hand the requirements from the building program is accomplished. It indicates the improvement of the regulations that has happened the last couple of years, regarding environmental issues.

The field of fire safety in the UiS-project, was as mentioned not one of the field included in the BIM. This could be because the FSEs are premise givers, and does not necessarily follow the whole projection, or because the fire aspect of BIM is not yet implemented, which this paper could bring one step closer to. The FSE in the UiS-project , Egil Kvamme (Multiconsult), expresses his experience with BIM in the UiS-project as a "show-off", with no practial signification or improvement on his field. He emphasizes that it has been positive to see the possibilites in BIM and get an idea of how the development evolves, apart from that, his delivery to the project has been as traditionally.

Figure 31 - *Old FPE 2D-paper vs. idealized BIM, with automatically generated digital 2D mapping of the escape routes*

One of the goals with the using of BIM in the UiS-project, was to do energy analysis' based on the IFC- model of the buildings. According to Multiconsults Magnus Killingland, this is has no reason to be problematic, as IFC has come far considering the energy aspect of buildings. When the model first was imported to the energy-software, RIUSKA, the importation was problem-free. As the project evolved and the model got more and more detailed, the problems started to show. According to Magnus the model got to complex. His opinion is that everyone is so busy adding information to the model, that they forget if the information is relevant. This understates the relevance of making IDMs, which filters the relevant information to the correct receiver.

He also emphasizes that some of the information is incorrect, and not in accordance with the IFC coding, and points out how it can be a problem that architects choose objects that are not yet connected to the IFC-library, and may not be exported as they should from the CAD software. Making the import to the energy simulation software unreliable, and the result incorrect.

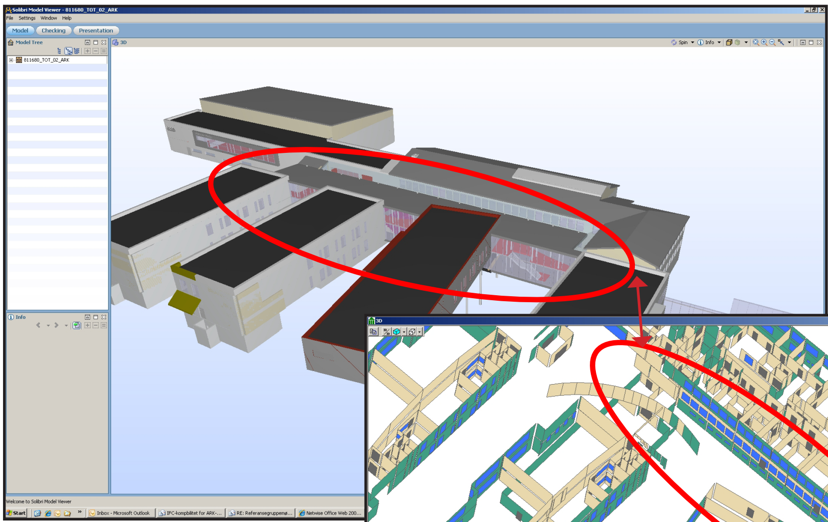


Figure 32 -
Midtbygda School (Solibri)

Figure 33 -
Midtbygda School (Riuska)

The following pictures are taken from another Multiconsult BIM-project, Midtbygda School. From figure 32, one can se how the buildings are connected with a hall of glass. The figure is taken from Solibri model viewer. On the next figure (33) from Riuska, one can see how the glass hall has disappeared in the import to Riuska, making the space between the buildings invisible. This would make the results from energy simulations in Riuska incorrect and useless.

This problem can be looked on a parallell to how this building would appear in a fire simulation software. As the export from the architect-model would be the same. This problem emphasizes the need for IDMs and accurate property sets in BIM. What information is needed to perform a fire simulation is discussed in the next chapter.

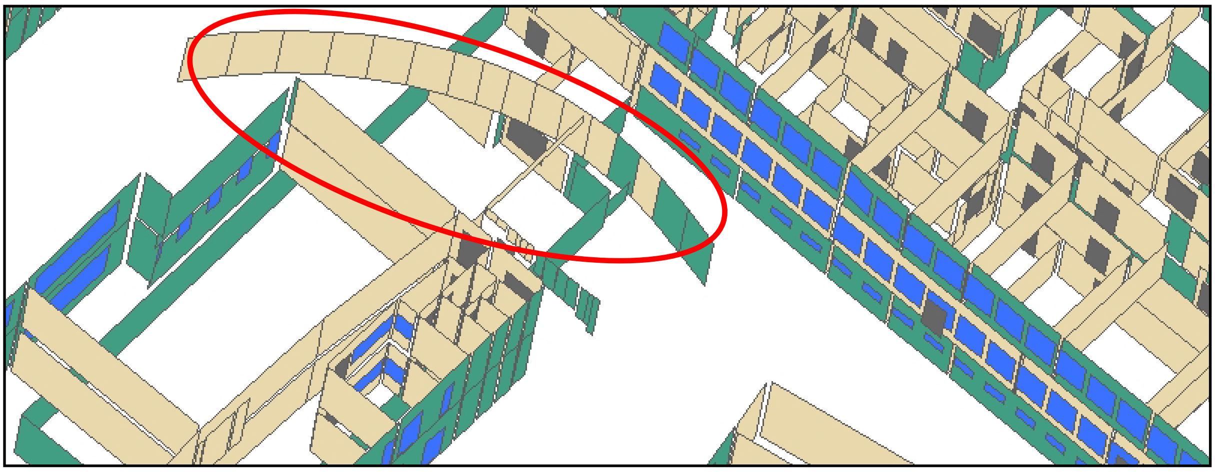


Figure 34 - *Curtain wall (glass), imported to Riuska for an energy analysis. (Riuska)*

The figure shows how the software chosen to do the energy consumption analysis, RIUSKA, get incorrect information from the CAD-tool utilized, ArchiCAD. In this example the “curtain wall” which in fact is made of glass, is red by RIUSKA as a normal wall. This will make the result of the simulation inaccurate. The reason for that this glass-wall is red as a wall, is that it is a new application from ArchiCAD, and that it might not be updated to the IFC2x4. The figure (34) is generated from Riuska, which labels the curtain-wall with a “wall-color”, it should have been shown as blue, like all the other glass.

Multiconsult has also experienced difficulties in the cooperation with Statsbygg in the UiS-project. Statsbygg, the builder, wants to be in total control of the project. From the beginning dRofus was used in the programming. The programming is traditionally a term of contract, in which in this project was substituted by dRofus, to make the most out of the intended mindset of utilizing BIM. Statsbygg did not approve dRofus as a replacement, making Multiconsult have to deliver the room programming in the traditional way, in addition to dRofus. This led to a multiple jobholding on Multiconsults behalf, which is one of the main objectives of avoiding in BIM.

Thor Ørjan Holt (Multiconsult) emphasizes the positive effects BIM has had on the project. He express how the decision-basis has has been stronger with BIM. The decisions could have been made at an earlier point in the projection, because of the effects BIM has given. The restrictions has, according to Holt, been contract terms. There is a high potential of customizing the contracts to fit a BIM mindset. If this is not done, the fully potential of BIM will not be utilized, claims Holt. (Holt, 2009.)

5.2.4 Challenges

Some of the challenges regarding a collaboration in BIM is to have a common understanding of the content of model through the project. This is important in exchanging models between the fields. By having declared the definitions of what information the model should consist of in the different phases, the frustration of that the imported model lacks information that can delay the project is eliminated. This is where it can be relevant to look at a way of defining the BIMs content of information. The model will through the whole project get enriched, and the amount of information will as a consequence of this increase gradually, a filtration of information is necessary.

This paper looks at how the Danish divides the level of information, chapter (2.3.3). (There is not yet been published a Norwegian report on this.) Defining clear levels of information between stakeholders and attach these to the different stages in the building process, could be helpful for the different fields and in contracts and in the development of IDMs. A change in the contracts is clearly a consequence and challenge to the introduction to BIM, but could for the FPE be a step closer of getting the fire concept better integrated in the building process.

Until now the builders have not required an utilization of BIM in their projects, but this is about to change as Statsbygg already have signified. This demand leads us to several other obstacles in implementing BIM, as the challenging mentality in the construction industry. The lack of expertise on the subject will clearly be one main issue, as the industry is conservative and not willing to change. BIM is based on an idea of being “open”, which until now has not been the situation. The engineers’ wants to keep their secrets to themselves and are afraid of what changes an introduction to BIM might give on their working-life. The people involved in building projects does not recognize the benefits of BIM, their attitude towards it is negative, and their willingness to learn is low. (Valen, 2007) Some will even claim that the restrictions (costs) are higher than the potential (savings).

Earlier in the paper it is mentioned that the focus on the early phase of a project must not come in conflict with the architects creative thinking. This is also a big challenge in BIM, as the time designing will somewhat be shortened down, by implementing the other fields earlier.

are given, making is more user-friendly for others than the developers .

5.3 “Tools” for implementing the fire safety considerations to the model

This paper looks at the possibilities to utilize BIM as a tool for the considerations of fire safety in buildings. Today there is no wide spread procedure on how this should be done in the construction industry. A preconseption of being able to implement the work of FPE into BIM, is that the format, properties and IDMs needed on this area is fully developed.

5.3.1 Property sets

One of the biggest challenges due to the developing of BIM to be a usable tool for an implementation of the fire protection consideration of buildings is to find a standardized way of documenting the fire measures of products. A standardization of products is important in the work in imposing information to different IFC-objects. To get the IFD to reach the right information in a database, the way the documentation is handled is important. It has to be standardized in order to help the IFD to find the relevant information. At the moment one is working on giving all objects a GUID-number, so the information is easier to recognize, independent of which language the information is generated in. This is a comprehensive work,

Name	Property Type	Data Type	Definition
MainFireUse	IfcPropertySingleValue	IfcLabel	Main fire use for the space which is assigned from the fire use classification table as given by the relevant national building code.
AncillaryFireUse	IfcPropertySingleValue	IfcLabel	Ancillary fire use for the space which is assigned from the fire use classification table as given by the relevant national building code.
FireRiskFactor	IfcPropertySingleValue	IfcLabel	Fire Risk factor assigned to the space according to local building regulations.
FireHazardFactor	IfcPropertySingleValue	IfcLabel	Fire hazard code of the space. The coding depends on the national fire safety regulations.
FlammableStorage	IfcPropertySingleValue	IfcBoolean	Indication whether the space is intended to serve as a storage of flammable material (which is regarded as such by the presiding building code. (TRUE) indicates yes, (FALSE) otherwise.
FireExit	IfcPropertySingleValue	IfcBoolean	Indication whether this object is designed to serve as an exit in the case of fire (TRUE) or not (FALSE). Here whether the space (in case of e.g., a corridor) is designed to serve as an exit space, e.g., for fire escape purposes.
SprinklerProtection	IfcPropertySingleValue	IfcBoolean	Indication whether the space is sprinkler protected (TRUE) or not (FALSE).
SprinklerProtectionAutomatic	IfcPropertySingleValue	IfcBoolean	Indication whether the space has an automatic sprinkler protection (TRUE) or not (FALSE). It should only be given, if the property "SprinklerProtection" is set to TRUE.
AirPressurization	IfcPropertySingleValue	IfcBoolean	Indication whether the space is required to have pressurized air (TRUE) or not (FALSE).

Figure 35 - *Table of Pset_SpaceFireSafetyRequirements (BuildingSMART)*

and still in the developing phase.

Today the IFC-format does not support the fire considerations of a building in a large scale. The property sets that are developed on the area is poor and in some extent not relevant for what a FPE or architect would need of information. In figure (35) you can find a fire property set for a space in a building; Pset_SpaceFireSafetyRequirements, but one could also imagine having property sets like this for all relevant objects, such as walls (ex. Pset_ WallFireSafetyRequirements), which is suggested in figure (30). This would be desirable to cover all areas needed for accomplishing a sufficient analysis of the fire safety in buildings through BIM.

The programmers have to opportunity to turn on and off properties in the porperty sets ("Implementers agreement"), this will help strain the information, so no unnecessary information is imported/exported between the different applications. This means that there are no limit of how many characteristics or property sets one can make. The question is how to navigate in the property sets when there is so many to choose from. One would need a “guide” to filter the information one is looking for. The figure (30) shows some of the characteristics a wall could consist of, concerning the fire protection of buildings.

Name	***Property Type***	***Data Type***	***Definition***
FireResistanceRating	IfcPropertySingleValue	IfcLabel	Fire rating identifying the entirety’s fire resistive value (e.g., 1-hour, 2-hour, etc.) so that its resistance to fire can be compared to that of the surrounding structure.
IfCombustible	IfcPropertySingleValue	IfcBoolean	Combustibility (YES it is combustible or NO it is not combustible).
SurfaceSpreadOfFlame	IfcPropertySingleValue	IfcLabel	Surface spread of flame characteristics.
SmokeProduction	IfcPropertySingleValue	IfcLabel	Production of smoke when on fire.
RateOfHeatRelease	IfcPropertySingleValue	IfcLabel	Release of heat.
Toxicicty	IfcPropertySingleValue	IfcLabel	Release of toxic gases.

Figure 36 - *Suggestion for Pset_WallFireSafetyRequirements*

The challenge is that engineers are not programmers, and would not find it efficient to go through property sets and characteristics to find what he is looking for. This emphasizes the need for a standardized system of property sets and characteristics, which is easy to navigate in for the “normal” engineer.

For the FPE all the parameters in figure 35 are relevant, but not necessarily needed to perform a simulation. The IDM between the architects model and the a smoke simulation software is suggested later in this chapter.

5.3.3 *E-COMMERCE*

One of the solutions could be to develop fire documentation, property sets, that follows the products through the whole building process. This would give the executer, the planner and the builder an overview of the products abilites due to fire protection. This has already been done for the documentation of the environmental aspects of products, ECOProduct, and it should be no different for the fire protection. The CE mark of products could be look on as a parallel to the ECOProduct, as they ensure the quality considering the health, environment and safety of the products. But this is not a satisfying marking due to fire protection measures, as it involves more than the parameters listed in the CE today.

By developing a database where one could find the fire protection documentation of each and every product, would give the opportunity to compare the different products, to make sure the choice of product is optimal. This again emphasizes the need for further development of property sets and IFD.

BIM have the opportunity to support E-commerce, one can in the future see a possibility to use IFC for buying products online. This has a huge potential, but one would first have to develop databases representing the products available on the market, and sufficient information about the products documented on a standardized format. With the utilization of e-commerce, the BIM would be enriched with the specific product information as the products were purchased. This information could be fire safety, environmental documentation and technical descriptions of the products amongst other things. This is already implemented in the offshore industry, and there are no reason for it not to be a part of the building and construction industry.

5.3.3 Software

Solibri Model Checker

By converting building codes and knowledge into algorithms (checkers) that can analyze the digital information representing the building and report findings that need to be corrected in the design, flaws can be detected at an earlier phase in the projection, more efficiently than traditional, which also makes them less costly.

Solibri is a software application that analyzes BIM-using the open IFC format. It offers visualization with walk-in functionality, highlighting clashing components and checking that the model complies with the building codes, program requirements (figure 37) and international and national standards etc.

As Solibri Model Checker (SMC) is a non-intelligent program it will be impossible to use the program to define which walls should be of a specific fire resistance class, but it can check if all the walls have been classified and if the fire resistance class on the wall and window/door are united. It can also check if the walls have been given a sufficient fire resistance class based on the fire class and risk class of the building. This would be a programming matter where the Model Code Checker (MCC) would have to check if the object in a specific fire zone is higher than a given class. (Boolean). If the walls did not satisfy the demands for that specific class, the checker would tell by giving the walls a different color or in other ways. (Figure 38)

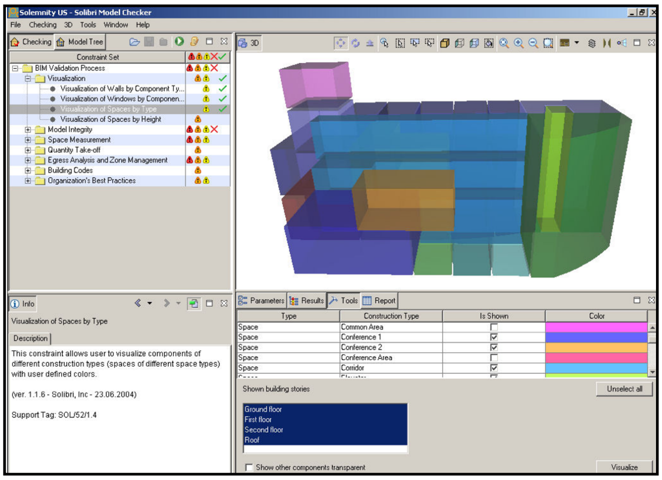


Figure 37 - *Solibri vizualisation of the building program*

Solibri have the opportunity to check if the geometrical demands for escaping a fire is fulfilled. This because the instructions from the government states a demand of how far the nearest emergency exit can be from any given point in a building. (Kvamme, 2009). This includes that the distance from the emergency exit is satisfied, that the width of the escaping route are wide enough, that the opening mechanism on doors are specified, that the hand of the door are right and that the sectioning of the building is done according to the fire concept.

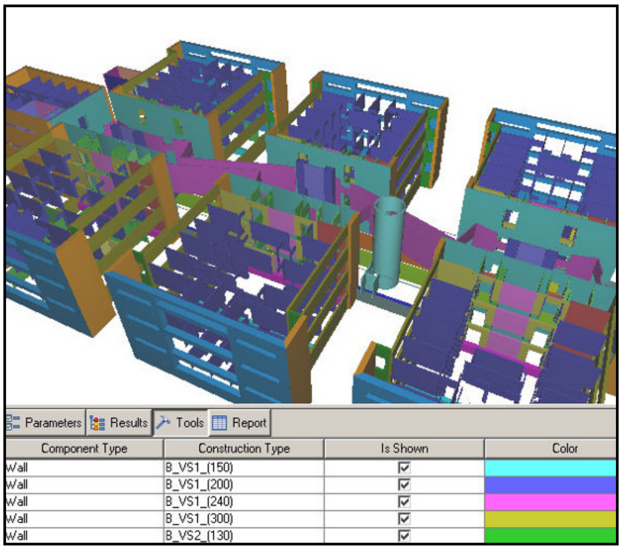


Figure 38 - *Solibri vizualisation of different wall types*

Solibri can check if there are a sufficient amount of fire hoses in a building, based on the area that is available from the design, but it cannot locate the fire hoses itself. That would be up to the architect to do, as the FPE does not have access to any model. Which leads to a question of responsibility which is further discussed later in the paper.

How Solibri can consider the geometrical demands of a building is already done by implementing some requirements for the Universal Usability of a building. (Figure 39)These tests are based on the a scheme for a new ISO-standard. Solibri reviews the building based on some of the elements in the ISO-standard, and uses specific parameters chosen by the user or the regulations to check if the demands are fulfilled. This is shown in the figure on the next page (39).

This means that the regulations must be transformed into “mathematical” measureable values. This because this is the only language the digital MCC understands. The easiest is to translate geometrical and physical demands of a building. This could in the view of universal usability be turningcircles for a wheelchair (figure 39), the width of the doors and so on. In a fire safety point of view, this could include the distance from each point in a building to the nearest emergency exit, or fire hose, the width of the escaping route amongst others. (Figure 40).

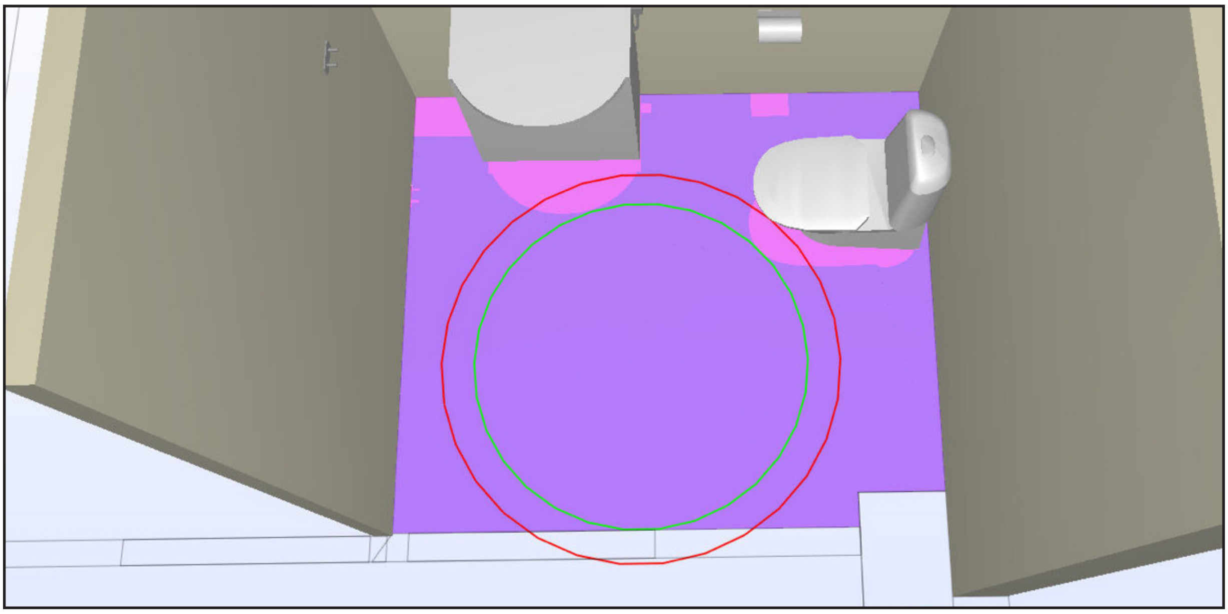


Figure 39 - *Solibri used to control the universal usability in a building*

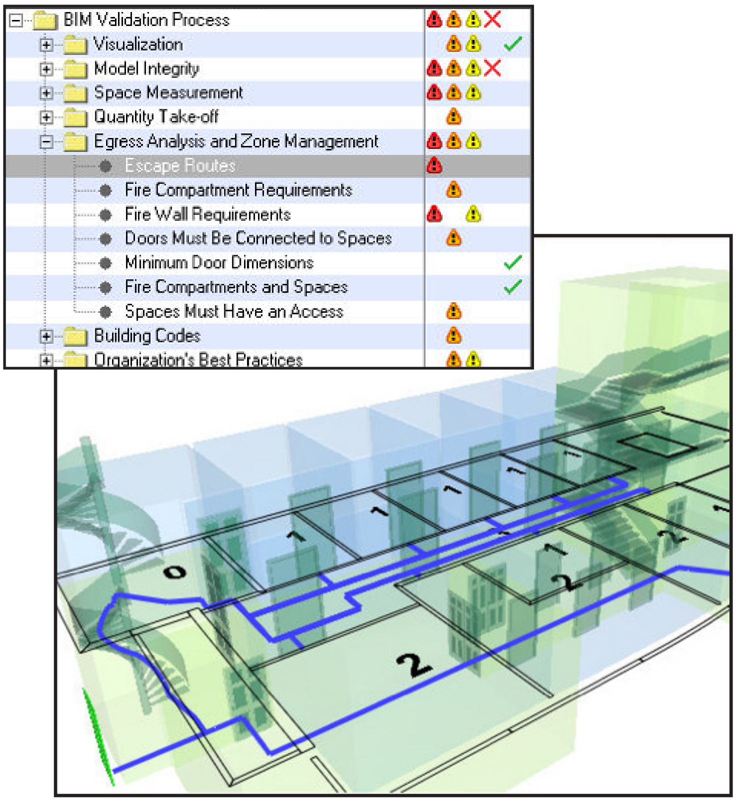


Figure 40 - *Solibri used to mark the escape routes in a building*

The important is that the requirements has to be translated into a language the software can read. The considerations a FPE does, is often based on knowledge and not always possible to translate into geometrical measures. What happens to the algorithms when sprinklers is installed or if a glass wall is changed to a more solid material which will behave differently in a fire safety point of view. This is parameters that a computer would have difficulties of handling, making the role of the FPE somewhat unchanged. (Figure 41.)

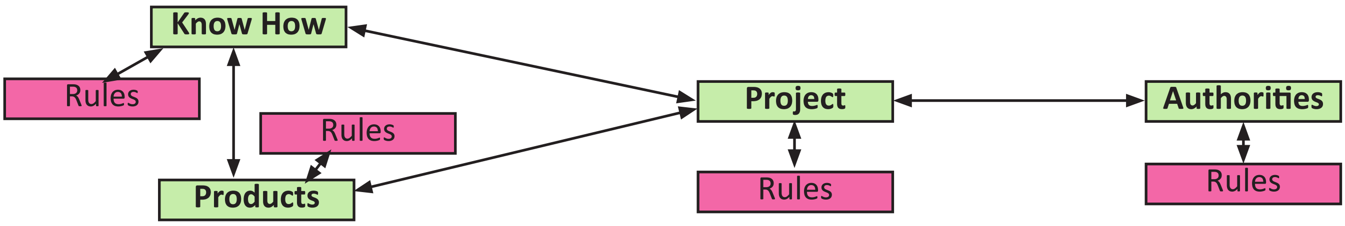


Figure 41 - *All rules converted to algorithms can be checked in the building process*

The figure 36 is based on an empirical use of Solibri Model Checker to check if all the walls have been given a specific fire resistance, other model checkers may also be utilized. The figure (42) shows that the wall would get a different color (in this case green), or give another warning signal, if it was not given a specific fire resistance in the architect model. Including the fire resistance to the walls in the model, the fire concept will be better implemented and the possibility that the correct fire resistance is chosen for the right wall in the execution is bigger.

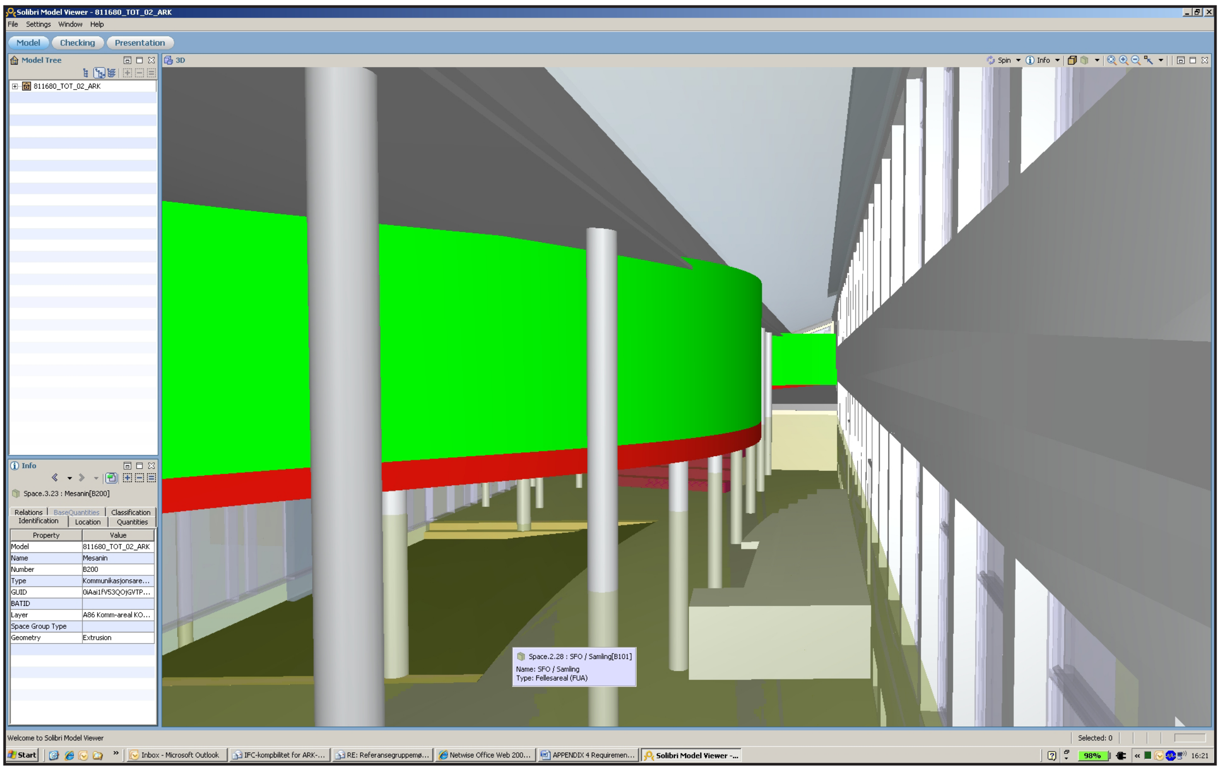


Figure 42 - *Empirical use of Solibri to check if the walls has been given a specific fire resistence*

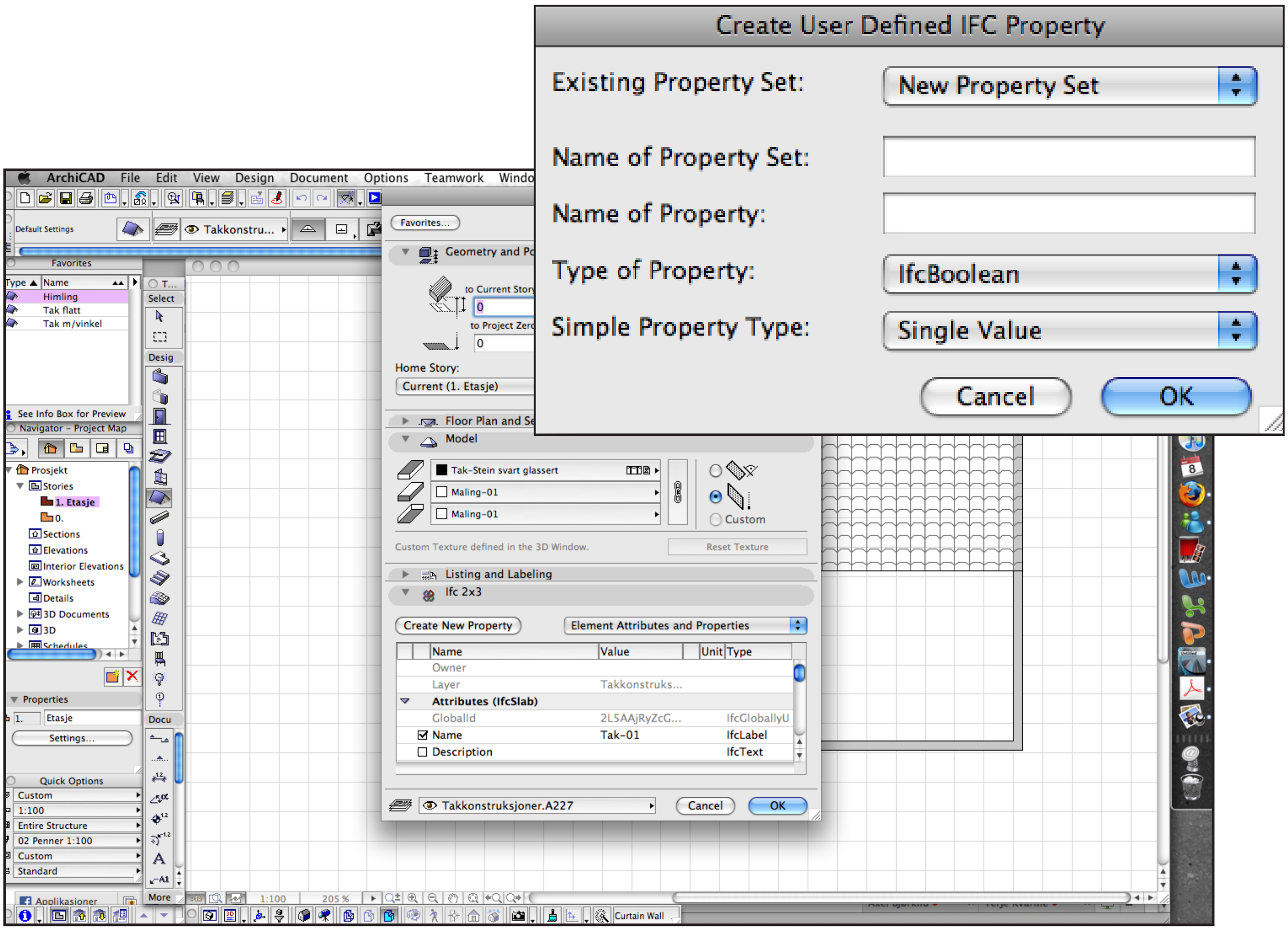


Figure 43 - *Making property sets in ArchiCAD*

ArchiCAD

This software is an architect application used to design buildings. ArchiCAD has, as shown in the figure (43), the opportunity to generate property sets. This is an adjustment made by Graphisoft to make the software more compatible to the use of BIM. Earlier in this paper the importance of developing a standardized system for property sets is discussed, this is one of the main challenges ArchiCAD is fronting when giving the opportunity to create own property sets. What happens if the user gives objects characteristics that are not approved by the IFC-format, this could create problems for the software that are importing the architects model.

Up until now most engineers has chosen to model the architects model over again, even though the possibility for an import has been available. The architect-model has, in best case, been imported and used as a "background", a reference-model. The reason for that the engineer chose to rebuild the model is that it has been more time-consuming to debug an inaccurate model, than build it all over with the architects' model as reference.

The engineer is responsible for the documentation he produces, and wants to have control of what he is doing, and therefore also control that the model is correct. This leads to a more complex problem, how to import a model of a low level of accuracy into a program which requires a high level of precision? And how can one fast and simple "fix" the model, and in the same time have full control?

To run an analysis the need for accuracy is high. By have a small error in the architects model, the analysis may not be accomplished, or the result might be useless. As one of the architects in Link-Signatur explains:

"*The architects often utilize some of their own libraries, which they have created themselves and that are not compatible with the open standard IFC. This could be a small detail as a door sill, which the architect software does not have a satisfying object of. The Architect will then have to create their own object, by extruding and drawing, in which they utilize where needed. This door sill will not appear in a IFC-file, as it is not included in the export of the model. This could be crucial for a possible analysis, as this would be an error in the model. In a fire or energy analysis, this door sill will function as an open space and let through both heat and smoke. This will off course be unfortunate for the analysis, which will end up being completely useless.*" (Skjelstad, 2009.)

On a 2D drawing a small error like this will not necessarily be any problem, as the door sill will not show as it is on a layer "under" the door itself, but with the introduction to BIM small errors like this could have a big influence on other fields.

Architect software as ArchiCAD is the only software available which have the opportunity to enrich objects with characteristics such as fire resistence. This significates that the architects model is also the only model in which the special fields, such as the FPE can complete his work of giving the objects the properties they are given in the traditional fire concept. But giving the FPE access to the architects model is not desirable, as he is not known with the software, and can easily change the design by accident, without being aware of it. A solution to this could be to give the FPE access to a layer, whos only task was to add relevant properties to the objects. In this way the FPE would have the responsibility for his area, and the architect would still be in control of the design.

Another option would be to develop a software which only imported the objects needed for the FPE, in which the special fields could add their expertise to the model without interupting the architects work. A model like this could be appreciated by the field of acoustics, fire protection, those who labels the objects with environmental properties etc. (Figure 44).

Figure 44 - *Example of how one can enrich a model with information from the fields that traditionally are not related to a model*

dRofus

According to nosyko; dRofus is a "*dRofus is software developed to support different work processes in complex building projects.*" This includes the architectural programming, room requirements amongst others. Each room and building can be connected to a sheet that holds information on what the room/buildings function is, how many people it can contain, what kind of surface materials that are etc. By implementing the fire concept in the room database, the key information about the space and function of the room, including the furnishing (which could be important for a possible simulation), all the different parts and professions of the project can be updated on the fire safety considerations in the building.

"*The equipment database*" function in dRofus is a module for planning equipment and furnishing. By integrating the furnishing at an early stage of the project, the simulations from the FPE can be done with a higher level of reliability. This information is of high quality and details, which increases the level of details in design phase.

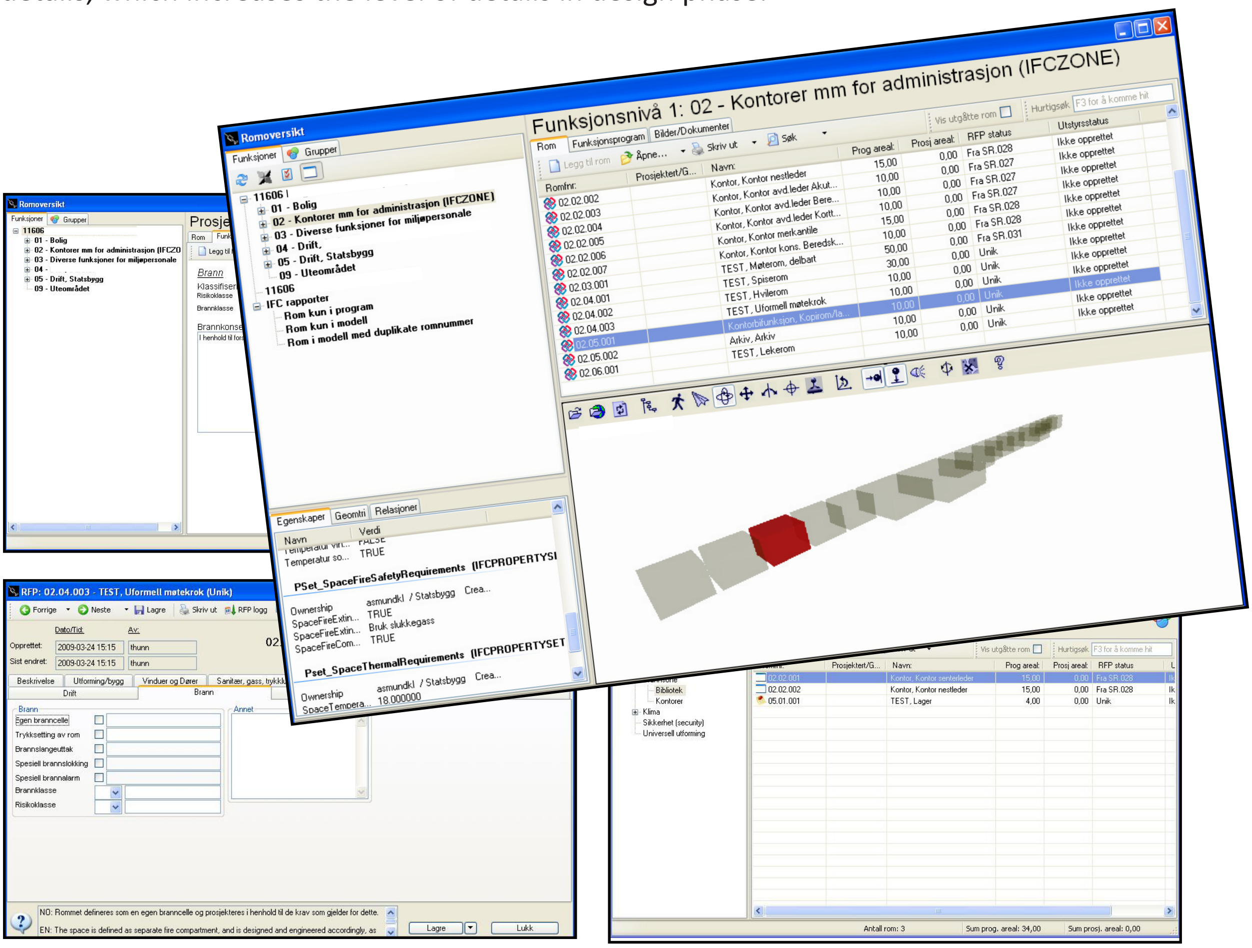


Figure 45 - *Example of how one can use dRofus to implement the fire concept to the digital building process*

Making dRofus a tool in the projection, the fire concept would be easier to reach. Because of the opportunites BIM gives regarding the interactive interaction between stakeholders, one would at all time have the correct and updated version of the fire concept in dRofus. (Figure 45.) Traditionally the fire concept has been comprehensive and difficult to navigate in. By connecting the class of risk and other fire safety parameters to rooms, spaces and buildings in dRofus, the availability of the fire concept would be better.

Simulation programs

By simulating different types of fire in a projected building, the FPE can get a better view of how a building would perform in case of fire. This is important, especially in in some of the complex buildings built today. With the introduction to BIM, the FPE would no longer have to model the building over, as one can import the architects model directly using the IFC-format. With this import it is important to know what properties is needed and wanted to perform the simulation, if this is not considered, the software may not be able to read the import correctly.

The level of detailing, is as mentioned, also important to maintain. Using a software such as, Fire Dynamics Simulator (FDS), the geometry of the building as well ass ventilation is the parameters needed. This means that the IDM, which is suggested in the next chapter, must be concentrated around the objects geometry, not as much the characteristics connected to the objects, as they are not integrated in the simulation itself.

The article “Sharing Fire Engineering Simulation Data Using the IFC Building Information Model” concludes that the standardized IFC can be utilized to achieve interoperability between electronic building models and fire simulation models. For this to happen the simulation software is depended on that the model from the architect identifies spaces, boundaries and openings, and the relationship between them.

FDS is one of the simulation software that is developed to be compatible with the new IFC-format. Since this development still is new, there are some challenges before it can be fully utilized. One of the examples is how FDS is built up by square-spaces, which makes the import of a curved objects difficult.

In the information table it is shown which information that should be used to perform a simple smoke simulation.

The table (48) shows the demands of information that is needed for an simulation of smoke development in a building. The IFC is lacking, as mentioned, a fully developed property set to cover all fire safety characteristics, as shown in the table. This can be done by adding new types of elements such as *IfcFireResistanceValue, IfcInflammability* or *IfcfireFumeEmission* as examples.

By implementing classes with elements such as the ones mentioned, the necessary considerations due to the fire aspect of the objects are easy to add. Today there are few property sets for this area of application available in the IFC-format. *IfcPropertySingleValue* is used both for the temperature and surface description of objects, this does not divide the description into the necessary parts needed to perform a simulation.

5.4 Suggestion of IDM

What the IDM is based on is further discussed in the chapter 2.2.3.

The general structure of the IDM for the Fire Safety in buildings can be divided into

1. Examine

2. Collect

3. Analyze

4. Report

5.4.1 The general IDM for fire protection considerations

The structure of the IDM	**Analysis of the fire safety in buildings**
Process Map A map of the process of analyzing the fire safety in a building and the production of the fire concept of the building, Figure (NUMMER) shows an IDM of the process of assuring the fire safety in buildings.	***Main Process:*** Evaluating fire safety ***Sub process 1:*** Check if the information is available in the BIM/IFD. gather necessary information from the model. ***Sub process 2:*** Collect information from the different standards and instructions. ***Sub process 3:*** Analyze the information from the BIM. Check if the fire safety in the building is according to the regulations and instructions. ***Sub process 4:*** Rapport the analysis to the BIM.
Exchange requirement A non-technical description of the information that should be available in the BIM, and accessible for analysis.	A description of the information that should be available to vomplete a fire safety analysis of a building. Figure 51 shows the exchange requirements needed for a analysis of fire safety.
Functional parts A technical description of the information that has to be available in the BIM to the architect and the FSE	Shows the information, which IFC-properties that should be available in the model, at a more detailed level. What attributes should have value. This information should be written so it can be read by a computer.

Figure 46 - *Suggestion of a superior structure of an IDM for fire protection considerations*

In figure 47 an suggestion to a process map for the consideration of fire safety in buildings is made.

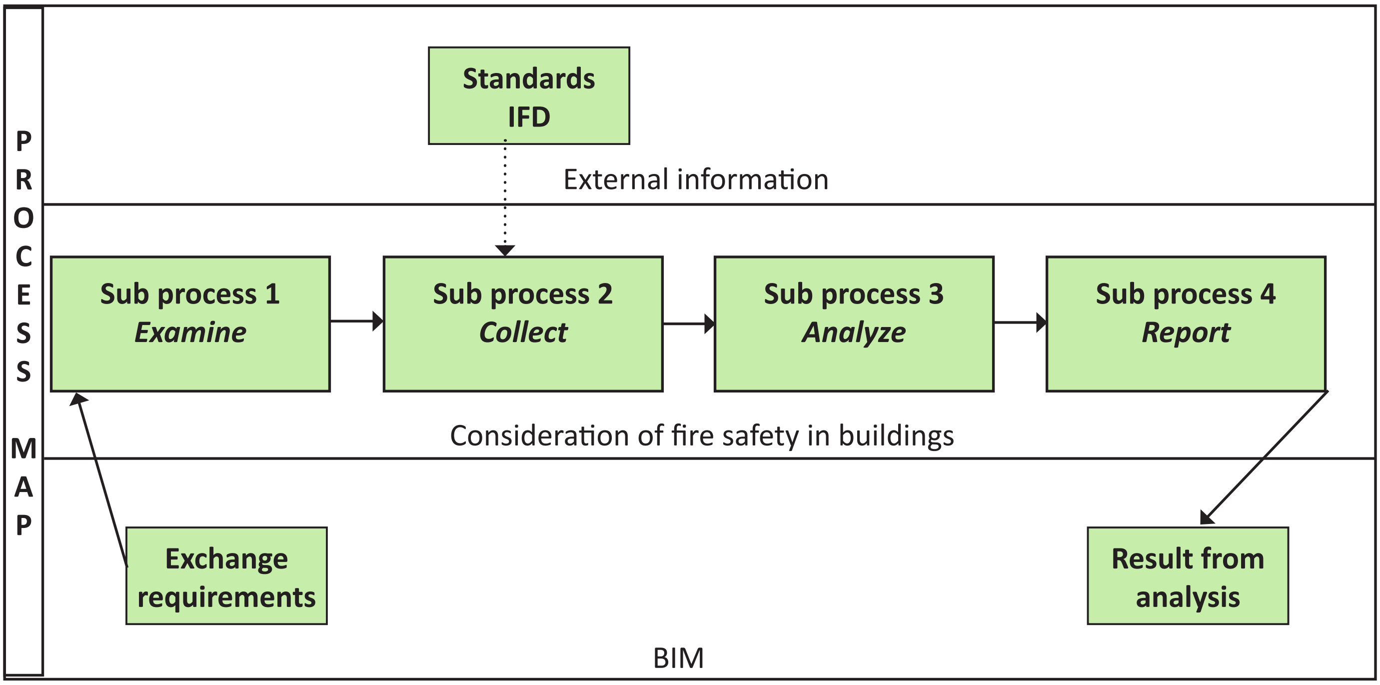


Figure 47 - *Example of a process map for the fire safety considerations*

In figure 47 the information needed to perform a analysis in a smoke simulation software is shown. The figure show the flow of information in the analysis, it is produced to visualize the information that makes the basis of smoke spread simulation. The IFC- 2x3 is utilized, as mentioned this IFC-standard is not fully developed regarding the fire safety in buildings.

5.4.2 Exchange requirements and functional parts

The figure 48 shows an outline of which information is required to perform an smoke spread analysis in a software like FDS. The simulation software is depended on that the model from the architect identifies spaces, boundaries and openings, and the relationship between them. This topic is formerly discussed in the chapter on tools for implementing the FPEs' work into BIM.

Exchange requirements			Functional parts
Information	*Specific Information*	*Value*	*Information import based based on the IFC 2x4 standard*
		IMPORT	
Building Geometry	Width Length Story height	mm mm mm	IfcBuilding IfcBuilding IfcSpace
Walls Roof Slab Door Windows		mm mm mm m^2K/W m^2K/W	IfcWallCommon IfcRoof IfcSlab IfcThermalResistanceMeasure IfcThermalResistanceMeasure
		CALCULATION	
Simulation time	Time	min	
Active fire measures	Sprinkler system Smoke/heat detectors	Y/N Y/N	IfcBoolean IfcBoolean
Temperature	Inside Outside	K K	IfcThermodynamic TemperatureMeasure IfcThermodynamic TemperatureMeasure
Ventilation	Air replacement	m^3/h	IfcAirTerminalType
		EXPORT	
Spread of smoke			

Figure 48 - *Suggestion of a superior structure of an IDM for fire protection considerations*

From figure 48, one can see that the column with functional parts is not completed. This is due to the lack of an extensive database to cover all fields of fire protection measures. New characteristics and property sets to fill in the missing parts is suggested earlier in this chapter, such as *Pset_WallFireSafetyRequirements.*

6 Discussion

6.1 The implementation of BIM

The use of BIM has increased gradually, and its usability differs from project to project. As projects involve a different need of information, due to its complexity and extension, the process of BIM will also vary. The complexity of a building will always be connected to the context of the building process.

At the lowest level of information-development are the standardized buildings. Prefabricated houses, gas stations (figure 49), big warehouses etc. have well defined functional properties and a fixed building character. In the process of building such buildings, the builder knows well ahead what is delivered, and the development of new information is low. Knowledge of the expected outcome is prescribed, including the design, construction methods, fire resistance and energy consumptions.

From a FPE point of view, these are buildings that are already analyzed and their job would not be of a significant character. The architect has already chosen the walls, in which already has a specific fire resistance.

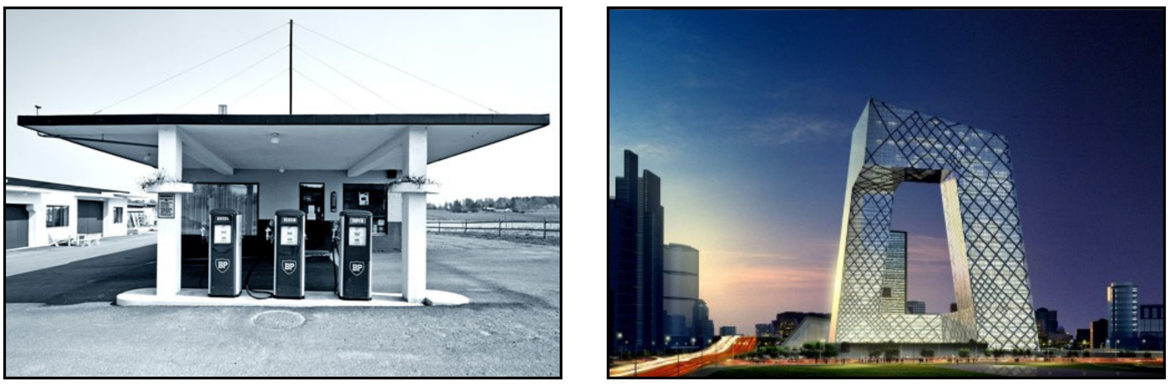


Figure 49 - *Shows the difference in complexity in building, Gas-Station vs. the new CC TV building*

In more complex buildings the FPE has to be more involved, as the information is not already developed for this specific building. This is where BIM is challenged. Who should be involved in the process of fire-classifying the objects, such as walls, columns, windows and doors in a building? As the FPE have no model to relate to, he has no option to enrich the joint BIM with any information. This is why the process of giving objects properties are highly depended on the building process and the complexity of what is being built.

Software, such as ArchiCAD, has the possibility to specify properties as fire resistance, to the objects in the architect model. The question is if this is the architects field of responsibility. This might be one responsibility the architect does not want, as it does not belong to his field of work.

With a rising level of information, the need for more detailed property sets is demanded. This is another challenge the implementation of BIM is facing. As these property sets is often developed by programmers that not necessarily have a background from the construction industry, the property sets holds information that is irrelevant and in some cases wrong.

Name	Property Type	Data Type	Definition
Reference	IfcPropertySingleValue	IfcIdentifier	Reference ID for this specified type in this project (e.g. type 'A-1')
AcousticRating	IfcPropertySingleValue	IfcLabel	Acoustic rating for this object. It is giving according to the national building code. It indicates the sound transmission resistance of this object by an index ration (instead of providing full sound absorbtion values).
FireRating	IfcPropertySingleValue	IfcLabel	Fire rating given according to the national fire safety classification.
Combustible	IfcPropertySingleValue	IfcBoolean	Indication whether the object is made from combustible material (TRUE) or not (FALSE).
SurfaceSpreadOfFlame	IfcPropertySingleValue	IfcLabel	Indication on how the flames spread around the surface, It is given according to the national building code that governs the fire behaviour for materials.
ThermalTransmittance	IfcPropertySingleValue	IfcThermalTransmittanceMeasure / THERMALTRANSMITTANCEUNIT	Thermal transmittance coefficient (U-Value) of a material. Here the total thermal transmittance coefficient through the wall (including all materials).
IsExternal	IfcPropertySingleValue	IfcBoolean	Indication whether the element is designed for use in the exterior (TRUE) or not (FALSE). If (TRUE) it is an external element and faces the outside of the building.
ExtendToStructure	IfcPropertySingleValue	IfcBoolean	Indicates whether the object extend to the structure above (TRUE) or not (FALSE).
LoadBearing	IfcPropertySingleValue	IfcBoolean	Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).
Compartmentation	IfcPropertySingleValue	IfcBoolean	Indication whether the object is designed to serve as a fire compartmentation (TRUE) or not (FALSE).

Figure 50 - *Property set for a Pset_WallCommon (BuildingSMART)*

In the figure (50) the property set of a common wall is described (*IfcWallCommon*). One of the parameters is “FireRating”. A fire rating of walls is not practice in the industry, as the fire rating most often would be of the whole building, not specific objects defining the building. A periphrasis of this specific parameter could be “FireResistance” as this is most probably the classification the programmers intended.

This is just one example of the challenges the industry and BIM is facing in the future. The need of a common vision on the different property sets have to be emphasized. IFC is ready to be implemented, but is challenging a problem due to its usability. If the properties are not standardized, BIM would be difficult to use as intended.

There are many countries involved in the development of BIM, which leads us to another challenge, a standardized reference system. Most countries have their own standards, use European standards, international standards or are not following any standards at all. This is a challenge because the property sets would have to be adjustable to fit the specific standard used in the project. The software will have to be adjustable to fit the standard used, and the technical specifications have to be standardized.

The signification of fire resistance could be of a different meaning in various places in the world. This makes the value of the property sets diffuse, because one is not always known with the signification of the different parameters. Foreign software could be an example of this, as they are based on standards other markets are not known with. This again can lead to mistakes and a BIM with a high level of wrong information, which emphasizes the need for an IFC standard.

The outcome of adding wrong information into the BIM also emphasizes the need of having people with experience from the construction industry to develop and program the software used. There are no help in a new version of IFC, if the people who are utilizing it do not know where and what the information they are looking for is. Having the right people with a relevant education help to structure the IFC, the chance of BIM being more user-friendly is bigger. This because of the underlying understanding, of that people with the same background and interests speaks the same "language".

Pset_FireRatingProperties		
☐ FireResistanceRating		IfcLabel
☐ IsCombustible	False	IfcBoolean
☐ SurfaceSpreadOfFlame		IfcLabel

Figure 51 - *Adding properties to objects in ArchiCAD*

ArchiCAD one of the applications where one can define the fire resistance of objects. As the figure (51) shows, ArchiCAD gives the opportunity to make own property sets .

This can in many situations be useful, such as to add the fire resistance of objects, but it can also create problems, as there are no common reference system in which is used. This means that each architect can create their own reference system which would be exported from ArchiCAD and imported by software, without having defined what the current parameters are. (Figure 38). Small differences in their "coding" would be crucial for any import/export of the model, as computer software does not notice small differences in the programming.

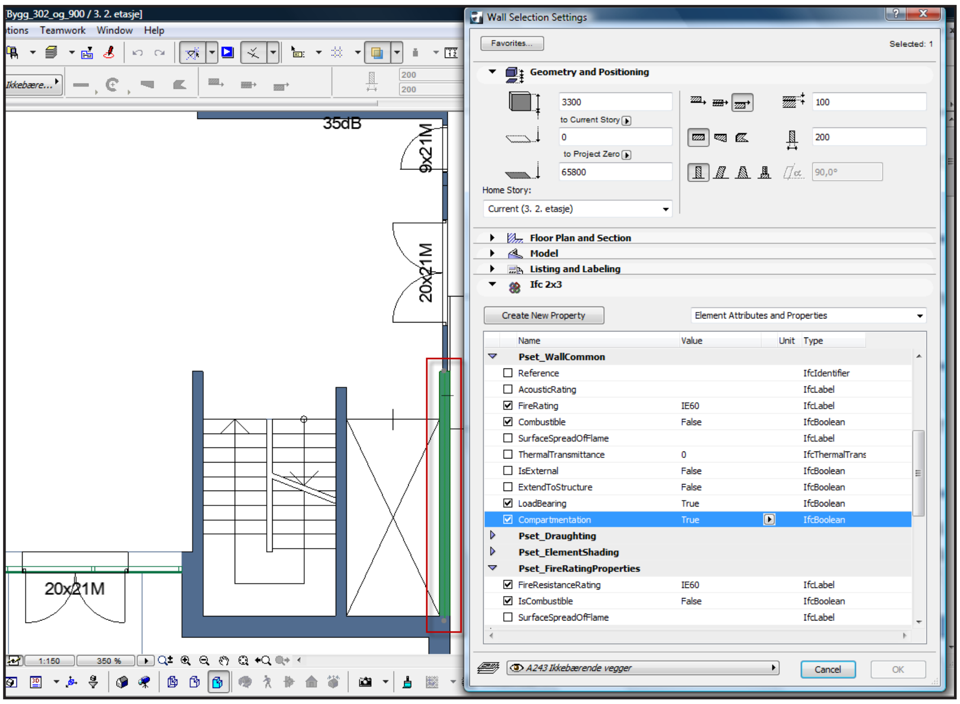


Figure 52 - *Adding property sets in ArchiCAD (Goderstad, 2009)*

The complexity of the building could also create a problem for this application of ArchiCAD, as more information has to be added, in which could create a problem due to the IDMs developped. The IDMs and property sets has to be of such quality that no unecessary information is exported or imported to the different profession models. Unecessary information can for stakeholders be confusing and lead to misconceptions and errors in the software.

As mentioned this paper concludes with that IFC is not the retaining factor in the implementation of BIM. The stakeholders are.

6.1.2 The influence of BIM on the building process

In the chapter 2.1. the traditional way of projecting is described. The information is here normally exchange by 2D- files (dwg or pdf) and "notes". The information flow is coordinated by the project supervisor through project meetings, where the different fields' solutions are discussed. These meetings can be looked on as a "tool" for the interaction between the parts of the planning, to prevent clashes and collisions between the fields. Empirical the time and resources used on coordinating the information is beyond reasonable.

BIM can take part in making the flow of information more streamlined. The effects of creating a joint BIM, with all the information and which all stakeholders in the project has access to, is highly welcome and an innovative thought in the conservative construction industry. The project-meetings will still, be a good "tool" for the interaction, but BIM will decrease the time used on these meetings, as the exchange of information more rationally can go through the BIM, as experienced in the UiS-project.

In the project-meetings of the UiS-project, the BIM was used frequently to navigate in the buildings. This made is easier for both Statsbygg and Multiconsult to get a good visualization of the project. The basis of discussion and solutions was in the project more profound than it would have been with the normal procedure of projecting.

As the information that was added to the BIM early on in the project was accurate, it was of a great value later in the project. Multiconsult and Statsbygg both emphasizes the importance of that the information is correct when enriched to the BIM, as it is of no value if not.

The new technology makes it possible to perform “loops” in the project, which was done in the UiS-project. Loops signify that it is possible to go back and forth in the project to evaluate the selected solutions. This was an example used when the builder wanted to cut the costs in the UiS-project, and the fire measures was evaluated. It became clear that, by not having sprinklers, the costs could be cut with 0,5 million NOK, after the rest of the building objects were considered regarding the new fire aspect. This is one of the “loops” the projection group did through the project.

One of the main challenges due to the introduction of BIM as a tool in the projection is the digitalization of the project. The first preconception is that the stakeholders’ software must be compatible with the new open, international standard, IFC. This work is still in progress, but one has already come far in developing IFC. In the UiS-project the problem was that some of the software was lacking an IFC-identification on certain objects. In particular this was problematic, when exporting the architect model from ArchiCAD, and importing it into e.g. Riuska, to perform an energy-analysis. What happened in the UiS-project was that some of the objects from ArchiCAD did not get the correct identification in the IFC reader. The “curtain walls” used in the architects model, as mentioned earlier, was red as normal wall in the reader, whereas they should be red as windows, to get a correct energy analysis.

This problem could easily be look on as a parallel to what would have happened if the model were transferred into a fire simulation program. As the preconceptions to energy analysis and fire simulations would be similar. A window due to a fire would behave differently than a wall. This “error” in the model would make the analysis useless, and emphasizes both Multiconsult and Statsbyggs view of the importance of getting the information in the model correct.

As not all the fields of the project are compatible with the IFC-format, this would give “holes” in the model, and the BIM would not have the same efficiency as it could if all actors in the project used the same format. The experience from the UiS-project was that the diverse software red the IFC files differently, this was also the case regarding the energy analysis, an led to that the same information was abound to be generated over. One had also to adjust the model in some software, to make it fit into the composition of the software used.

One other challenge the UiS project met, which also will be crucial in the further implementation of BIM, is the lack of proficiency and knowledge about the IFC-format, the process and the new software that all parts has to get into.

To get an efficient building process, the whole project relay on having competent people with the right professional background on the correct places. The work of manufacture user-friendly applications who supports the IFC model-servers is on-going, but the lack of competence is something the construction industry itself has to do something about.

The experience from the UiS-project is that stakeholders in the construction industry have little or no knowledge about the BIM-process. It requires a great effort in order to get an acceptable level of competence before the BIM-process could be used as a useful tool in projecting. The work has already started, and Statsbygg has claimed that they will use BIM as their tool in projects from year 2010. As Statsbygg is one of the biggest builders in the Norwegian construction industry, the smaller enterprises will have to follow their example and gather as much competence as they can, to be able to maintain in the business.

6.1.2 The influence of BIM on the delivery from the FPEs

As described earlier, the fire concept is delivered in an early phase of a project. The concept provides premises for the whole projection, which the project-group will have to maintain through the whole building process. If changes in the design are made, this must be considered in relation to the fire concept.

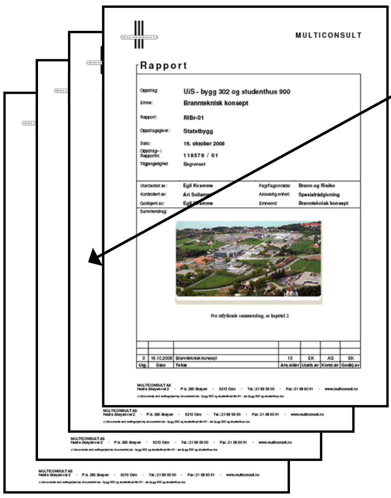
As the documentation in the traditional building process is somewhat difficult to navigate in, as all stakeholders involved does not have a clear view of where to find what information at what time, the potential of making the interaction between the fields better is high. By introducing BIM to the project, the fire concept would be easier to find, as it would be connected to the objects and spaces in the joint model.

In the UiS-project, the fire documentation was not implemented, and therefore there are no expertise or experience on the field. This paper suggests software and methods regarding how to implement the fire protection aspect of buildings into BIM. By implementing the fire protection considerations at an early phase into the BIM, the chance of that the relevant fields will consider it, is bigger.

By using different projection tools, such as dRofus, ArchiCAD and Solibri, the fire concept of a building is more available by all the parts in a projection. Having an easy access to the fire concept, and other premises, will make the foundation of choosing the optmized solutions better. As these decisions earlier often were based upon experience, the BIM is now the basis of what solutions could be made from.

The task of choosing and marking the walls with the correct fire resistance is not today a part of the architects work, but rather in the field of the FPE. This is one of the challenges the FPE will encounter with the introduction of BIM. This paper has emphasized the importance of that the stakeholders keeps their special fields separated, to get the best results.

The specific task of marking a wall with a fire resistance would be in the interface between the architect and the FPE, as the FPE have no model in which he can enrich. The architect could mark the walls with a fire resistance, by looking it up in the fire concept developed by the FSE, and add it in his model as this is an application in software such as ArchiCAD (Figure 46). The assurance and responsibility of this being the correct classification is not be defined. As shown in the figure 47 the resistance is given in a table, and not connected to a specific wall, but to the specific zones that the FPE has defined. The architect would have to go through the whole fire concept, to find the correct fire zone, to make the classification correct. The fire concept is difficult to navigate in, which makes it both time-demanding and inefficient for the architect to do.



Felles brannkrav for byggene

- Byggene fullsprinkles. Ledesystem i rømningsveier og fluktveier. Brannalarmanlegg i kategori 2.
- Brannkrav til hoved- og sekundærbæring er R60 og R30 på trappeløp.
- Brannkrav til branncelleskille er EI60 (vegg, dekke, dør), dør til rømningsvei kan ha klasse EI30.
- Brannkrav til overflater er In 1 og K1, i rømningsveier må kledning være ubrennbar dvs K1-A
- Hvert bygg er egen brannseksjon. Avstand til Studenthus / nabobygning minst 8 m. Evt gangbro og forbindelseskulvert må brannsikres særskilt.
- Brannslanger monteres slik at alle areal kan nås og merkes med etterlysende plogskilt.
- Brannvesen må ha kjørbar atkomst frem til hovedinngang. Brannkummer plasseres rundt bygget slik at alle fasader kan dekkes med maks 50 m slangeutlegg.
- Byggene er særskilte brannobjekter iht Brann- og eksplosjonsvernlovens §13.

Figure 53 - *Table from the fire concept (Kvamme, 2009.)*

To let the FPE go into the architects software to mark the walls with the correct fire resistance, would not be appropriate nor practical. The resources needed to make the FPE capable to use the software would be big and unwanted. The architect would reluctantly give the FPE permission to fumble in his design and artwork.

6.1.3 *INFORMATION MODELS*

The flow of information is one of the main challenges in the traditional way of building. The load of information is too much to handle, the information has to be stored manually in databases or by "notes". This way of exchanging information can often be untidy and inefficient. Information can easily "disappear", as one have to rely on one persons' ability to keep have the complete control over where the updated information is. This can lead to that information has to be regenerated, which is costly and unnecessary. The position of being a project-supervisor is connected to a big responsibility, as one has to make sure that the correct information reaches the right person at the right time.

In BIM one have the opportunity to add a large amount of information, the information is connected to the objects, which symbolizes specific products or characteristics. One has also the opportunity to connect the BIM to different product databases, such as Sintef Byggforsk or NOBB. This makes it easy to enrich the BIM with technical solutions, fire documentation, cost estimation and so on. This will also be a part of securing the flow of information in the project. When the information is added to the BIM, the information will follow the life-cycle of the building. In this way the BIM can help the project group in making decision on a more solid foundation. This again leads to fewer flaws, less costly buildings and a shorter process of projecting.

The conclusion to this paper is that there is a desire and need for an application where one can add qualities to objects in the model, without having to use applications crosswise the fields. This is desirable for all the special fields of a project, such as; acoustics, fire safety, specifications of environment solutions in a building etc. These fields have not necessarily their own model, but functions as premise giver for the whole building process. With the introduction to BIM, they would need an application to be able to implement their premises into the model, rather than giving the premises as a traditional note.

Work is under progress due to the implementation of new fields to the IFC-format. The possibility to attach information due to fire protection is not yet completed, but this is something that should be done in order to be able to get a fully optimized BIM.

6.1.4 *Flow of information*

The exchange of information between stakeholders in a project is fronting a challenge due to the accuracy in the models. There is no use of a flawless IFC-export from the architect, if the accuracy needed to perform a fire analysis is not maintained. (The intention is not to represent the architects work as inaccurate, but the work of an architect is at another level of precision, with a different focus than engineers needs in their simulations.) This guides us to one important issue concerning the BIM mentality, the desire of still keeping the different profession separated. Even tough the models should be able to unite in one joint BIM, stakeholders in the project should still focus on their field of expertise. This should also concern the software of the different stakeholders as well, as an architects job is to create the best design possible, not to carry out smoke simulations.

The FPEs simulations are depended on a different level of detailing, depending on what analysis that is performed. In other fields of engineering, this detailing is crucial to get reliable results.

The solution to the "accuracy issue" in the models is up to the FPE to solve, as this is where there is anything to gain due to time and cost. It would not be desirable to instruct the architect to rise the level of detailing on his drawings up to an unnatural level. The question of responsibility is also an aspect that has to be reviewed, if the architect was to define the fire resistence of objects in the model. To be able to be responsible for a field, it is important to know what has been done.

The core point in the flow of information, between the architect and the FPE, is how to go from a low detailed architect model to a sufficient detailed model for the FPE, without having to model the building over, but still be in full control of the model and its contents. How is it possible to convert an architect-model to a simulation-model, without the concern that some parts are missing or that there will be flaws in the analysis?

A presumption for a converting like this would be a sufficient level of safety, regarding the export and import itself. One way to resolve this would be that the engineer at all times has to be updated on what changes are made. The changes has to be documented, if the architects moves a wall in his model, the wall could be shown as a different color or visualized in a different way in the model viewer, to tell the other parties that a change has been made. The FPE is then given a kind of control position, in which he can use to enrich the objects in the model with relevant fire demands as the model is changing, i.e. that a wall could be of a certain fire resistance if the wall signals a certain fire zone.

As the BIM allows the fields to attach specifications to spaces in the building, the FPE could also give the rooms characteristics as "special fire object", plans for furnishing etc. By giving the walls a certain quality the model can be sent back to the architect who can "update" his model with the new information, and change the wall into the correct thickness and fire resistance, making this information follow the model through to the joint model.

6.1.4 IDMs for fire protection

In chapter (5.4) a suggestion for an IDM for the consideration of fire protection is presented. This suggestion has to be further developed, before being implemented. As mentioned, the IFC-format is not ready to be used in full scale, regarding fire protection characteristics and measures. The property set *Pset_SpaceFireSafetyRequirements* is not sufficient.

A standard for IFC is a matter of necessity to be able to work with the joint model across borders and software. This standard would also make it easier to consider the characteristic values that

6 Conclusion

In this paper the potential of BIM for the FPE is discussed. By implementing the special fields into a joint model, the method of BIM would be one step closer of being an adequate tool in the planning, execution and management of a building.

The significance of implementing the fire concept at an early stage of the planning can be crucial for an assurance of that the fire protection of buildings is maintained through the whole life-cycle of a constuction. With the BIM-mentality the preproject-phase of projects is emphasized, and the communication between stakeholders will be more seamless and parallel compared to the traditional way of building, making the building process more efficient and implicit less costly.

By converting building codes and rules into algorithms that a Model Code Checker can analyze, the control of the model during its project-phase is improved. By implementing as many rules as possible, this would be a appropriate tool in the application of BIM. A challenge will be to concretize the non-geometrical rules and regulations regarding the fire protection of buildings.

There are benefits using a standardised format, such as IFC, but these benefits do not come without challenges. The ability to share the architects model between stakeholders has the potential to assist the FPE during the design process. The building design can quickly and accurate be transferred from the BIM into software for simulation etc. However, the mechanism for a correct import/export between the software are not trivial matters.

Users and software developers need to have a common view of what information is relevant. With different BIM applications and fire simulation programs, each in which differs in their specific requirements of an import/export, emphasizes the demand of a standardized IFC-library. This, including a further development of IDMs and property sets for the fields missing, are preconsumptions that has to be intact before the full potential of BIM can be utilized. Before this is developed the opportunities in BIM is in some way locked.

However, the biggest challenge for the implementation fire protection considerations to BIM is not the software nor the format, but the people involved. The knowledge of BIM in the building industry is low. Experience from the UiS-project shows that the treshold of using new IFC-software is too high. The advanced technical operations are difficult, making the project depended on developers from the software industry.

6 APPENDIX

8.1 REFERENCES

Andersen, H.C.2009.Agency of Planning and Building Services (PBE). P*ersonal correspondence.* 12.02.2009.

Baggetorp, M. 2007.*"Informasjonsflyt I byggeprosessen*", masterthesis UMB, 2007.

Bjørkhaug, L.2007.[Cited 20.02.2009]; Available from http://dev.ifd-library.org/index.php/Ifd:IFD_in_a_Nutshell

BuildingSmart, Unknown. "*BuildingSmart - den nye elektroninske måten å jobbe på.*" [cited 2008 21.01]; Available from: http://www.buildingsmart.no.

BuildingSMART 12.08.2008 [cited 20.02.2009]; Available from http://www.buildingsmart.com/about_buildingsmart

BuildingSMART, 2007. *"BuildingSMART and IFD"*. [Cited 27.02.2009]; Available from: http://dev.ifd-library.org/index.php/ifd:buildingSMART_and_IFD.

Byggforsk,1999. 220.010 *"Programmering av byggeprosjekter, Norsk byggforskinstitutt. Byggforskserien*",

Byggforsk, 1999. 321.025 *"Dokumentasjon og kontroll av brannsikkerhet, Norsk byggforskinstitutt.Byggforskserien"*

Det Digitale Byggeri & bips. 2006. *"3D arbejdsmetode 2006"*. Denmark.

Eastman, C., Sacks, R., Liston, K. and Teicholz, P. 2008. *"BIM Handbook, A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors."* New Jersey: John Wiley & Sons. Inc.
Eikeland, P. T. 2001. *"Samspillet i byggeprosessen"*. SiB, Trondheim.

Europe INNOVA initiative (coordinated by Svein Erik Haagenrud, Sintef), 2008. *"STAND-INN, A practical output of the STAND-INN project; Standards for innovation and sustainability in construction and facilities management."*

Haugen, T. I. N.D. [cited 20.02.2009]; Available from http://www.metamorfose.ntnu.no/dok/Paper99gothe.pdf

Goderstad, O. 2009 Graphisoft. Personal correspondence, *"BuildingSMART- workshop"*. Oslo, 23.01.09.

Haug, D. 08.02.2007. *"BIM i teori og praksis,BIM og Statsbygg for BA-nettverket."*

Hedemann. 03.03.2009. Personal correspondence. Interview at Veidekke, Oslo.

Hjelseth, E. 23.01.09. Personal correspondence, *"BuildingSMART- workshop"*. Oslo.

Holt, T. Ø. 2009. Multiconsult. Personal correspondence. Oslo, 23.04.2009.

Ingvaldsen, T. 2001, *"Skader målingpå bygg - grunnlag for systematisk, Prosjektrapport"* BYGGFORSK, 2001.

IAI, 2009. *"Information Delivery Manual, Guide to Components and Development Methods."* [Cited 27.02.2009]; Available from: www.iai.no/idm/idm_resources/idm_methods_guides/IDM2_Methodology_20071022.pdf

Jacobsen, R. 01.04.1997, *"Kontrollplaner og kontrollformer"*. [Cited 27.03.2009]; Available from: http://www.be.no/beweb/info/benytt/971/kontrollplan.html

Killingland, M. 2009, Multiconsult. Personal correspondence. Oslo, 23.04.2009.

Kvamme, E. 2009. Multiconsult. Personal correspondence. Oslo, 23.04.2009.

MacLeamy, Patrick. AIA. "The American Institute of Architects." [Cited:13.02.2009.] Available from: http://www.aia.org/SiteObjects/files/db_london_p4.pdf

Lyngtveit, T. 2008. Personal correspondence. Ås November, 2008.

Microsol resources, unknown. [Cited:13.03.2009] Available from http://www.microsolresources.com/CAD2008/revitArchitecture.cfm

Mohn, K. I. 2009 Personal Correspondence, "*BuildingSMART- workshop*". Oslo, 23.01.09.

Moum, A, N. D. *"ICT an the architectural deisgn process – introduction of an ICT impact matrix".* [Cited:10.02.2009] Available from
http://www.metamorfose.ntnu.no/dok/050708ICTHelsinkipaperAM.pdf

The National BIM Standard, 2006. [Cited:18.02.2009] Available from:
http://www.nbims.com

NOBB (Norsk Byggevaretjeneste)[Cited:14.04.2009] Available from:
http://www.nobb.no/nobb/

The Planning and Building Act (PBL- Plan og bygningsloven) , 2007.
"§ 97 - Kontroll med tiltak. Ansvarlig kontrollerende for prosjektering og utførelse"

Skjelstad, S. 2009. Personal correspondence, Oslo, 23.02.09.

Spearpoint, M.J. 2006. "*Sharing Fire Engineering Simulation Data Using the IFC Building Information Model",* University of Canterbury , New Zealand.

Statsbygg, 2008. *"BIM- manual - Versjon 1.00.*" 2008.

Statsbygg. 2007. *"Statsbygg går for BIM."* [Cited:14.02.2009] Available from:
http://www.statsbygg.no/Aktuelt/Nyheter/Statsbygg-gar-for-BIM/.

Sjøgren, J. 2009. Personal Correspondence, *"BuildingSMART- workshop".* Oslo, 23.01.09.

Sjøgren, J.(b) 2007. *"A smart way for implementation of standards."* [Cited:14.04.2009] Available from:.
http://www.s1000d.org/events/OSLO/Thursday/buildingSMART%20-%20Jons%20Sjogren.pdf

Strafaci, A. 31.09.2008, *"Building information modeling and sustainable design for civil engineers. "*[Cited:29.01.2009] Available from:http://www.cenews.com/article.asp?id=3137

Technical Regulations under the Planning and Building (TEK- Forskrift om krav til byggverk og produkter til byggverk), 2007.

Teknisk Ukeblad, 2009. *"Rekordår for Multiconsult."* [Cited:10.05.2009] Available from
http://www.tu.no/bygg/article208583.ece

Ulfsnes, M. K. And Danielsen, U. 2004. *"Ivaretakelse av branntekniske krav i byggeprosessen"* 2004, Sintef, Trondheim.

Valen, M.S. 2007. *"Barrierer mot bruk av bygningsinformasjonsmodeller"*. NTNU, Trondheim.

Wix, J. unknown. "BuildingSMART - What is BIM." [Cited 15.03.3009.] Available from: ftp://ftp.buildingsmart.no/pub/idm/learning_materials

Øvernes, 2007. *"Det virtuelle rom, et sted å rasjonalisere byggeprosessen?" UiS, Stavanger.*

8.2 ILLUSTRATION LIST

8.3 SOFTWARE MENTIONED IN THE PAPER

ArchiCAD	*www.graphisoft.com*
Solibri Model Checker	*www.solibri.com*
Fire Dynamics Simulator (FDS)	*www.fire.nist.gov/fds/*
RIUSKA	
dRofus	*www.drofus.no*

8.4 ABBREVIATIONS

AEC – Architecture, Engineering and Construction

BIM – Building Information Modelling or Building Information Model

CAD – Computer Aided Design

FM – Facility Management

FPE – Fire Protection Engineer

GUID- Global Unique Identifier

IAI – International Alliance for Interoperability

ICT – Information and Communication Technology

IDM – Information Delivery Manual

IFC – Industry Foundation Classes

IFD – International Framework for Dictionaries

KBE – Knowledge Based Engineering

MCC - Model Code Checkers

NHF - Norwegian Association for Disabled (Norges Handicap Forbund)

NS- Norsk standard (Norwegian Standard)

PBL – The Planning and Building Act (Plan- og bygningsloven)

STEP – Standard for the Exchange of Product Model Data

TEK - Technical Regulations under the Planning and Building Act