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Utilizing Building Information Modelling in Construction Procurement

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Opinnäytetyön tavoitteena oli selvittää tietomallintamisen käyttömahdollisuuksia hankinnoissa ja muodostaa yrityksen hankintoja palveleva ohjeistus aiheeseen liittyen. Työtä varten tutustuttiin tietomallintamista koskevaan kirjallisuuteen ja tieteellisiin julkaisuihin sekä Yleiset tietomallivaatimukset 2012 -tietomallinnusohjeistukseen. Eri hankinnoista ja urakkalaskennasta vastuussa olevia henkilöitä haastateltiin, jotta heidän näkökulmansa ja käyttökokemuksensa tietomallien saralta saatiin esille.

Tutkimuksen aikana opinnäytetyön tilannut yritys aloitti ammattikorkeakoulu Metropolian uuden kampuksen rakentamisen. Hankkeen tilaajalle oli oleellista palkata urakoitsija, jolla oli mahdollisuudet hyödyntää projektia varten tehtyä tietomallia. Hankkeen tietomallintamista painottava tilaaja mahdollisti sen, että hanketta pystyttiin käyttämään opinnäytetyössä tuomaan reaalimaailman esimerkkejä tietomallin käytöstä hankintojen apuna.

Opinnäytetyön ensimmäiset luvut käsittelevät tietomallinnuksen perusperiaatteita ja erilaisia urakkamuotoja myöhempien lukujen käsitellessä haastattelutuloksia, YTV2012-tietomallinnusohjeita, kampushankkeen aikana havaittuja käyttötapoja sekä käyttöön liittyviä haasteita. Työn tuloksena saatiin hankinnan tietomallien laajempaa käyttöönottoa palvelevaa tietoa, sekä yrityksen hankintahenkilöstölle kokemusta mallien käytöstä.

Työn aikana havaittiin yrityksellä olevan vaatimattomasti kokemusta tietomallien käytöstä hankinnoissa, joskin urakkalaskennan puolella kokemusta oli jonkin verran kertynyt. Havaittiin, että tietomallien laajemmalla käytöllä voidaan parantaa hankintaprosessia. Tietomallien hyödyntämisellä voidaan säästää merkittävästi aikaa niin visualisoinnin kuin määrälaskennankin saralla. Kolmiulotteisuus helpottaa myös eri suunnitelmalajien ristiriitojen havaitsemista sekä niiden ennakoimista ja korjaamista.

Avainsanat	tietomalli, mallintaminen, hankinta, rakentaminen, YTV2012, Metropolia, BIM

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The goal of this Bachelor’s thesis was to identify potential uses of building information modelling (BIM) in construction procurement, and to generate guidelines to help in larger scale BIM utilization.

Scientific articles and books were the foundation for the theoretical background for this work, together with the previously published *Common BIM Requirements 2012 (COBIM2012)* - guidelines for building information modelling. Various people responsible for procurement and cost estimation were interviewed to bring their experience and views to the report.

During the writing of this report, the construction of the new campus of Metropolia UAS in Myllypuro was begun. The project had contractual obligations regarding greater use of BIM in the project. The project was used as a case study in the thesis to bring real-life examples on utilizing BIM in construction procurement.

The thesis introduced the basic principles of building information modelling and the various project delivery methods that have major influence on whether a particular approach works. The interviews, COBIM2012 and the current situation were discussed. Guidelines for a more efficient implementation of BIM were created to serve the procurement teams of the company.

In the course of the project, it became apparent that YIT Construction Ltd. had not used BIM that extensively, with cost estimators having the most experience. It became evident that BIM has tremendous potential in raising productivity and efficiency during the procurement process by adding tools to visualization and quantity take-off and analyses.

Keywords	building information modelling, procurement, construction, BIM, COBIM2012, Metropolia

Contents

Abbreviations

BIM	*Building Information Model/Modelling*. The life-cycle data of the construction at hand. Consists of building components, products and their locations and characteristics.
BIM coordinator	The person responsible for the facilitation of communication and for a correctly executed BIM workflow.
BSS	*Building Services Systems,* such as heating, ventilation, home security
COBIM2012	*Common BIM Requirements 2012*, industry-made guidelines for BIM designers, with 14 parts, or series as they are officially called, and three appendices
Combination model	Combined IFC-type model, withholding the models from all fields of design, that is architectural, MEP and structural. Can also contain models for specific items, such as kitchens.
HVAC	*Heating, Ventilation, Air Conditioning*
IFC	*Industry Foundation Classes*, a format with which to transfer different models to create a combination model, as in "model.ifc."
LCC, LCA	*Life Cycle Cost, Life Cycle Analysis* – both are analytical approaches to determining the financial and environmental impacts of a projects, respectively.
MEP	*Mechanical, Electrical, Plumbing*
Native model	The designer's BIM in its original format, for example ".rvt" for Revit Architecture.
OpenBIM	Each model made by different designers is shared between other stakeholders in the project using previously agreed upon methods of information sharing, most notably IFC-format.
YTV2012	*Yleiset Tietomallivaatimukset 2012,* the Finnish original for COBIM2012.
Quintet	The new planning and production software that YIT Construction Ltd. implements in the coming years. A work in progress, but with potential to help BIM implementation in the future.

1 Introduction

Building information modelling has slowly made a breakthrough in the construction industry, after decades of computer assisted drawing (CAD) and 2D paper pictures. The advantages of three-dimensional BIM use over the more traditional methods are, for example, enhanced clash checking, faster quantity estimation and visualization of the project.

Figure 1. Logo of YIT Construction Ltd [1].

YIT Construction Ltd, whose logo is shown above in figure 1, is undergoing a “performance leap,” to boost its productivity and revenue. This is not to be done by laying off personnel, but by advancing the various processes the company utilizes before, during and after construction projects. Building information modelling can help achieve the aforementioned result. Therefore, Teemu Takala, the procurement manager for YIT Construction Ltd. Business Premises unit, commissioned a paper looking into the integration of BIM solutions to the procurement processes of YIT Construction Ltd.

The goal of this report is to set up guidelines on how to utilize building information modelling, especially in the procurement process. A guide listing potential uses for BIM is compiled, using COBIM2012 guidelines and empirical findings as examples.

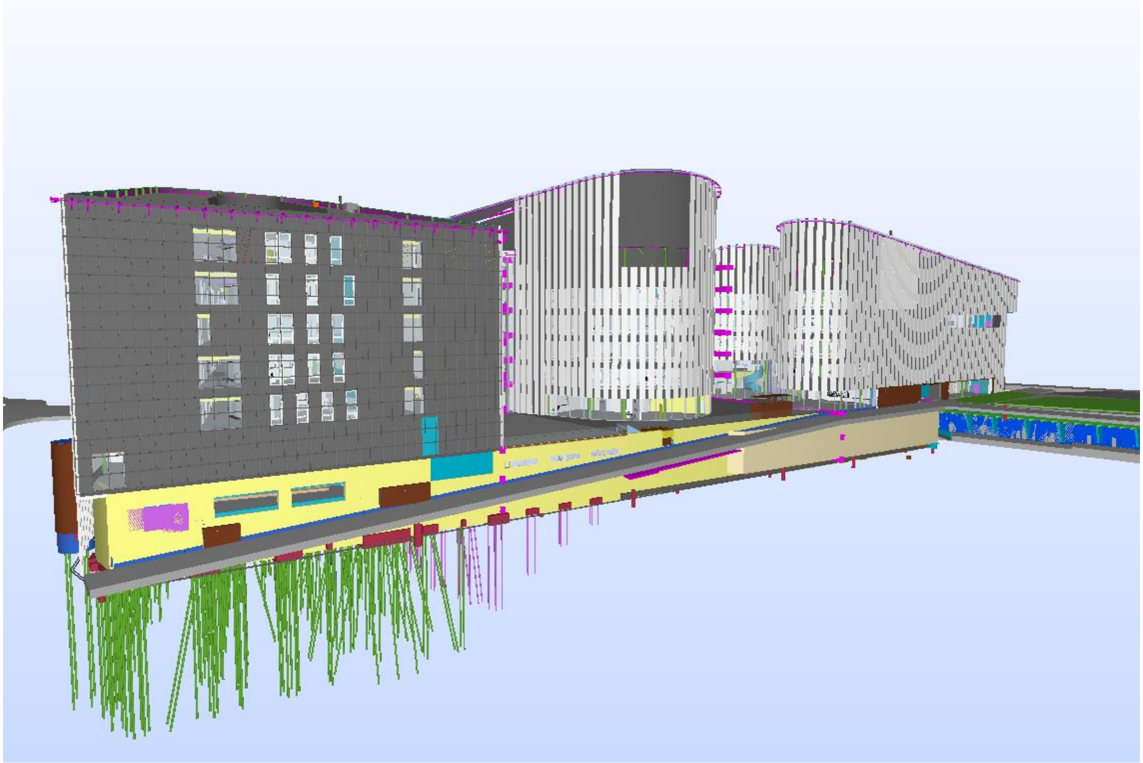

Figure 2. The preliminary model of the new campus of Metropolia [2].

For the YIT Business Premises procurement team to reap maximum benefits from building information models while procuring, the first thing is to find out the benefits of BIM compared to 2D paper drawings and other archaic design methods. Coincidentally for this project, YIT Construction Ltd. Business Premises unit has won the contract for the new campus of Metropolia University of Applied Sciences. The campus is, at the time of writing of this paper, being built in Myllypuro in Eastern Helsinki. The construction will continue until 2019. The project has its own building information model coordinator, whose duties are explained below in chapter 5. The use of BIM is emphasised by the client in this particular project. Figure 2 above shows the preliminary building information model of the building.

2 Theoretical background

The COBIM2012 modelling guidelines discussed further in the report make up the backbone for the implementation of BIM based design and construction. Other sources for this report are various reports and theses done by academia around the globe. Particularly well established BIM nations in terms of investments in research and development include the United Kingdom, Australia, Norway and Finland. In all of them, research on and implementation of BIM has been encouraged by the governments, according to Bolpagni. [3,3.]

2.1 Building Information Modelling

According to Jäväjä et al. the construction industry has been making 3D models of buildings long before the invention of computers. These miniature-sized buildings have been used to aid in the visualisation of projects and, thus, attract clients and investors. In addition to not being made of wood and plastic, the major difference of modern 3D building information models and old miniatures is the amount of data the models contain. A 3D BIM file of a building can hold information about the quantities, materials, heat-emission capabilities and more, depending on the level of design of the model. The model can also be transferred, evaluated, moulded and shared between stakeholders via the internet and cloud services, which enables faster decision making and can save both time and money. [4,12-13.]

In layman's terms, a building information model is a collection of objects, such as walls and windows, their characteristics and the connections between the objects. Usually, different designers create their own models of the same project. For example, the architect first creates a rather plain 3D model, upon which the structural, HVAC and electrical designers create their own corresponding plans. The various designs are made with the designers' BIM program of choice, but the designs are combined afterwards into a single model with a standardized format called the IFC (Industry Foundation Classes), which enables data transfer between the various design programs listed on the following page. [4,13;2,37]

There are dozens of scientific papers on BIM use, but not nearly as many about procurement and none that actually cover the sub-contracting procurement in detail, the line of work that the YIT Construction Ltd. Business Premises unit's procurement team does. Thus, interviews and empirical findings weigh heavily on the conclusions of this report.

2.2 BIM Programs

There are many programs with which to create, view and analyse building information models. The software of choice for procurement is Solibri Model Checker, or similar. Like the name suggests, the programme is used to check all created models and to draw information from them. With so many programs to choose from, making sure the programs are all capable of saving data in the IFC format is one of the first things to do to affirm the smooth flow of information between the stakeholders of a project. Below are listed the most common BIM integrating programs.

Architecture

- ArchiCAD
- Revit Architecture
- CADS Planner House
- Nemetschek Allplan Architecture
- Bentley Microstation

Structural design

- Tekla Structures
- Revit Structure
- Vertex BD
- CADS Planner House
- Nemetschek Allplan Engineering

Building Service Systems

- MagiCAD
- Revit MEP
- CADS Electric
- CADS HEPAC

There are also various programs with which one can view models, gather quantity information and facilitate clash-checking. The production phase of a construction project would most likely be using these. [4,48.]

- Solibri Model Checker
- Solibri Model Viewer (Free version of the above)
- Tekla BIMsight
- Autodesk Navisworks
- Tekla Field3D (for mobile devices)

There are programs created to extract information from BIMs for the use of scheduling, process management as well as quantity and cost forecasting. Unlike the previous ones, these do not display the 3D model in the program. [4,48.]

- Vico Office
- Modelspace
- Tocoman

There are also programs designed to analyse structural strengths, energy-efficiency, acoustics and other variables. Unfortunately, according to Jäväjä et al, further development between analysing programs and building information models is needed to completely fulfil the demands for their compatibility. Nevertheless, they can be of use when doing major life-cycle decisions during the planning phase. [4,48.]

2.3 COBIM2012

To help with the deployment of BIM in the Finnish construction industry, the state-owned Senate Properties released guidelines for the use of BIM as early as in 2007. These guidelines were updated in 2011-2012 with the help of several property-developers, contractors and software companies in a project called COBIM (Common BIM Requirements). The end result is known in Finnish as YTV2012 (Yleiset Tietomallivaatimukset 2012) or COBIM2012 in English. COBIM2012, the cover of which is shown below in figure 3, contains 14 parts, or series as they are called in the translation, with guidelines

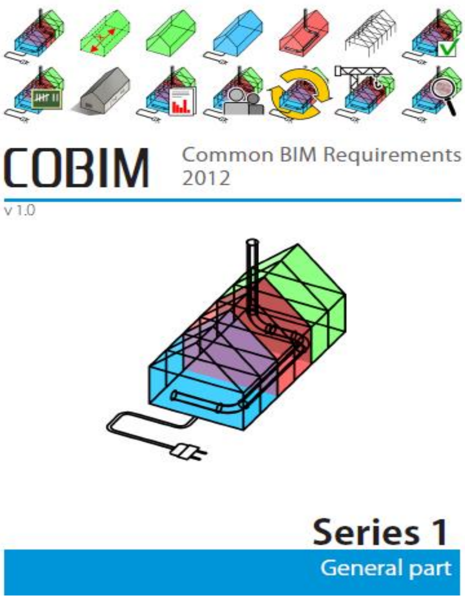

Figure 3. COBIM2012 Series 1, "General part" cover page. [5]

for architectural planning, structural design, quality control and management of BIM-based projects. [5.]

The COBIM2012 guidelines make up a large portion of the material for this study. The COBIM2012 is based on the concept of Open BIM, where each model made by different designers is shared between the other stakeholders in the project. This is done using previously agreed upon methods of information sharing, most notably the IFC format. The necessary communication is encouraged by weekly design meetings, reporting and BIM coordination. [4,9.]

2.4 COBIM2012 Series

The use of BIM in construction projects demands clearly laid out rules and frameworks for the various stakeholders involved. It is important that the client lists what information the model should contain, and defines the level of the desired information at each phase of the project. This is where using COBIM2012 guidelines is helpful, as they describe the recommended minimum level of BIM design. There are also additional requirements, if the minimum is deemed too little by the project personnel. Additionally, the COBIM2012 guidelines cover both new construction and renovation work. COBIM2012 has 14 series and three appendices, listed below in table 1:

Table 1. COBIM2012 is divided into 14 parts and 3 appendices. [4,34-36.]

Series number	**Name**	**Main users**	**Contents and goals**
1	General part	Everyone	Description of basic principles, demands and concepts related to BIM use in a project.
2	Modelling of the starting situation	Designers	Details the modelling of the starting situation, the measurements related to it, doing the inventory and other research. Furthermore, the documentation of aforementioned tasks and their required contents.
3	Architectural design	Architectural designers	Details the requirements for the content delivered by the architectural designer during various phases of construction. Also has a later added appendix.

4	MEP Design	MEP designers	Details the modelling of MEP systems and the required content about the building service systems to be included in the model.
5	Structural design	Structural designers	Details the modelling of the structural design and the content to be generated by the structural designer. Covers the design of the structural model, that will be receiving additional details during the rest of the designing.
6	Quality assurance	Everyone, especially designers	Main goals of BIM quality assurance are enhancing the quality of design models, facilitating the communication between stakeholders and through that, enhancement of the entire design process. Design model in this case meaning the native model of the designers as well as the IFC-model taken from the native models.
7	Quantity take-off	Client, contractors	Goal of this series is to determine what is meant by model based quantity take-off. Series only details quantity estimation from the model, not the use of such quantities in, for example, LCC, LCA, budget forecasting or scheduling.
8	Use of models for visualization	Everyone	Details the basic concepts, tasks and implementations related to the visualization of a construction project using a BIM.
9	Use of models in MEP analyses	MEP designers	Covers the possible MEP analyses using BIM, such as flow rate dimensioning.
10	Energy analyses	MEP designers	Covers the tasks related energy analyses and indoor environmental quality analyses that ought to be done during design and construction phases. Also includes verification of such analyses during the operational phase.
11	Management of BIM project	Client, contractor	Covers the management of a BIM-based project. Goal is to detail how using BIM as a way of design should be taken in to account from the point of view of the project management team and the BIM coordinator, so as to facilitate a successful construction project.
12	Use of models in facility management	Client, owner of facility and facility management teams	Cover the use of BIM in the operational/maintenance phase of the life cycle of the construction.

13	Use of models in construction	Client, contractor	Presents the needs of the production for the designers, modelling tasks of the production team and the delivery of data for the creation of As-built model by the MEP and construction contractors.
14	Use of models in construction control (only in Finnish)	Client, designers	Describes the modelling of a project and the use of said models from the point of view of the construction control. So far, the use of building information models in construction control has depended entirely on the proficiency of the official.

Series 3, 4 and 5 have appendices to help in presenting the client's needs to the designers. The appendices are only available in Finnish.

3 Levels of Building Information Modelling Design and Use

In the beginning of a project using BIM, the level of modelling design must be decided. The levels describe the accuracy of the content in the relevant model, with level one being the least accurate. COBIM2012 lists three levels of design for architecture, shown on the next page in table 1, and four for structural design shown in table 2 also on the following page. MEP designers, that is mechanical, electrical and plumbing, have their own industry-specific guidelines regarding the level of their modelling. [6,2;7,2;8,1-9.]

3.1 Levels of Design

This section presents tables 2 and 3 detailing both the architectural and structural design levels. Both tables are presented on the following page and describe what types of information a model of a particular design level holds. Knowing the level of detail when looking at models is useful, so as to not go looking for something that is not there, such as dB ratings from a purely visual model. Such a visual model would be a level one model in the architectural design level table.

Table 2. Description of the level of architectural design. From COBIM2012 series 3, appendix 1. [6, 2.]

Level of modelling	Description of the level of architectural design
1	Typical use of the model is collaboration and communication between the designers; the position and geometry of the model are according to the requirements; building parts are named descriptively.
2	Typical use of the model is in pre-design and sketch design phases is energy analyses and in bidding phase quantity take-offs; the position and geometry of the model are according to the requirements; building parts and types are named correctly and they are modeled in such way, that the quantities and other essential information for the cost estimations can be read from the model.
3	Typical use of the model is for construction scheduling and contractor purchasing; the position and geometry of the model are according to the requirements; the relevant information for contractor purchasing has been added to model objects in such way, that they can be listed (window type, part dimensions, decibel requirements etc.).

Table 3. Description of the level of structural design. From COBIM2012 series 5, appendix 1. [7,2.]

Level of modelling	Description of the level of structural design
1	Basic geometry and location modeled.
2	Basic geometry done so that structural quantities can be taken from the model. Model structural components as individual elements.
3	Modelling of structural named elements and cast in place structures with their respective connections, reinforcements and casting materials. Structural steel components are modeled akin to the concrete elements, connections included. (Connecting columns also include reinforcements.) Other parts are modeled with their connections and casting materials included in terms of geometry and location.
4	Modelling of all elements and cast in place structures correctly in terms of their geometry and location, connections, reinforcements and casting materials included. Steel structures to be modeled to workshop level of detail. (Connecting columns also to include reinforcements.) Pile measurements are transferred to the model and the piles are finally modeled according to their actual positions in the real world.

Due to the complexity of the MEP design, similar rating level for design is understandably not done in the COBIM2012. More on this in the COBIM2012 Series 4, appendix 1.

3.2 Levels of BIM Use

Due to the variations in BIM utilization skill level, it is recommended for a contractor or the client to define the intended uses for the model and to figure out if they have the necessary skills to do so. Investments in the IT-skills on the worksite are essential for the maximal potential to be unlocked. In the most extreme case, the modelling process of a project can be taken so far as to virtually “construct” the building beforehand. This is futile if it cannot be taken advantage of. Below, table 5 will list different levels of BIM use and the proficiency required at the worksite to apply them. [4,93-97.]

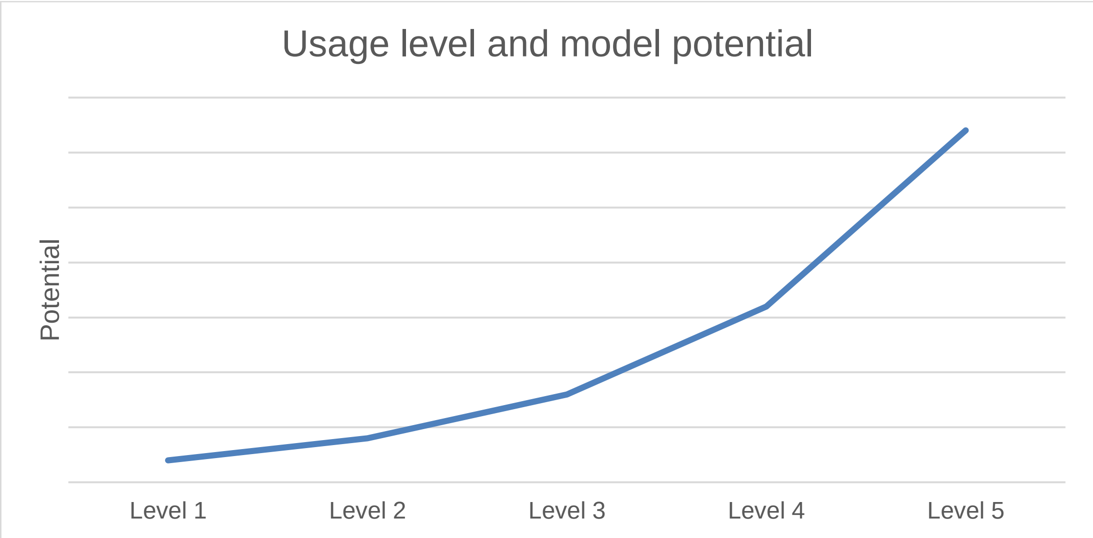

Figure 4. As personnel get more proficient in BIM use, the potential benefits also rise [4,92.]

For companies still new to BIM, Jäväjä et al. recommend to start off slow. Gradually, as the personnel build their confidence and skills in using the related software, they can start utilizing models in more creative ways, with the evolution depicted in figure 4. Further description of usage levels and their respective required levels of proficiencies listed below in table 5. [4,94].

Table 4. Levels of BIM use in a project and their required levels of proficiency and prerequisites. [4, 95-96.]

Usage level	Description of usage level	Specific proficiency needs for the contractor	Determining of proficiency and required conditions
1	Designs are made based on a preliminary model and the designers have access to the IFC-files. Contractors only get 2D drawings and isometric pictures drawn from the model.	-	-

2	An IFC-model from a specific designer is given to a contractor to use.	Proficiency in using IFC-viewer software. Information take-off from the model.	Confirm from the designer that the IFC-model in use by the contractor is up to date and that the drawings are made specifically *drawn from the model.* Confirm that the models are easily available to all personnel, for example in the project bank. Acquire the necessary software to view IFC-files, such as Solibri Model Viewer, Tekla BIMsight or Tekla Field3D. Make sure your personnel have the skill to use the aforementioned programs. Use the software diversely, try looking for new, creative ways of utilizing BIM in your field of work. Acquire the necessary hardware, such as powerful computers, mobile devices and monitors.
3	All the models from the designers and their combination model is available for use by the contractors.	Proficiency in using IFC-viewer software. Proficiency in using the analysing programs for the combination model.	Like usage level 2 and in addition: Acquire the essential combination model checking programs, such as Tekla BIMsight and Solibri Model Checker. Make sure the designers are always providing you with the latest and clash-free combination model.
4	Like level 3, but all native models are made available for use of contractors to meet the needs of production management.	Proficiency in using IFC-viewer software. Proficiency in using the analysing programs for the combination model. Proficiency in using model-based production control software. Proficiency in using models to create schedules and cost related data, such as estimations and budget predictions.	Like usage levels 2 and 3 and in addition: Confirm from the designers that all the native models in use are up to date, that the drawings are drawn from those models and that the IFC-models drawn from the native models are up to date. Make sure that you have the necessary model utilizing production control programs. Furthermore, make sure your personnel have the proficiency for these kinds of programs.
5	Like level 4, but in addition the contractors have made a production model, containing for example site planning and falling protection plans in the model.	Proficiency in using IFC-viewer software. Proficiency in using the analysing programs for the combination model. Proficiency in using model-based production control software. Proficiency in making the necessary models with the suitable modelling software.	Like the previous levels but also in addition: Make sure you have the necessary modelling software available. Confirm the proficiency of your staff related to modelling the required models, such as the site plan and falling protection plans.

Figuring out one's own level of proficiency is vital for uncovering the potential of BIM utilization still left untapped. Even though one starts to use BIM slowly, there should be a clear goal for BIM use in the future.

4 Construction Project Delivery Methods

According to Holzer, the project delivery method chosen has major influence on whether the main contractor can influence the design and, consequently, the building information modelling process. The possible methods are described in the following pages, beginning with *construct-only projects,* where the main contractor is given a set of plans and practically said "build this." After that come the *design-build projects,* where the main contractor is responsible for both the detailed designing and the construction of the building. Finally, there are the *project management contracts,* where the main contractor works as a kind of a consultant for the client, helping them choose the best possible designs and implementations, with the related costs and benefits split evenly between the contractor and the client. [9, 214-243.]

Of the following project delivery methods, the design-build method is the easiest for the implementation of strict design and modelling requirements, since using that method, the designers work for the builder and not for the client. On the other hand, the contractor may easily skip BIM use if they deem it not worth their time. [9, 241-424.]

Bolpagni states that most project delivery methods require the client to make preliminary plans on which the competing contractors then bid on, each using their own methods of cost estimation and each filling in the incomplete plans in slightly different ways. The insufficient level of planning can lead to a situation where the contractors do not compete in productivity and efficiency, but in cost estimation to win contracts. Incomplete plans inevitably lead to increases in the product price due to extra details added later after the contract has been signed and construction already begun. From the client's point of view, this is unbearable, but the situation is not optimal for the contractors either. The contractors will have difficulties in budget forecasting and after they have won the contract, will have to hurry in sub-contract procurement with the relevant, detailed plans coming too late to help with the tendering process. [3,117-118.]

Using building information modelling with a high level of detail prior to the beginning of the tendering process can bring advantages in enhancing the comparability of bidders. BIM forces the contractors to actually compete against each other in terms of productivity instead of just clever pricing. The contractors also benefit because they can show the client, who is not necessarily a professional, their designs and implementations in 3D. [3,117-118.]

4.1 Construct-Only Projects

In a traditional construct-only project, also known as a design-bid-build project, the client purchases the plans from a third party, usually a design office, and then asks for the main contractors to bid on the contract according to the plans. According to Holzer, the main challenge in the usual design-bid-build form of construction contract is the lack of communication between the designers, quantity surveyors and the main contractor. The organizational hierarchy of a construct-only project is shown below in figure 5. The contractor's requirements for the model are not delivered to the designers, and the designers do not have a clear idea of what the contractors want and, thus, easily make assumptions. [9,241.]

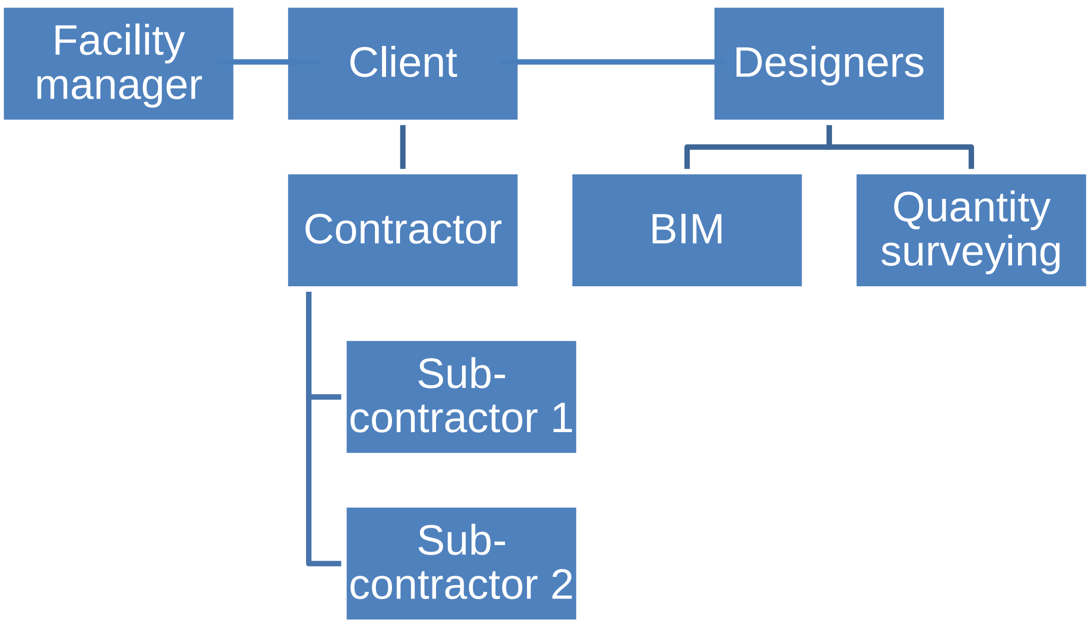

Figure 5. Construct-only project delivery method hierarchy. [9,241].

Holzer also claims that an issue with construct-only projects is the lack of incentive for the contractor to require better models, since they are not the one responsible for the management of the design process where the models are created. Poor planning can affect the situation in such a way that stakeholders may end up as rivals on evaluating the feasibility of plans given by the client. [9,241.]

4.2 Design-Build Projects

The design-build method of project delivery is used when the client wishes to reduce risks by letting the main contractor do both the building and the designing. Holzer claims that the advantages of a design-build contract are self-evident, as the designer and the main contractor are both in the same team, visualized below in figure 6, resulting in greater transparency and better communication between the parties. [9,241-242.]

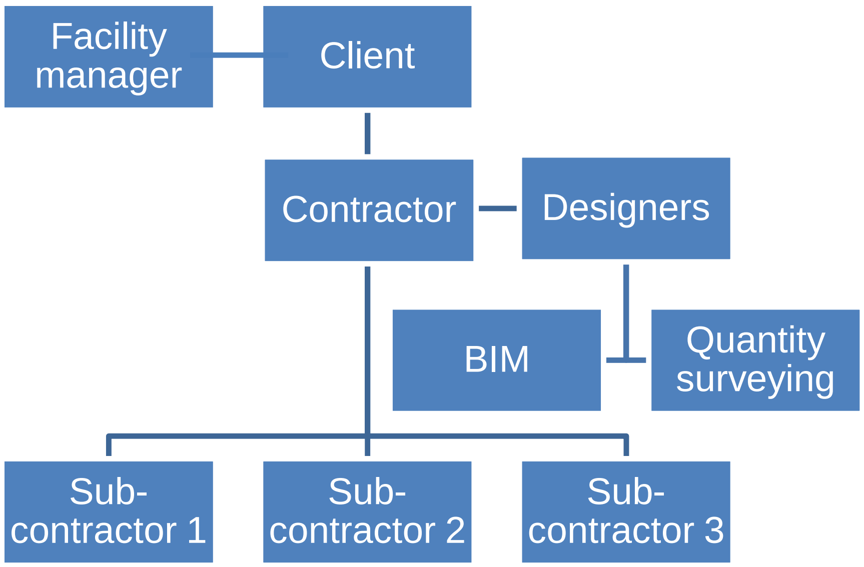

Figure 6. The design-build delivery method hierarchy. [9, 241.]

According to Holzer, the designers are better motivated to create the models, because they know that the models will be used in sub-contract tendering and information gathering. [9,242.]

4.3 Project Management Contract

In project management delivery type of projects, the contractor works as a consultant for the client. This levels the hierarchy and aims to help the stakeholders to work together. According to Holzer, both the risks and benefits from designs and implementations are shared equally between the two main stakeholders of the project, the client and the project manager. In terms of BIM utilization, the project management delivery method enables the main contractor, that is the project manager, to take part in the development of the project. [9,242-243.]

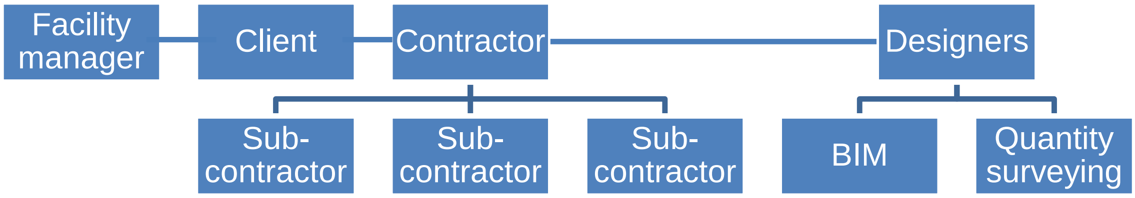

Figure 7. The project management delivery method hierarchy. [9,243].

Holzer states that due to the shared risks and benefits, it is beneficial for both parties to be heavily involved in the design, thus enabling the creation of a more accurate model earlier on by making use of the contractor’s experience in construction production. [9,243]. This is the type of project delivery method used in the case of the new campus of Metropolia UAS, analyzed in chapter 8.

5 BIM Coordinator

According to BuildingSMART Finland, integrating BIM into a construction project may increase risks related to project management when the stakeholders are not adequately prepared. All parties must be made aware of their respective duties related to the building information modelling of the project, such as decision making deadlines and the level of modelling detail. The intended uses for the model should be made clear for all parties, as well as the required level of content in the model. Examples of the uses are given in chapter 8. Uniform reporting templates, scheduling and quality control must all be sufficiently discussed as early as possible in the design process. One proper way to do this is to follow the COBIM2012 series 11, *Management of a BIM project.* [10,5.]

The COBIM2012 series 11 details first the principles and planning requirements necessary for managing a BIM-project. Due to the large number of designers and stakeholders working on a project, a designated BIM coordinator is vital for a successful completion of one. The BIM coordinator is appointed by either the client or the main contractor. The responsibility varies depending on the project delivery method chosen for the project. Project delivery methods are explained in chapter 4. [10,7.]

The BIM coordinator should be an experienced project manager, with sufficient skills in both building information modelling and project management. Some of the duties of a BIM coordinator are listed below, but are not necessarily limited to just those. A more thorough list can be found as an appendix in the COBIM2012 series 11. [10,7.]

According to COBIM Series 11, the duties of a BIM coordinator are to:

- Agree upon the BIM requirements, goals and intended level of use with the project management
- Map the responsibilities of individual stakeholders regarding BIM, that is the client, designers and contractors
- Delegate and coordinate modelling responsibilities throughout the project working closely with the main designers
- Report on the progress of modelling to the management of the project, for example during design meetings, explaining
    - Evolution of the status of the model since the previous meeting
    - Found clashes and actions undertaken to fix them
    - Modelling schedule and quality control
- Produce combined IFC-models from the native models created by the various designers, unless an another person is designated for it. [10,7.]

6 Benefits of BIM

According to Bolpagni, there are several benefits to utilizing BIM in construction contract tendering, both for the client and the contractors. As the client is not necessarily always experienced in the construction business, the modelling process allows for an easier visualization of the upcoming project, especially due to the ability to hide certain layers like in figure 7. Furthermore, the information is collected in one place, and it is easily accessible with no need to search through multiple PDF files. The compliance of the bids from contractors with the requirements given by the client can also be checked with model checking tools, such as Solibri Model Checker. This in turn makes the comparison of bids easier, giving more transparency and accuracy to the whole process. [3, 126.]

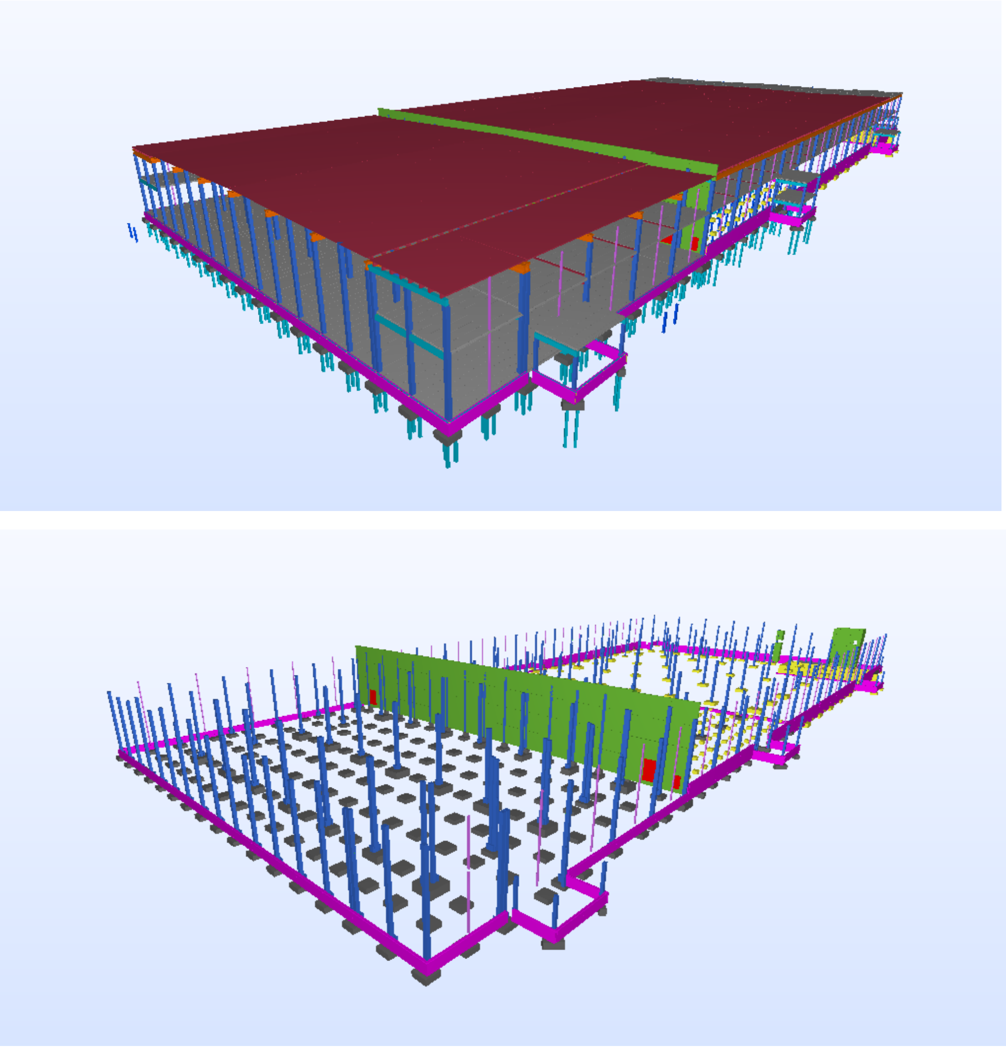

Figure 8. By hiding specific parts of a model, visualization of certain structural components that are left hiding under the finished building can be made more easily comprehensible. [2.]

It is also beneficial for the contractor if the client uses BIM. Using models, the client can have an easier time communicating their exact needs, consequently making the cost estimation process easier. Increased accuracy in the preliminary bids decreases the risk involved for both parties. Clash-checking programs can also be used to avoid unnecessary mishaps in the bid. In addition, the model can easily be utilized when discussing alternative solutions during meetings. [3,126.]

7 Interviews

To gather the previous experience of YIT Construction Ltd employees in BIM, a questionnaire was sent to the relevant personnel. This included cost estimators, procurement managers and site personnel. The employees were asked if they knew of any YIT Construction Ltd. projects that had utilized modelling, particularly in procurement, and if they perceived any potential benefits from an increased use of modelling.

Unfortunately, modelling had not been extensively used in the company. Most projects had models, but their level of design was insufficient to be used in construction phase procurement where the required level of detail is very high. Information on material choices, sound and fireproofing, details on joints and fixings are necessary for the procurer to be able to make as exact inquiries as possible. Any loose ends cause major price differences in the sub-contractor's offers due to them having to make their own decisions on the product characteristics. This makes price comparisons difficult and thus decreases the potential savings from the procurement process.

According to some of the interviewed personnel, the major benefits foreseeable in the near future were mostly in the structural design. This is most likely due to the fact that a structural model is the basis on which the other designers have to design. A cost estimator mentioned the use of structural models in pre-fabricated element design and manufacturing. Large element companies such as Parma Ltd. already do their design with BIM. For the pre-fabricated element manufacturers to be able to do this, the structural model must be of sufficient quality, at least on a par with the one recommended by the COBIM2012 series 5, which covers structural design.

When asked whether they had used building information modelling, the YIT Construction Business Premises Ltd. HVAC and Electrical specialists working in the procurement team responded that they had not found much use for models. Their main concern was that the models they received did not contain enough information, the layers were incorrectly designated and the coordinates were conflicting in the different designers' models. Incorrect designation of layers means that finding information from the models can be tricky and information that should be found with a simple search bar search will remain hidden. Improper coordinates in combination models make the production of holes and ductwork based on the models very risky, as the ducts and holes need only be designed a few centimeters apart to make for a difficult situation in the production phase.

Another matter pointed out by the specialists was the insufficient software and training in the HVAC and electrical sub-contracting sector, where there are only a few large companies and several smaller ones who do not possess enough resources to devote to adopting BIM. Larger companies on the other hand already model their HVAC and electrical design according to the COBIM2012 Series 4, which covers the modelling process of the building services systems. The series 4 also has an appendix specifying the client's perspective, much like the ones in series 3 and 5.

A particularly interesting key point that came up in the interviews was the combined use of BIM and the upcoming project control program to be used in YIT Construction Ltd, Quintet™. This program is still being worked on, but the following scenario of controlling quantities in the next paragraph could be easier to execute in the new system than in the haphazard combination of various software used today.

The scenario, described by Heikki Uusitalo in his thesis for the Tampere University of Technology, recommends that quantity estimation should be done initially based on location of the building components and their respective stories, along with the usual way of categorizing them by building part i.e. walls and doors. The cost estimation should then be done the same way, after which the data is transferred to whichever production software in use. The software can then be used to generate timetables and procurement packages. This could reduce the need to recalculate quantities repeatedly over the course of a project, for example by clearly showing how many windows or how many square meters of wall have to be installed in a story of a building to be constructed, making for faster and clearer production scheduling. [11, ii.]

8 Metropolia UAS Myllypuro Campus

The new campus built for the Metropolia University of Applied Sciences was bid on and subsequently won by YIT Construction Ltd. This campus project consists of four large buildings, connected by walkways and underground compartments. The client placed specific emphasis on BIM utilization and decided to hire an outside BIM coordinator from Tieto Oy. [12,1.]

8.1 Metropolia Modelling Plan

The version 1.0 of the modelling plan of the project was dated the 17th of March 2016. Construction began in the fall of 2016. It was decided that level 3 of BIM design according to COBIM2012 was sufficient. This level of detail requires thorough planning and monitoring throughout the building process.

According to the modelling plan created by the BIM coordinator, the goals for building information modelling in this project were to:

- Help the decision making processes in the project
- Commit all stakeholders to the goals of the project using BIM
- Help visualize design implementations
- Help design and design cooperation and to avoid clashes
- Increase the quality in the building process and, consequently, the finished building
- Increase the efficiency of the building process
- Support LCA and LCC analyses
- Support the flow of information from the construction phase to the operational phase of the building

After the initial listing of goals, the modelling plan details the uses meant for the models about to be created.

The designated uses for the BIM during the project planning and design phase in this project are:

- Design quality control, clash checking and cooperation
- Hole, hatch and duct design
- BSS analyses, energy consumption and energy efficiency calculation
- Quantity and cost estimation purposes for structural elements

[12,1-2.]

The designated uses for the BIM during the production phase in this project are:

- Planning the build order and visualizing the plans in the model
- Visualizing the construction schedule in the model
- Visualizing the percentage of completion of the project in the model
- Affirming work safety implementations in the model, like in figure 8.

[12,1-2.]

It is of utmost importance to make sure that everyone in the project has a clear vision about the purposes of the model, so as to reduce wasted time and to make sure everything is done as previously agreed upon.

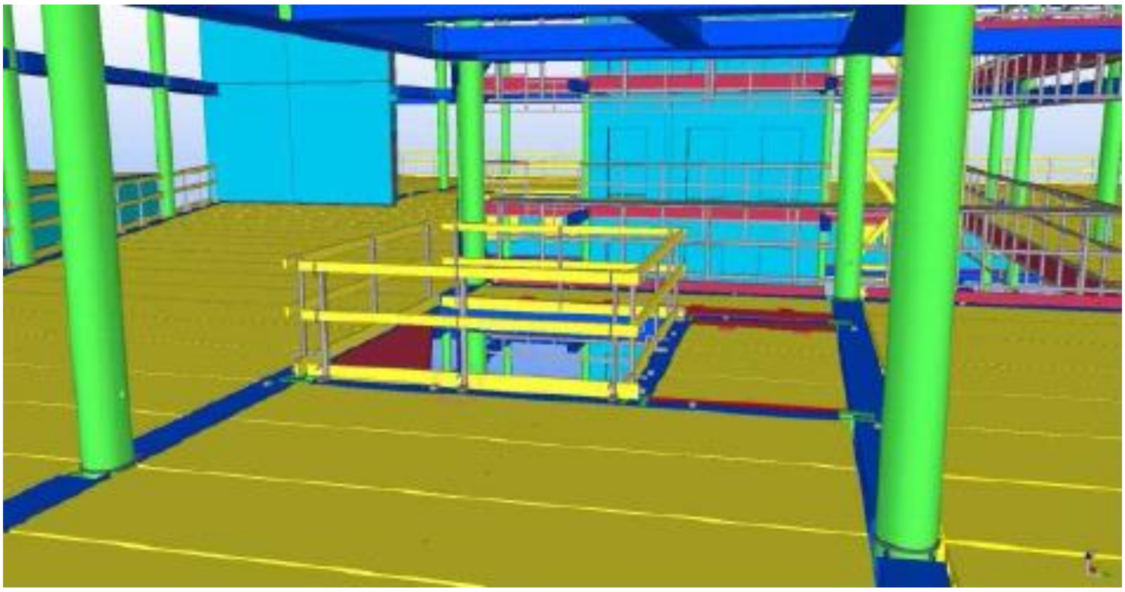

Figure 8. Planning of railing and scaffolding can also be done using BIM, increasing the safety of the work site. [3,74.]

The client will acquire all the material rights to the models at the end of the project, so it is safe to assume that the model can be of use during the whole life cycle of the building. One use could, for example, be to check the wall materials when making new holes or fixtures for projectors and such school equipment. Especially during demolishing, it may be vital to know what the contents of a structure are.

8.2 Uses Discovered for the Model During the Project

The modelling plan of the campus project encouraged the use of the model during the construction process. In spite of not having much previous experience with model checking programs, the procurement team found some small uses for the model in their processes. Most help the team received was in terms of visualization to help the sub-contractors at the negotiation table comprehend the new job site quicker than from 2D schematics.

Second, being able to locate building components using the search bar located in Solibri Model Checker in the top right corner of the screen was helpful. For example, with fifteen different types of partition walls, finding their respective locations inside the massive campus project can be difficult. Using the search bar, one can discover different building components more easily than from drawings. Finding components quicker is of help when planning project scheduling and workflow. In figure 9 below, placement of a certain type of partition wall is shown in the model, while the rest of the building is transparent.

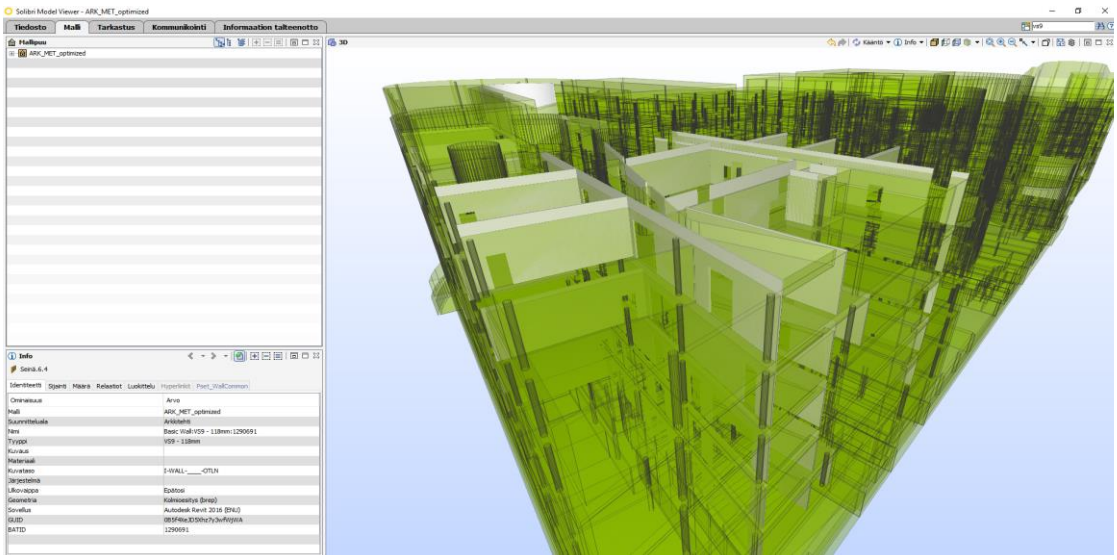

Figure 9. One can also show the placement of a specific type of wall within the building by selecting first the wall type using the search bar and by ticking the "show spaces" option. [2.]

Third, quantity take-off could be facilitated by the model. The process of quantity take-off depends heavily on the flawlessness of the designs and the labelling of the objects visible in the model, as could be found out during the creation of new quantity lists containing all the partition walls of the building. The usefulness of such lists drawn from the model was mainly limited to double-checking the quantities prior to negotiations, as YIT Construction Ltd. commonly delegates the responsibility of affirming quantities to the relevant sub-contractor. After all, they are the ones usually buying the materials as well. The process of taking off quantities from the model is done step-by-step in the guidelines that YIT Construction Ltd. requested. Below, in figures 10 and 11, the quantities of the partition walls visible in the model view are transformed into an Excel-file containing their relevant data.

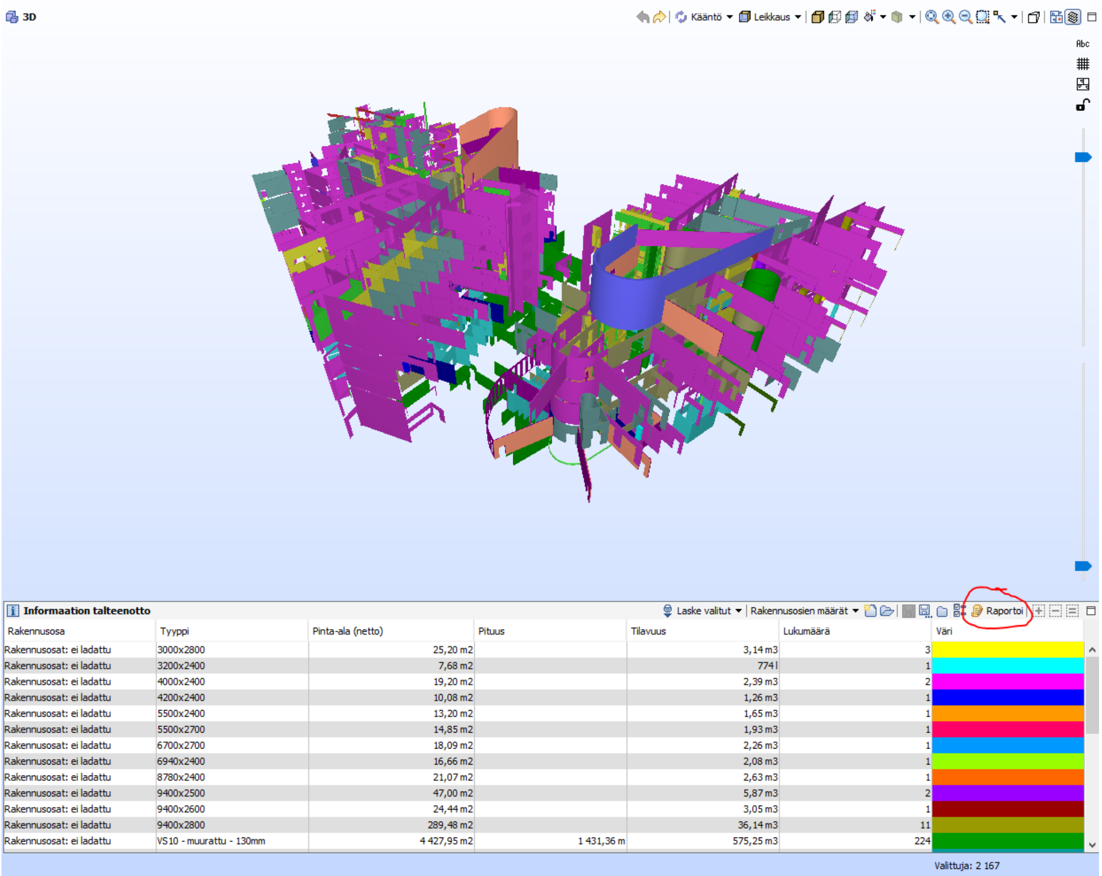

Figure 10. Having successfully picked the correctly labeled partition walls and having run the quantity calculation in the model checker, one can click on the “Report” -button, that will generate an Excel spreadsheet containing the relevant data. [2.]

The process of creating new quantity lists can be overwhelming in the beginning, but fortunately the learning curve of Solibri Model Checker appeared to be relatively short.

A few repetitions and the user should grasp the basic principles of quantity take off. There are some challenges that hinder this process, such as incorrect labeling by the designer, but with a bit of cleverness from the user, they can be worked around. Deeper analysis of the challenges of quantity take off is on the following paragraphs.

	A	B	C	D	E	F
1	SOLIBRI	Määrälaskenta Väliseinät kaikki				
2						
3	Mallin nimi	1923_MET_170309 Versio: 9.7				
4	Tekijä	fiuhassihe1				
5	Organisaatio					
6	Aika	16.3.2017				
7	ark_met	Date: 2017-03-07 18:48:27 Application: Autodesk Revit 2016 (ENU) IFC: IFC2X3				
8	RAK_MET	Date: 2017-03-07 15:10:12 Application: Tekla Structures IFC: IFC2X3				
9	LVI_IV_MET	Date: 2017-03-07 12:27:42 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
10	LVI_LJ_MET	Date: 2017-03-07 13:13:24 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
11	LVI_SPR_MET	Date: 2017-03-07 17:32:06 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
12	LVI_VV_MET	Date: 2017-03-07 07:56:24 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
13	säh_met	Date: 2017-03-03 09:26:49 Application: MagiCAD-E 2016.4 IFC: IFC2X3				
14	Metropolia_pihasuu	Date: 2017-03-02 16:43:15 Application: Autodesk Revit 2016 (ENU) IFC: IFC2X3				
15	ARK_Metroradan	Date: 2016-01-20 14:35:03 Application: Autodesk Revit 2016 (ENU) IFC: IFC2X3				
16	säh_reikävaraukset_	Date: 2017-02-03 13:35:15 Application: MagiCAD-E 2016.4 IFC: IFC2X3				
17	LVI_UA_MET	Date: 2016-08-24 07:23:21 Application: MagiCAD HPV 2015.4 IFC: IFC2X3				
18	ARK_julkisivuverhou	Date: 2017-01-16 12:52:49 Application: Autodesk Revit 2016 (ENU) IFC: IFC2X3				
19	LVI_VESIKATTO_M	Date: 2017-03-07 11:10:55 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
20	LVI_R_MET_0_KR	Date: 2017-03-03 08:24:42 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
21	LVI_R_MET_1_KRS	Date: 2017-03-03 08:25:45 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
22	LVI_R_MET_2_KR	Date: 2017-03-03 10:22:45 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
23	LVI_R_MET_3_KR	Date: 2017-03-03 10:23:09 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
24	LVI_R_MET_4_KR	Date: 2017-03-03 10:23:31 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
25	LVI_R_MET_5_KR	Date: 2017-03-03 10:23:53 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
26	LVI_R_MET_6_KR	Date: 2017-01-16 07:55:42 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
27	LVI_R_MET_7_KR	Date: 2017-01-11 07:10:20 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
28	LVI_R_MET_K_KR	Date: 2017-01-16 07:54:56 Application: MagiCAD V&P 2016.4 UR-1 IFC: IFC2X3				
29	Met-keittio	Date: 2016-09-06 16:20:50 Application: Autodesk Revit 2016 (ENU) IFC: IFC2X3				
30						
31						
32						
33	Rakennusosa	Tyyppi	Pinta-ala (netto)	Pituus	Tilavuus	Lukumäärä
34	Rakennusosat: ei lada	3000x2800	25,2		3,14	3
35	Rakennusosat: ei lada	3200x2400	7,68		0,774	1
36	Rakennusosat: ei lada	4000x2400	19,2		2,39	2
37	Rakennusosat: ei lada	4200x2400	10,08		1,26	1
38	Rakennusosat: ei lada	5500x2400	13,2		1,65	1
39	Rakennusosat: ei lada	5500x2700	14,85		1,93	1
40	Rakennusosat: ei lada	6700x2700	18,09		2,26	1
41	Rakennusosat: ei lada	6940x2400	16,66		2,08	1
42	Rakennusosat: ei lada	8780x2400	21,07		2,63	1
43	Rakennusosat: ei lada	9400x2500	47		5,87	2
44	Rakennusosat: ei lada	9400x2600	24,44		3,05	1
45	Rakennusosat: ei lada	9400x2800	289,48		36,14	11
46	Rakennusosat: ei lada	VS10 - muurattu - 130mm	4427,95	1431,36	575,25	224
47	Rakennusosat: ei lada	VS11 - muurattu - 85mm	262,21	93,26	22,29	55
48	Rakennusosat: ei lada	VS12 - 217mm	594,27	144,99	128,57	17
49	Rakennusosat: ei lada	VS12.1	1397,3	200	156,48	42
50	Rakennusosat: ei lada	VS12.2	1517,95	211,47	159,34	23
51	Rakennusosat: ei lada	VS13	41,55	12,2	9,61	1
52	Rakennusosat: ei lada	VS14 (kevyt väliseinä/verhous)	8,7	22,68	0,721	7
53	Rakennusosat: ei lada	VS15 - 118mm Röntgentilojen seinä	175,85	51,25	20,6	6
54	Rakennusosat: ei lada	VS16	237,29	65,82	94,18	7
55	Rakennusosat: ei lada	VS5 (valuharkkoseinä 150mm)	80,28	17,84	12,03	1
56	Rakennusosat: ei lada	VS7 - 92mm	2741,07	846,61	252,12	326
57	Rakennusosat: ei lada	VS7.1 - 92mm	1049,92	360,79	96,49	190
58	Rakennusosat: ei lada	VS8 -121 mm	2437,5	691,5	294,74	168
59	Rakennusosat: ei lada	VS8.1 - 121 mm	194,8	53,56	23,56	21
60	Rakennusosat: ei lada	VS9 - 118mm	14017,35	4606,45	1651,06	743
61	Rakennusosat: ei lada	VS9 - 118mm alakatto-otsa	115,24	129,35	13,59	29
62	Rakennusosat: ei lada	VS9.1 - 118mm	2029,64	617,41	239,18	133
63	Rakennusosat: ei lada	VS9.1X - 146 mm	15,5	17,09	3,19	2
64	Rakennusosat: ei lada	VS9.2 - 116mm	2412,73	719,75	279,69	137

Figure 11. The quantity list compiled by the model checking program is relatively easy to read and thus can be used in various ways, such as any other quantity list. [2.]

In this particular quantity estimation case, the process was done so that the procurement team could check to see how much the quantities have changed since YIT Construction Ltd. placed their preliminary bid for the contract. This knowledge can be utilized when billing the client, as changes are practically unavoidable between the preliminary bidding and the production phases. These changes always have a cost, and must be taken into account.

Coming back to the earlier mentioned challenges in quantity take off, one major challenge is the incorrect or incoherent way of labeling the components of the building. In the campus project, drawing quantities as accurately as possible required cross-checking of the model with the drawings. This was due to some of the building components being inadequately labelled. Such was the case for ground bearing slabs, where most slabs had their designated type as *maanvarainen or ground bearing* and numbering between one to fourteen. This was not the case for wet spaces, where one would notice the absence of a slab in the middle of the building when typing *maanvarainen* in the search bar and running “Find.” The slab was modelled, but the type of it was, for some reason, *pohjalaatta*, or *bottom slab*, even though other documents contradicted this by grouping the missing slab with the rest of them. A missing slab is fortunately quite easy to notice, as can be seen in figure 12 below, and also to locate in the model. Once the user finds the slab, they can just click on it to see the relevant information of it. In this case, it was the area of the slab that the procurement team was looking for.

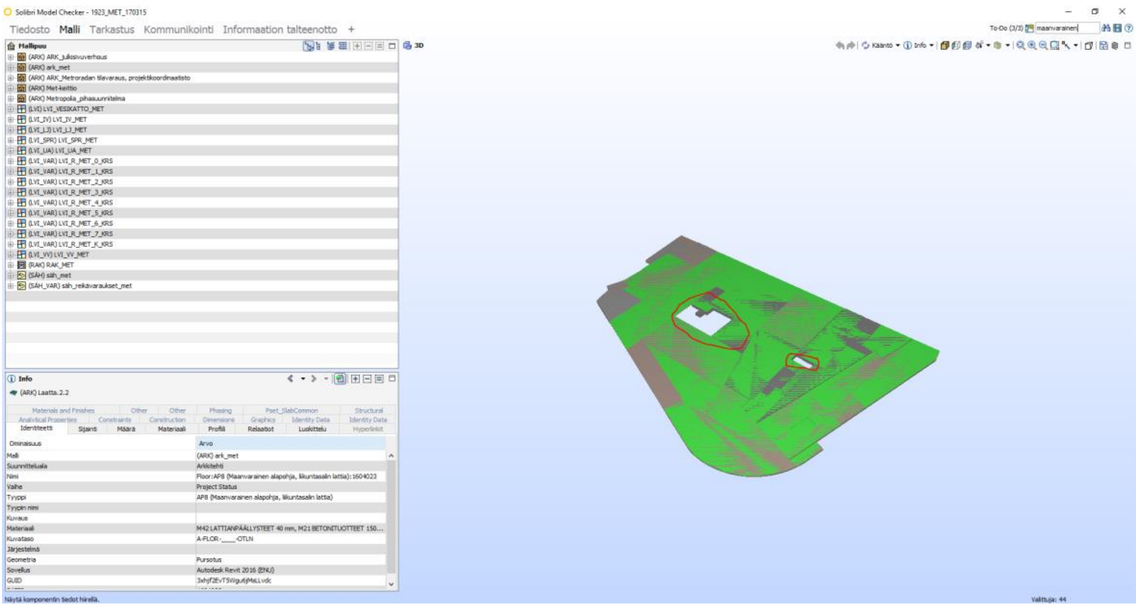

Figure 12. Visualization is indeed useful for noticing conflicts in the plans and for making sure one has really taken all relevant objects into consideration when doing quantity take off. [2.]

To avoid the such challenges related to incorrect labeling of building components, the same sort of TALO2000 system labeling of components should be done in a BIM project as one would do in a traditionally organized construction project. TALO2000 labeling system is an updated version of TALO80 that has been in use in the construction industry for decades. This was the labeling system in use in the Metropolia UAS campus project. [13,1.]

9 Conclusions

While writing the report, it became evident that BIM has considerable potential from the construction procurement point of view. Enhanced 3D visualization of the building with the latest design implementations can greatly help when questions arise during negotiations, and looking for exact documentation would be too time consuming. Being able to virtually step inside the building model can help with the description of spaces and the planning of the best production methods. There will always be forces resisting change in any form, such as adapting to BIM, but they can all be overcome with diligent marketing and intelligent application of building information modelling in construction projects.

9.1 Key Benefits and Uses

Visualization also brings more power to the process of clash checking. In an optimal situation, clash-checking of designs is done before the procurement process begins, but anyone with enough proficiency in clash-checking software, like Solibri Model Checker, can perform their own clash-checks for extra assurance of the compatibility of the plans.

Being able to make the layers of construction transparent and even completely hiding them can be a powerful tool in showing exactly where a certain space or object is. One can search for either a single object or multiple objects, such as doors or walls, by using the search bar that is easily locatable in the upper right-hand corner in the Solibri Model Checker. Alternatively, the user can hide the suspended ceilings to show the MEP systems hidden above them, or peel off layers of walls to show their contents such as insulation or fireproofing coating. Adequate care in the naming of layers and components should be taken, to avoid unnecessary time spent searching for building components that are just poorly named. COBIM2012 and Talo2000 naming systems should be used as much as possible to avoid this.

Building information models can also be used to create procurement specific quantity lists, that are often necessary, as the procurement packages of the client and the contractor may differ in substance. An example was given in chapter 8, where the quantities of partition walls were taken off using the Solibri Model Checker. The time saved by this action alone can be hours, if not days, thanks to the multiple ways to quantify items and objects when the building components are correctly labelled.

For cost-estimation purposes, BIM can be used in various ways. Even if no model is given by the client, the contractor may benefit from creating their own model, from which they can extract rough quantities to help with their cost estimation and planning. To make such a model would not take long and could potentially promote the bid of the contactor to the client.

Finally, the use of BIM in construction procurement negotiations can be a good way to save time. Instead of searching certain sections from a large folder of ambiguously named PDF files, the BIM offers a possibility to make section cuts anywhere in the model. The same is true for trying to find any kind of documentation or details. Search tools for specific parts of the building are potential time savers during meetings as well, when neither party is yet fully certain of anything and the plans can still evolve.

9.2 Challenges

As for the challenges regarding greater BIM use, some key points arose. Since the actual use of BIM in the construction industry has been almost completely visual until now, the demands laid out for the models by COBIM2012 guidelines have not been sufficiently enforced. This has not motivated the designers in their model creation, thus leading to poor models. Engineers and contractors have also had doubts about the worth of modelling. This report alone should prove the worth of BIM, as well as show that there are individuals and organizations that wish to see greater BIM implementation throughout all levels of the industry and beyond. Full utilization of COBIM2012 and hiring of sufficiently proficient BIM coordinators to oversee the processes is vital for further successes in the field of building information modelling.

Furthermore, software training on BIM should be mandatory practically for all personnel working in the industry. The key here is to help individuals realize that their previous methods of working can be made significantly more efficient if full BIM utilization is achieved. This can be done for example by streamlining of the quantity take off and negotiation visualization. If a person working on a project does not know that they can use BIM to achieve whatever they want to achieve, they probably will not think of using BIM either.

Finally, it can be deducted that the decision to implement BIM-based design and construction will always be initiated by the client. This may call for new types of tendering and contracting processes, one such example being the Alliance model that has been used in some of the larger infrastructure projects around Finland. It is the hope of the writer that the process of digitalization and BIM utilization will bring the various project stakeholders closer together, creating a cycle of improvement that will most likely feed itself.

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