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Master Thesis

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Quantity Takeoff process for bidding stage using BIM tools in Danish Construction Industry

Student:

Daniel Roginski s091160

Supervisors:

Jan Karlshøj (DTU), Morten Alsdorf (Rambøll), Niels Treldal (Rambøll)

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Abstract

The purpose of this study is to make an overview of existing problems in Danish construction industry regarding preparation of Quantity Takeoff material for bidding stage which determines reliability of bid price and to provide suggestions improving this process. This is done with a focus on use of Building Information Modelling tools.

Before digging into practical issues, theoretical part is provided which serves as a background for escalated issues. It includes description of construction bidding process, Building Information Modelling technology, Quantity Takeoff process from Building Information Modelling perspective, interoperability issue and Information Delivery Manual concept.

Project is developed mainly in three phases. First phase is based on the interviews conducted with project managers and estimators from consultancy and construction companies. In this phase overview of bidding process and issues related with quality of bidding material content from two different perspectives is provided. It presents interviewees' opinion about existing practice of tendering process and issues related with bidding material content which makes it difficult to provide reliable bid price.

Second phase addresses issues related with capability of Building Information Modelling software to support bidding process. It is based on tests performed on chosen modelling applications. First test gives an overview of Quantity Takeoff in Tekla Structures. Then interoperability between different software is tested. It describes how Tekla Structures model behaves in Revit Architecture and Solibri Model Checker. Also one test was performed to check how Revit Architecture Model behaves in Solibri Model Checker. Last test describes the way to make Quantity Takeoff of Tekla Structure model in Solibri Model Checker following Information Delivery Manual requirements.

Third phase of the thesis is a sum up of information developed during first two phases. It highlights problems in bidding process and bidding material content which makes it difficult for contractor provide reliable bid price. Here also suggestions for highlighted problems are provided.

Preface

Recently Building Information Modelling (BIM) has become one of the most discussed topics in construction industry. From theoretical point of view this technology, where IT solutions play key role, brings the industry to new level where behaviour of project participants is changing and processes become more controlled and automated increasing working efficiency.

However, this technology is very difficult to implement in practice. Even though IT developers release many sophisticated programs to support the idea of BIM - improvements are still needed. There are still many problems related with software capabilities to function accordingly to theoretical, ideal BIM concept that need to be solved.

There are many issues to be investigated in BIM technology. For this Master thesis it has been chosen to focus on Quantity Takeoff (QTO) processes for bidding stage using BIM tools. It have been decided make an overview of existing bidding practice between Danish consultancy and construction companies, to identify problems in preparation of bidding material, which make it difficult to obtain reliable project price, and to determine the situation of BIM technology and related issues with it in bidding process. Based on this information I have provided some suggestions how this process could be improved.

Acknowledgements

I want to thank a lot to my supervisors Morten Alsdorf and Niels Treldal from Rambøll A/S and Jan Karlshøj from Technical University of Denmark for help setting directions for my thesis and consultancy along its development.

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Special thanks I give to my family who have supported me during my studies in Denmark and who made it possible for me to obtain Master degree in one of the best technical universities in Europe.

Table of Content

1. Introduction

1.1. Problem statement

Bidding in construction industry is very important process where available in the marked price of the project is being discovered. However, practice shows that this price usually rises up along the construction process not only due to errors in the project itself or changes applied by client, but also due to additional works and materials to be used which were not included or well described in bidding material.

Building Information Modelling (BIM) technologies help to reduce mistakes of the project by switching from error prone paper based way of doing design, management and information exchange to digital one which is easier to control and analyse. With BIM it is also possible quickly extract precise quantities of construction materials in the project and use them preparing bidding documentation. Nevertheless, unforeseen additional materials and works still appear and increase total cost of the project. The reason for this might be hiding behind lack of proper methodology for process of preparing reliable bidding material and misunderstandings between participants in bidding process.

Therefore, there is a need to review existing tradition of preparing bidding material and think of improvements which would help achieve more reliable bid price.

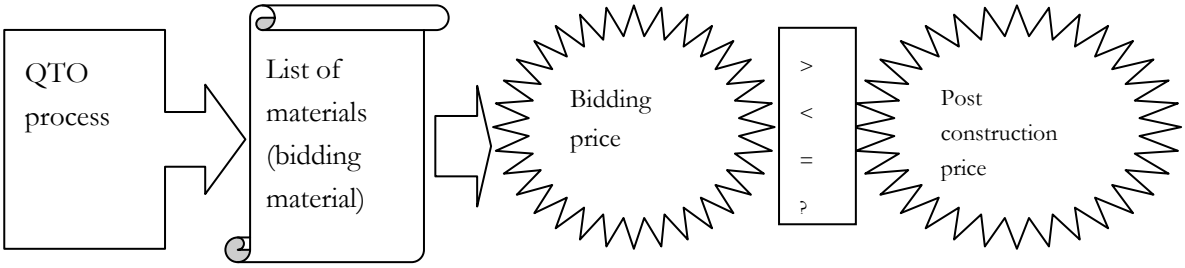


Figure 1 Investigated process

1.2. Aim of the Thesis

It is the aim of this Master Thesis to make an overview of existing bidding practice between Danish consultancy and construction companies based on experience of people involved in the process, to identify problems in preparation of bidding material which make it difficult to obtain reliable project price and at last to determine the situation of BIM technology and related issues with it in bidding process. Based on this information suggestions to improve bidding process are going to be provided.

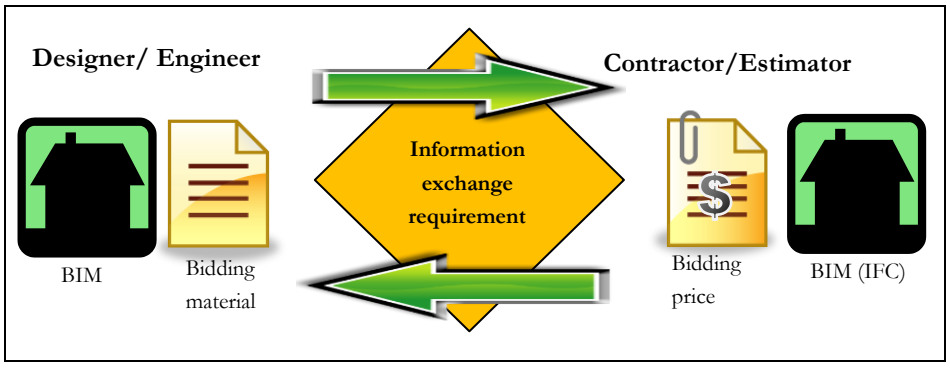


Figure 2 Objects of concern: requirements for QTO in order to obtain reliable bidding price

1.3. Methodology

Before digging into practical issues overview of theoretical topics related to the thesis is made. It describes Bidding process within AEC business model, theoretical concept of BIM with focus on QTO and interoperability. Information Delivery Manual also is described in order to give better understanding about information sharing processes and their structural content.

This thesis is dealing with identification of issues related with preparation of reliable information material used for bidding process. It includes investigation of the way this information is produced and determination of proper/right information which has to be included in bidding documentation in order to obtain reliable bidding price of the project. Investigation of this issue is mainly based on the interviews conducted with project managers and estimators from construction industry who are dealing with or somehow contribute to preparation of bidding documentation.

In this thesis BIM based QTO process is considered which most definitely is followed by interoperability issue. Therefore, overview and tests of chosen BIM software used in AEC also takes place in order to find out its possibilities to support process of extraction of proper/reliable information for bidding material required by design/consultancy company as well as by contractors participating in bidding process.

Based on gathered information during the interviews and performed tests overview of the bidding process is presented, problems highlighted and solutions for the problems suggested.

1.4. Scope of the thesis

This Master Thesis consists of following main parts: Introduction, Theoretical part, Main Body, Discussion and Conclusion.

In the **Introduction** problem statement, aim of the thesis and methodology of its procurement are presented.

In **Theoretical part** short overview of topics related with thesis investigation is presented. It includes chapters describing construction bidding process, Building Information Modelling technology, Quantity Takeoff process from BIM perspective, interoperability issue and Information Delivery Manual.

In the **Main body** bidding process from design and construction companies' perspective is described. It presents interviewees' opinion about existing practice of tendering process and issues related with bidding material content which makes it difficult to provide reliable bid price.

In the following chapters of this part several tests performed on capability of chosen BIM software to extract quantities are described. First, overview of QTO in Tekla Structures is presented. Second, interoperability between Tekla Structures Revit Architecture and Solibri Model Checker is tested. Last test describes the way to make QTO of Tekla Structure model in Solibri Model Checker following IDM requirements.

Discussion part of the thesis includes discussion about construction project tendering process with a focus on list of material quantities. Based on these discussions and test results issues in bidding process are highlighted and suggestions on how to improve this process are provided.

In **Conclusion** final thoughts about investigated topic are presented.

2. Theoretical background

In this chapter theoretical background of topics discussed in this Master Thesis is presented. It includes description of construction bidding process, Building Information Modelling (BIM) technology, Quantity takeoff process using BIM, interoperability issue and Information Delivery Manual (IDM).

2.1. Bidding processes

2.1.1. AEC business models

There are different contract methods used in construction industry. Most common are traditional Design-Bid-Build method, Design-Build one and variation of these two (Figure 3). Working principles of these AEC business models are described below based on BIM Handbook written by Chuck Eastman (1).

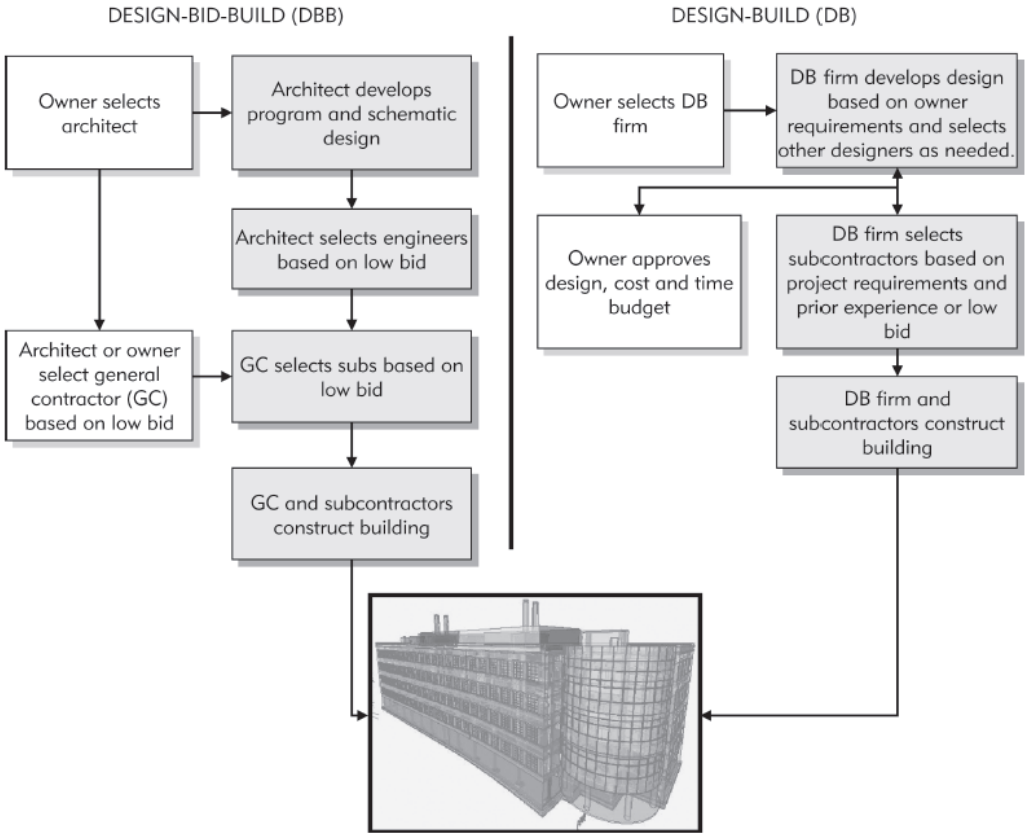


Figure 3 Schematic diagram of Design-Bid-Build and Design-Build processes (1)

Design-Bid-Build (DBB)

In the first stage of DBB model client chooses an architect who sets requirements for the building and objectives. The architect makes schematic design, develops it and makes contract documents. Structural and building service engineers then are involved to assist in design of structural, HVAC, piping and plumbing components. The end product of this stage is set of drawings and specifications which must be sufficient enough to go to construction bidding phase. Because of liability issues architects may choose to provide not too detailed drawings or they may add a note that accuracy of dimensions in the drawings is not precise.

In bidding stage general contractor for the project is being determined. Owner and architect usually decide who will participate in the competition. Competing contractors, after they receive set of drawings and specifications, make their own quantity survey. Based on those quantities bids are received from subcontractors and cost estimation of the project is determined. The winning contractor is usually determined by lowest bid price.

Before construction takes place contractors usually need to redraw drawings so they are sufficient for construction process. Those drawings are called "general arrangement drawings". Furthermore, subcontractors make their own "shop drawings" which are ready for production of items like precast walls, steel connections, piping runs, etc. Shop drawings are very precise and detailed. If they are based on drawings which already contain errors there might be conflicts on the site. And costs associated with this issue might be significant. To produce building elements offsite when detailed drawings may not reflect real situation onsite is not rational solution. Therefore, most of the fabrication has to take place onsite where all conditions are known. This, however, is more costly and time consuming; quality control of produced elements is not as good as it is in factory.

During construction phase there are often changes made in the project. They might be related with mistakes made in the design, unanticipated site conditions, changes in material availabilities, new client requirements, and new technologies. The problem with that is, that often contractors bid below the estimated cost in order to win the project and when changes appear they abuse the changes process in order to recoup losses from too low bid price. This way project may become even more expensive (Figure 4).

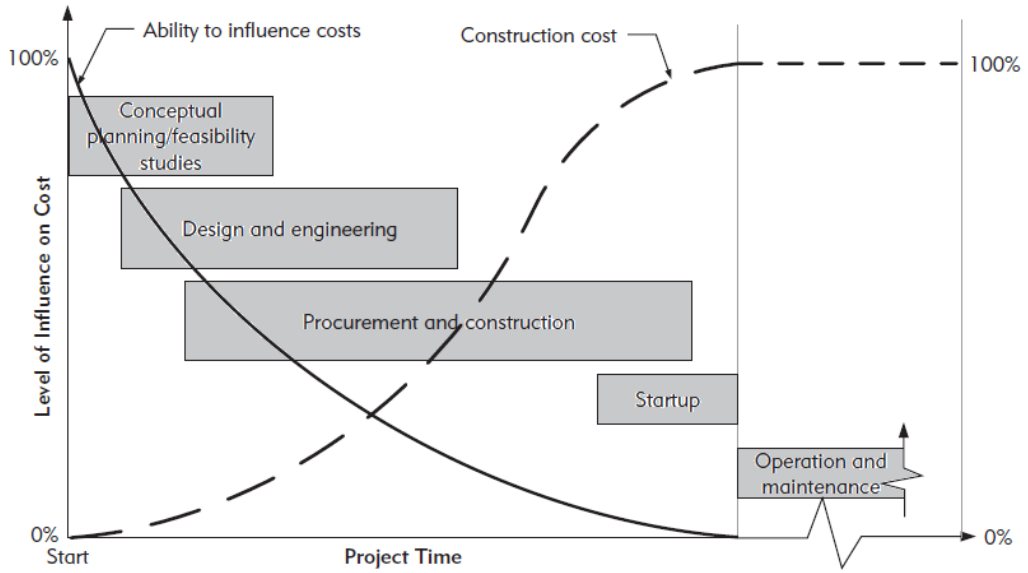


Figure 4 Influence of overall project cost over the project lifecycle (1)

DBB model is also more time consuming comparing to new developed models like Design-Build as it requires that the procurement of building materials is held until the owner approves the bid. This means that long lead time elements cannot be ordered early enough to fit the schedule.

The DBB model is completed when all systems of the building are checked and approved and project's "as-build" drawings, documentation and manuals are submitted to the client.

Design-Build (DB)

The Design-Bid-Build model is not the most effective approach to design and construction. Therefore other approaches like DB were also developed to overcome problems found in DBB.

The aim of the DB is consolidation responsibility for design and construction into single contracting entity and simplification of administrative tasks for client (Figure 3).

In this model the client contracts directly DB team which develops building program and schematic design. Then estimations of total project cost and time schedule is performed. Modifications of the project at this point may take place. After client approves all the modifications and building plan final cost estimation and schedule is established. Then DB contractor makes contracts with subcontractors based on project requirements and prior experience or low bid.

When construction begins all responsibility for further changes in the project, errors and omissions is transferred to DB contractor. As a result building is typically done faster with fewer legal complications. However, in this case owner has less flexibility in terms of making changes after design and size of the project is approved. On the other hand, within DB model all design modifications can be made already in early stage of the process, therefore, amount of money and time needed to apply those changes are reduced (Figure 4, Figure 5).

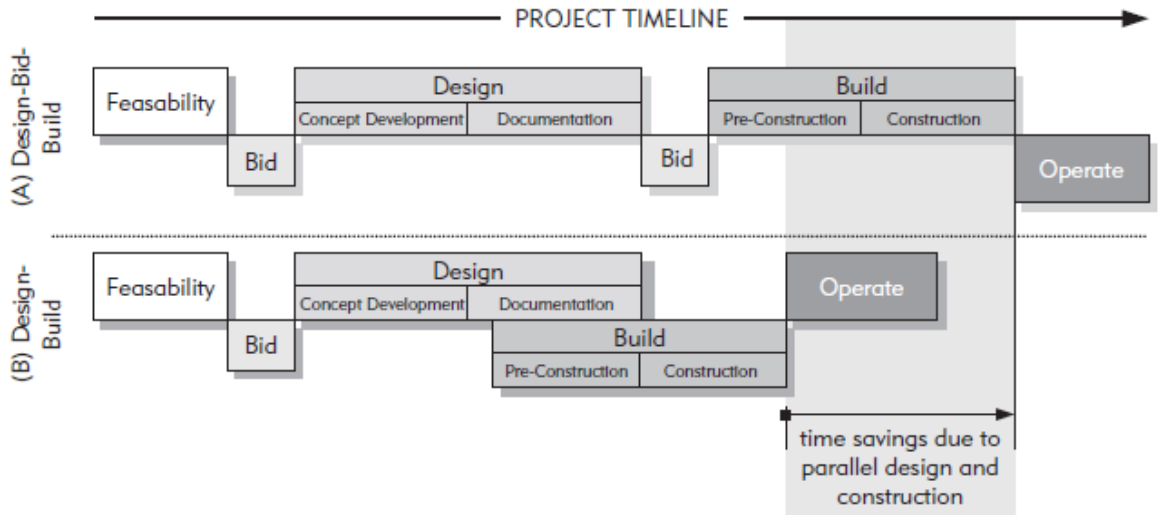


Figure 5 Diagram comparing two different delivery processes: A) the traditional single stage involves the completion of each phase prior to start of the next phase, often involving a different organization performing each phase in a non-integrative process; B) the design-build process involves an overlap of development phases leading to a shortened overall schedule and requires integration between designers and builders (1)

2.1.2. Description of bidding process within construction company

Bidding process in construction industry is a stage of the building/construction project where competition for the best suitable contractor for the project erection is held. Winner of the competition is usually defined by proper fulfilment of requirements set by client/consultant, lowest bid price and/or best solution proposed. There are various stages in preparing a tender and the action needed with successful tenders. The model of proposal preparation process is shown in Figure 6.

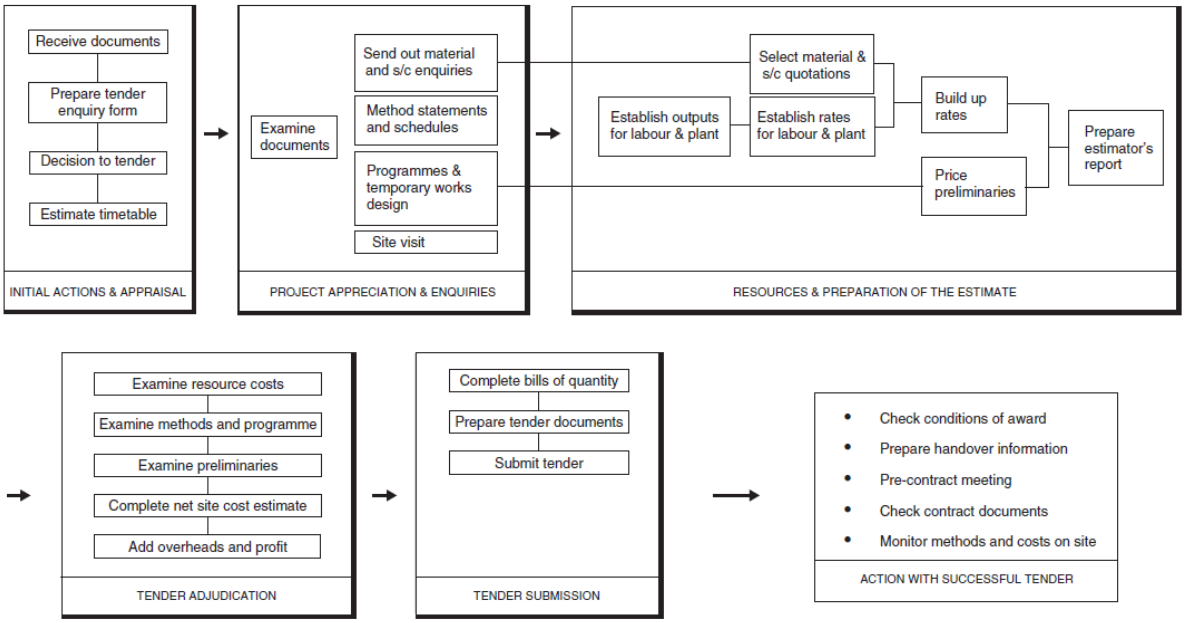


Figure 6 Estimating and tendering flowchart (2)

2.1.3. Tender documentation

Tender material in this sub chapter is described based on book written by Martin Brook (2).

Documentation is main form of communication in bidding process. It is a vital link between design and construction. Its quality is essential for good understanding and cooperation between project participants and determines the success of the project in terms of quality, time and cost. Therefore, it is worth to spend time to prepare documents so contractor is able to understand the scope of work well. This benefits finished product a lot.

The basis for cost estimation is set of documents consisting of general arrangement drawings, bills of quantities and work specifications. Drawings are the most common mean of communication in almost all construction projects. They give an insight for contractors about building complexity. Specifications are intended to provide technical information mainly on quality of materials and workmanship. A bill of quantity provides amounts of works and materials to be used in the project which should be priced taking into account information available in drawings and specifications. Therefore, there should be a good coordination of information shown on drawings with other documents.

The Coordinating Committee for Project Information has identified many problems which should be taken into account while preparing material for competition:

1. Missing information – not produced, or not sent to site;

2. Late information – not available in time to plan the work or order the materials;

3. Wrong information – errors of description, reference or dimension; out-of date information;

4. Insufficient detail – both for tender and construction drawings;

5. Impracticable designs – difficult to construct;

6. Inappropriate information – not relevant or suitable for its purpose;

7. Unclear information – because of poor drafting or ambiguity;

8. Not firm – provisional information often indistinguishable from firm information;

9. Poorly arranged information – poor and inconsistent structure, unclear titling;

10. Uncoordinated information – difficult to read one document with another;

11. Conflicting information – documents which disagree with each other.

2.2. Building Information Modelling (BIM)

2.2.1. What is BIM?

Traditional paper based 2D drawings have always been used in construction and design since ancient times until now. With a rapid development of IT new opportunities for improvements of processes in construction industry have been discovered and applied.

First of all, first main achievement was switching from pen based to computer based drawing. This new technology allowed work to be done faster as drawing technique become more flexible in terms of possibility to adjust quickly changes in drawings.

Second step was generation of three dimensional digital objects, which allowed creating 3D building models. With this feature due to possibility of visualization it become easier to understand volumetric geometry of buildings, make better architectural decisions. It also became possible to extract 2D drawings of the building like floor plans or section cuts. Making changes in 3D model they were reflected in all other 2D views respectively.

Third step was possibility to assign particular information to building model components. At this moment Building Information Model term was introduced and development process of such model was called Building Information Modelling technology.

Now there are many different definitions of BIM. Basically all of them are about innovative and efficient process of development of building information using digital building modelling and information sharing technologies.

According to Autodesk, one of the most widely used drawing and modelling software developers, "*Building Information Modelling (BIM) is an intelligent model–based process that provides insight for creating and managing building and infrastructure projects faster, more economically, and with less environmental impact."* (3)

Chuck Eastman, together with his co-authors of book about BIM (1), describes Building Information Modelling as "*one of the most promising developments in the architecture, engineering and construction (AEC) industries. With BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer - generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building.*"

2.2.2. Benefits of BIM technology

One of the main objectives of BIM technology is to support all the processes starting with feasibility study stage and continuing through whole building lifecycle. Major benefits presented by Chuck Eastman (1) for each building project lifecycle phase are described below.

Pre-construction phase

In feasibility stage client tries to determine the size of the project which would meet his budget. The estimation of the project at this point is very rough. But it is still not desired to spend a lot of time on cost estimation which at the end appears to be significantly over budget. Using BIM tools approximate building model can be linked to cost database and project price would be calculated instantly along with model creation/modification process.

Already in early stage when only schematic model is available it is possible to evaluate building functionality and sustainability using analysis/simulation tools. This allows defining right project development directions in early stage which increases the overall quality of the building.

Design phase

Entering the design phase 3D model is already available from previous stage. There is no need to generate model form 2D drawings. Models might be just ready for updates.

If object are assembled using parametrical constrains probability of error occurrence while design is changing is minimised.

There is possibility to extract accurate and consistent drawings for any set of object or specific view of the project. What is more, after each modification of 3D model all the 2D visual representations are modified respectively.

It is possible to perform automatic evaluations of 3D models in terms of satisfaction of set requirements like "Area of certain type room has to be of particular size".

Estimators using BIM can extract quantities and spaces which can be used for cost estimation. At the beginning estimations are made based on available quantities like areas. When more detailed design is done more accurate estimations can be performed. It helps to make better design decision along project development process as project price can be monitored continuously.

Construction and Fabrication

Using 4D BIM it is possible to simulate the construction process, visualize how building will be constructed day-by-day, and reveal potential problems on the site and opportunities for improvements.

BIM technology allows identify clashes between systems from different disciplines before construction takes place. This speeds up construction process, reduces risk for project cost raise due to clashes and need for solutions to fix mistakes, minimises probability of legal disputes.

In case design changes appear during construction, modified model, which is set with parametric rules, will update also cost estimate and schedule instantly.

BIM technology also facilitates fabrication process. 3D elements from the model can be sent to factories where element production process is fully automated.

Because of 4D BIM it is much easier to implement Lean Construction Technique.

Post-construction phase

BIM models are full of information which can be useful for building operation processes. It is desired that models support real-time monitoring of control systems, provide a natural interface for sensors and remote operating management of facilities. Despite the fact that those possibilities are not developed yet there is a room for such development.

2.3. Quantity Takeoff and BIM

Quantity Takeoff is a process of determination of the amount of materials and items used in a particular construction project. It is a base for determination of the associated materials and labour costs, and formulating a bid/estimate as part of the bidding process. (4)

There are many types of estimation processes going along the design process. At the beginning rough cost estimation of the project is made based on parameters associated with spaces and volumes, their types, perimeters etc. Together with the development of design process more information become available therefore more accurate estimates are being performed. (1)

Building Information Modelling technology incorporated with Quantity Takeoff software solutions makes material costing faster, easier, and more accurate. Cost estimators can create synchronized, comprehensive project views that combine important information from building BIM tools together with geometry, images, and data from other tools. Automatically or manually measure areas and count building components, export to Microsoft Excel, and publish to DWF format. (5)

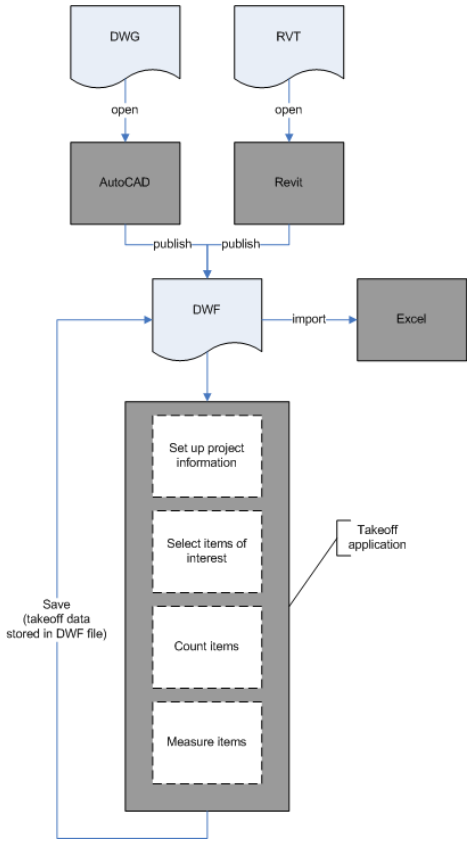


Figure 7 Basic Estimation process using most common software applications (4)

Linking the design model with the estimating processes enables to speed up QTO and overall estimating process. It also gives faster feedback on proposed design changes. The Hillwood Commercial project case study conducted by Chuck Eastman cites evidence that estimating with BIM early in design can result in a 92% time reduction to produce the estimate with only a 1% variance between the manual and BIM - based processes. (1)

Even though BIM makes it possible to achieve precise measurements for QTO it is important to state that QTO is not equal to whole cost estimation process which besides extracting quantities involves assessing conditions in the project that impact cost, such as unusual wall conditions, unique assemblies, and difficult access conditions. (1)

All BIM tools have capabilities to extract number of building components, areas and volumes of spaces, material quantities and present them in various schedules. However, to retrieve very precise cost estimate from contractor there might be a problem of insufficient definition of components which are not properly defined or there are missing quantities which are needed for cost estimating, for example, the area of interior partition walls may be available but not the quantity of studs in the walls. (1)

Estimators in building companies should consider using BIM technology not only because of more precise QTO but also for quick identification of assess conditions simply by visualizations and model exploration. This also provides more time to optimize prices from subcontractors and suppliers. (1)

No BIM software can fully support comprehensive cost estimation process. Therefore, estimators have to choose a method how to run this process.

There are three primary options (1):

- Export building object quantities to estimating software;

- Link the BIM tool directly to the estimating software;

- Use a BIM quantity takeoff tool.

2.4. Interoperability

Interoperability – the ability of BIM tools from multiple vendors to exchange building model data and operate on that data. Interoperability is a significant requirement for team collaboration. (1)

In old times information exchange between actors involved in development of projects was executed simply by sending paper based documents to each other. Received information usually was retyped/regenerated so it could be ready to perform other tasks in different environment. Nowadays, there are many software application provided by IT solution developers to support different tasks in construction industry: beginning with simple excel sheets and ending up with many sophisticated BIM platforms. However, in order to take advantage of these IT tools in terms of digital information sharing and reduce or even eliminate retyping process software developers made possibilities in their products to use files formats from other software vendors. Moreover, IFC format was introduced which enabled transferring information between different software platforms used by different discipline engineers, architects and managers.

In the Table 1 ability of several software to communicate through particular file types is presented.

Table 1 BIM software interoperability (6)

Nr.	Software	IFC file type		Other file types	
		Import	Export	Import	Export
1.	Tekla Structures	✓	✓	.dwg/.dfx/.xml/.std	.dwg/.dfx/xml/.std
2.	Revit Architecture	✓	✓	.dwg/.dfx	.dwg/.dfx
3.	VICO Constructor	✓	✓	.dwg/.dfx	.dwg/.dfx
4.	Solibri Checker	✓	✓	.dwg/.smc	.smc

However, problem with interoperability still persist. To make information transfer effective it is important to create information sharing schemes, which ensure proper information exchange between design process participants at proper time.

Industrial Foundation Classes provide comprehensive reference to totality of information within the lifecycle of constructed facility. But it does not provide it to individual processes within building construction. (7)

At this point Information Delivery Manual acts as a tool which solves this problem by describing requirements for proper communication in smaller scale processes.

2.5. Information Delivery Manual (IDM)

2.5.1. What is IDM?

This section describes IDM based on document provided by BuildingSMART – international Alliance of Interoperability. (8)

BIM handles numerous different information flows in a single operating environment, reducing need of paper document currently in use.

To use BIM effectively and accumulate benefit from it there is a need of proper communication between participants. It means that required information should be available at the time it is needed.

To achieve appropriate communication there should be a common understanding of building processes, the information needed for these processes and expected one after its execution.

Information Delivery Manual aims to provide integrated reference for processes and data required by BIM (Figure 8):

- Identification of discrete processes;
- Information required for processes;
- Information required from processes.

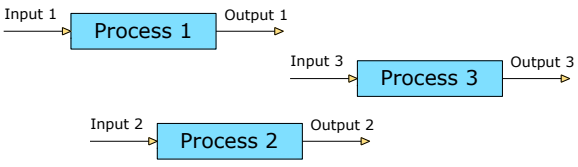


Figure 8 Main targets of IDM

IDM specifies:

- Location of the process and why it is relevant;
- Actors creating, consuming and benefitting from information;
- Information itself which is to be created and consumed;
- Software support.

While IFC compliant software is already widely used in practise, it is important to ensure secure and reliable information exchange/sharing along project development process. Shared information must be sufficient enough to perform tasks defined in the project and support business process.

IFC schema is a set of different individual topic schemas like structural analysis, HVAC, costs, materials etc. It contains all the information about project at all business stages. With IDM, on the other hand, only relevant information at different project stages to support business requirements is provided (Figure 9). This information is described in **Information Exchange Requirement** in non technical manner.

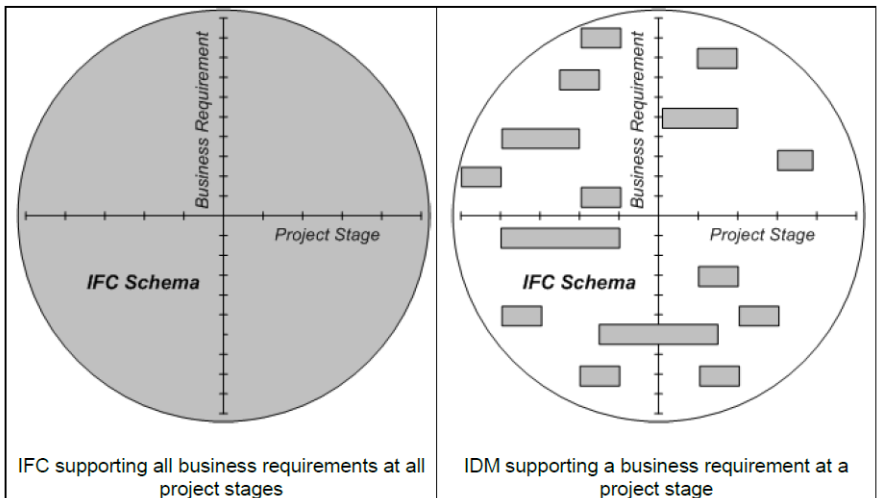


Figure 9 IDM support for business processes (8)

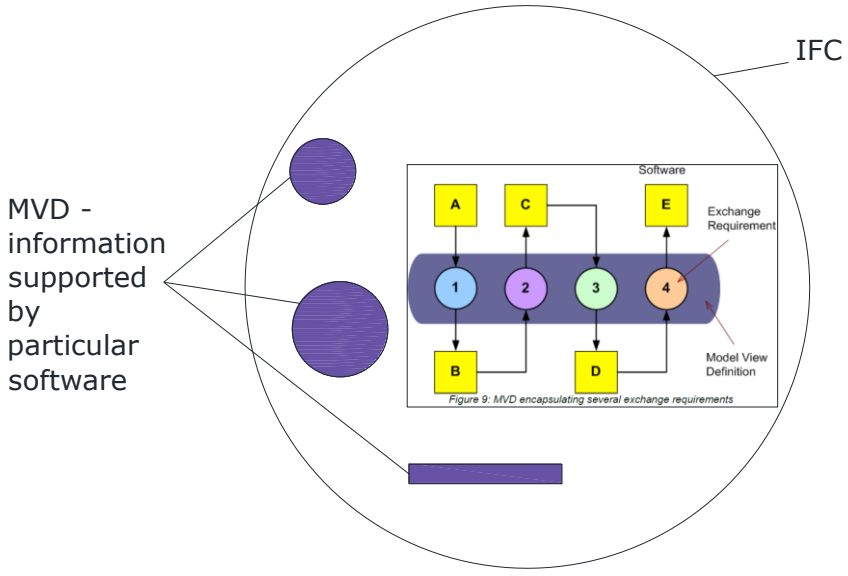


Figure 10 MVD encapsulating several exchange requirements (8)

2.5.2. IDM for QTO used in bidding process

There is an initiative to develop information delivery manual for planning and execution of consultancy works regarding calculation of material quantities which later become a basis for tendering process (Appendix A) (Figure 11). This manual is suitable for traditional design-bid-build business model.

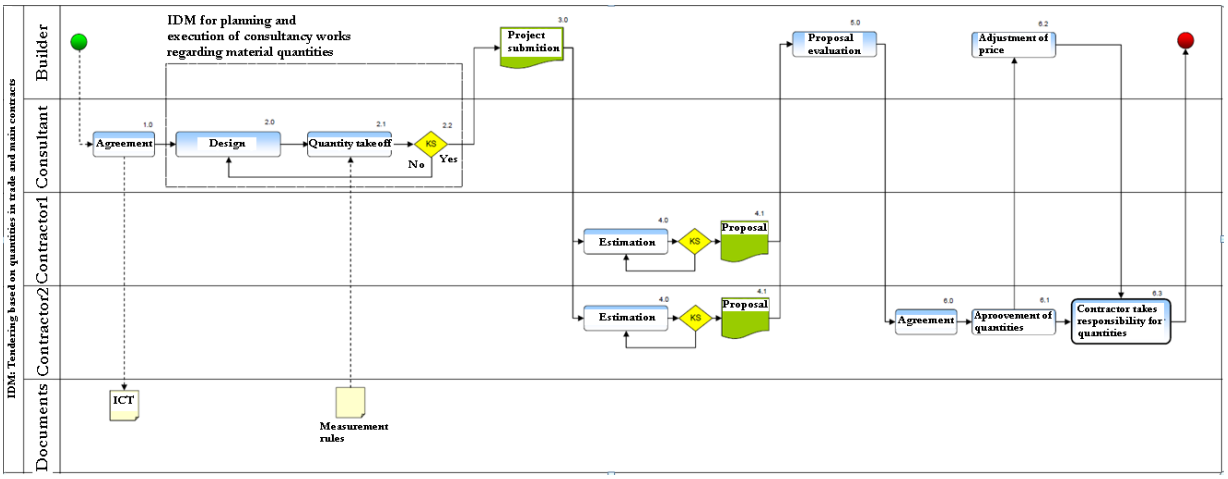


Figure 11 Appliance of IDM for planning and execution of consultancy works regarding calculation of material quantities in preconstruction process (Appendix A)

After the agreement between client and consultant firm is signed design process takes place where architectural, structural and all engineering systems and service parts of the project are developed. After the design phase is over Quantity Takeoff from different disciplines is carried out based on established measurement rules. Then analysis of overall project is been performed. In case it appears that project does not meet particular project requirements project is returned to design phase for improvements. Once all the requirements are fulfilled project is submitted to the client. Project documents include Building Descriptions, drawings and/or models, list with material quantities, the measurement rules, and documentation of assumptions. Set of these documents is sent out to a number of competing contractors who have to evaluate the project and provide proposal by filling tender document - setting prices for material quantities stated in the list. Client analyses proposals and signs an agreement with winning contractor. Chosen contractor recalculates material quantities which may lead to project price adjustment/negotiation. At this point contractor takes full responsibility for agreed quantities which are tied by the agreement.

One of the factors determining the success of the project is good planning and ability to oversee possible changes during the project development process. Project price is one of most important parameters client is concerned about. From this process map description provided above it can be seen that there are several moments when client is introduced to the project price. First of all, project is evaluated after compete design is made based on extracted quantities. Second, client receives proposals from contractors based on quantities provided by consultant. Third, final price is established after contractor examines all the quantities needed to build the project and for which he is ready to take responsibility. The better client can predict price early in the process less risk is taken to go over budget. For this reason it is important to develop procedures which ensure reliable evaluation of the project already in design phase.

Already in this manual it is recognized and emphasized that there is a need of measurement rules for quantity takeoff which should specify how to measure quantities correctly in each discipline (Table 2). This should help to obtain more realistic and controlled price before the bidding. Quantities have to be measured in the way that they fit definition of quantities for which unit price is assigned. Sending measurement rules together with bidding material helps contractor better understand provided quantities and assign correct prices.

Beside rules for measurements of building elements this IDM also states that there should be consistency between the project drawings, discipline models, building descriptions, list of quantities and prerequisite note. Applied classification must be continuous and have to be traceable in all discipline models, offers lists and descriptions of building parts.

Table 2 Example of IDM specification of wall element for tender (Appendix A)

Specification of data objects				
Area	**Building part**	**Quantity**	**Description of quantity**	**Manual or BIM**
Tender				
Requirements for objects Structures	Walls	Type (VE, V)	What type is involved, in-situ, prefabricated or sandwiches etc.	
		Height	Which height has the given wall	
		Openings/holes	Number of openings/holes	
		Classification	DBK or other classification.	
		Total length	It is the total length of the given price	
		Description	Description of object construction	

3. Quantity Takeoff and BIM for bidding process

3.1. Introduction

Construction project price is one of the factors which has a crucial impact on the client's decision to build construction or not, or eventually to reconsider the project size or quality.

Price surveillance starts already in initial phase of the project when estimation is based on limited information about construction like type of the building and its geometrical parameters (dimensions, volumes). Together with project development process more details about the project are revealed and consequently predicted estimated price becomes more precise and realistic (Figure 12).

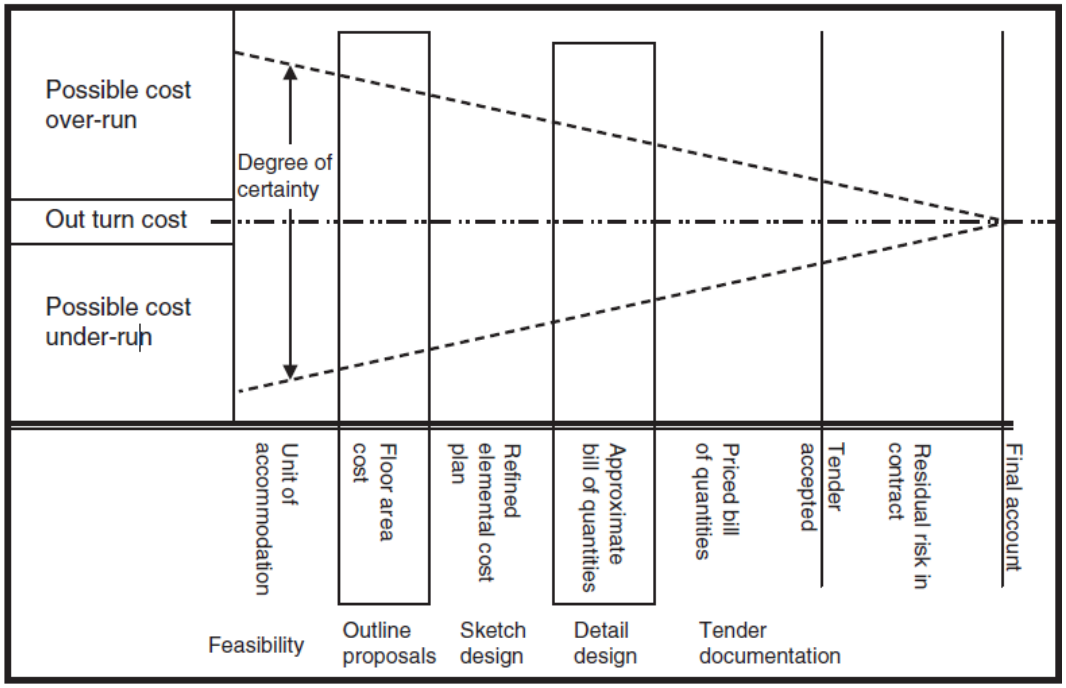


Figure 12 Degree of certainty for a typical construction project (2)

In pre-bidding, design stage client is more flexible in terms of making changes in the project trying to satisfy desires within the budget. Different scenarios of project development can be analysed with their impact on building price which at this point may be rough prediction. Client may feel safe so far in terms of money investment, as they are still in his/her pocket with no obligations. But when it comes to tendering process where available market price of the project is discovered and where agreement with chosen contractor should be signed, decisions play enormous role which are going to be tied with contract. Here reliability of bid price becomes very important as it determines if project will follow the budget or will go over it. It becomes crucial for client to receive realistic bid price which can be obtained only by proper quality bidding material.

In this thesis, therefore, main focus is put on investigation of bidding material content and its quality which would allow contractors to provide reliable bid price. To determine which project information is crucial in tendering documents it has been decided to conduct interviews with estimators and project

managers from consultancy/design and construction companies who are familiar with bidding process and could share their experience.

Building Information Modelling software vendors actively advertise their products as a solution which can handle numerous building project development processes in efficient way. Therefore, the aim of the thesis is also to check how particular software can support bidding process in terms of preparation of bidding material so it would satisfy both client's and contractor's requirements. It has been chosen to investigate interoperability between Tekla Structures, where building load bearing construction is modelled, Solibri Model Checker and Revit Architecture, which are tested for ability to create required reports about the building elements for bidding material from model made in Tekla Structures.

3.2. Bidding process from Design and Construction companies' perspective

One of the objectives of this thesis is to investigate current situation of bidding process in construction industry and define weaknesses in this process in terms of preparation of improper bidding material which often leads to unreliable bid price and later to running project over budget. To investigate this issue it has been chosen to conduct interviews with professionals in this field.

Usually in tendering process two main sides doing the business are involved: consultancy company and contractor. Therefore, next subchapters present two different views on current bidding process practice.

3.2.1. Bidding material from Design Company's perspective

This chapter is based on interview with Morten Darø Tranholm from Rambøll (Appendix B) who described existing practice of bidding process from consultancy company perspective. He highlighted problems related with bidding material content and gave some suggestions for its improvements.

Preparation for bidding process

Most of the information used for bidding process is generated during design phase. People responsible for development of different project parts like structures and services create documents describing their solutions. At the end of the design process information from all parts is collected into one package which should describe sufficient enough building and works to make an estimate. Afterwards, bid material is sent to competing contractors who need to give their project price. In case any information is missing in bidding material, which disables contractor give a price, queries are sent for designers who supplement bidding documents with required information.

Bidding material content

Tender documents consist mainly of three parts based on which project price is determined. They are drawings, in some cases 3D model, project specifications and list of quantities. There are two types of specifications. Overall description of the project provides information about how all the parts involved in the project will interact. Then there are descriptions of works which tell for instance what is the quality of material used in the building, what fire protection is required, how walls should be painted etc. Level of detail of drawings is usually the same as almost sufficient for construction phase. If drawings would not be detailed enough project price would rise during construction process when all details become available. Last part, material quantity list, serves as bill where prices for all works have to be assigned by contractors

based on material quantities and work descriptions. It has also category "adjustments" where contractor specifies the prices of additional material/works in case they appear.

Structure of list of quantities

The structure of list of quantities depends on the project size and complexity. But usually it is sorted by building element type. First, amount of beams at the bottom floors are listed, for example, and then beams which are different on upper floors or roof are presented. In case when there is a very tall building quantities may be grouped by certain number of floors.

Terminology

Names of the building elements in list of quantities do not follow particular standard. In some projects (especially in state projects) it cannot be specified too detailed what profile beam for instance has to be used. There may be only particular characteristics of beam which describe needed capabilities of the beam. Therefore, names are usually given in the way that they make sense.

Quantity calculation method/technique

Quantities are calculated for each discipline by the people responsible for development of their parts of design like structures, HVAC etc. It is usually done by extraction of quantities from 3D models. In smaller projects, where there is no need to develop BIM model, quantities can be calculated manually straight from drawings.

The problem with gathering the quantities is that people doing this work are not experts in this field. They are mostly focused on delivery of good architectural/engineering solutions. In England, opposite to Denmark, there is a practice where consultant company has an expert who does all the calculation of quantities and prices. Morten thinks that having such person in company would be very beneficial. However, in this case it is crucial that this estimator does not appear only before bidding process but is involved in design process as well. There is huge possibility that some details could be missed if quantities are calculated by pure estimator alone, therefore designers should take part in QTO as well.

Measurement rules

Consultant companies can measure elements in many ways. The most important thing for them is to understand how contractors want quantities to be measured in order to give exact price. It is possible to give different geometrical parameters for each element in the list quantities, but then risk appears of having an information overflow. Therefore, it would be very interesting to hear from contractors what geometrical parameters of different elements should be presented in list of quantities in order to provide reliable price.

There are attempts to make rules for measurements and calculation of material quantities, but they are not specific enough. In case the length of nonrectangular slab should be specified there would be a problem to figure out how to do it in right way so that everybody can understand the meaning of presented value the same. It is important for consultant to do measurements and calculations the same way as contractors do.

Morten thinks that the perfect way to solve this problem is to make the industry discuss and decide what is the best solution to do measurements and calculate the quantities, because today it is done differently from company to company and from project to project.

Morten, suggested the idea to include in bidding material explanations about how quantities are measured, admitted that this could help contractor better understand the quantities and provide more reliable price. However, this is not used in today's practise.

Budget overruns, claims from contractors

Increase of the finished project price comparing to bid price is often observed in construction industry. There are two main reasons for that. First of all, it happens due to changes applied for the project which are result of client's wish or design mistakes. Other source of unexpected costs lies in not well defined bid material which leads to situation where during construction phase it appears that there are more building materials and works to be done than it was stated in bid material.

One of the reasons contractors provide different material amounts comparing to those calculated by consultant is a different way of measurements. Consultant usually obtains precise quantities, which are used for bidding, from 3D models if they are available. But they may not necessary represent quantities to be estimated. Morten has provided an example with calculation of deck quantities. Usually deck price includes concrete slabs with casting. However, extracted square meters of the slab from the model may not include spaces between slabs which have to be filled with concrete (Figure 13). Contractor, on the other hand, often deals with manual measurement from the drawings and he most likely will take into account both, slabs and gaps between them.

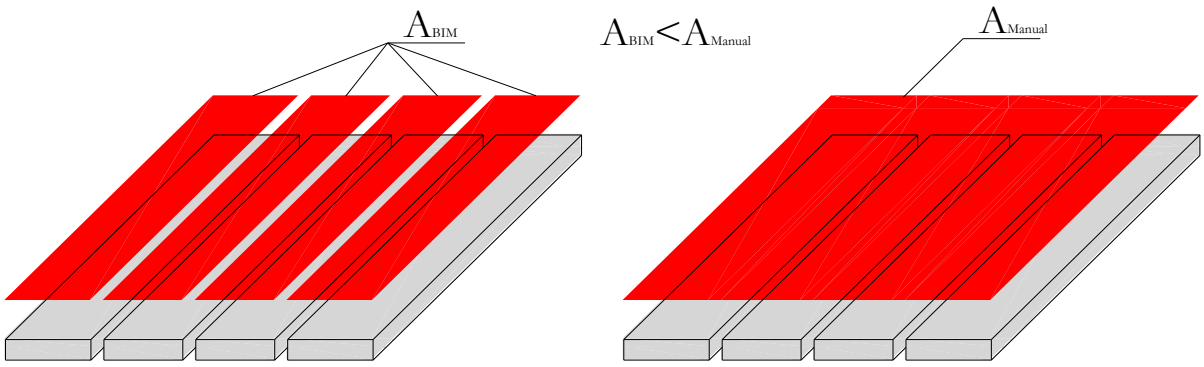


Figure 13 BIM based and paper based measurement accuracies

Contractor in this case could inform consultant that there are more quantities during the bidding process. This way bid material could be updated for all competitors. But this is not likely to happen. They will just give a price for amounts provided in bidding material and give the price for additional works in case they appear.

Usually, when offers from contractors are received contract negotiation process takes place. Here, contractors recalculate all quantities taking over responsibility for the amounts. In case additional amounts are discovered they firstly are discussed and then go as a supplement to the contract. And these supplements actually increase expected project price.

Building Information Modelling

BIM technology is used within the company on around 70 to 80 percent of all projects. The main benefit of using 3D models is better coordination between different disciplines. Structural model is made based on architectural drawings and sent to the architect. In case architect wants to move the door he asks structural designer to do it in structural model who afterwards sends IFC model back to the architect. Other disciplines are involved in the process similarly. To make design of installations BIM model is used to understand geometrical limitations. When particular installation solution is designed model is sent to structural engineers to adjust structural part to new elements appeared in the model. And this is a way of interaction which is much more efficient and less error prone using BIM. Changes made in the model will instantly reflect respectively on all 2D drawings extracted from the model.

Another huge benefit of BIM is possibility to obtain quickly list of quantities for internal estimations and bidding process. However, to use it as basis for tender material models have to be detailed enough to provide exact quantities which partly determine the reliability of received bid price. People doing quantity takeoff have to be aware of how quantities are calculated by the software and do these quantities represent exactly the amount of work to be done (Figure 13). As an example it can be "painting of the wall" in the room with suspending ceiling. It is not correct just to extract the wall surface area. Instead, it should be additionally defined in the model that painting of the wall is done just until the suspended ceiling.

With BIM it is also possible to create automatically list of building element descriptions what also contributes to time reduction of design process.

Despite all these benefits Morten says that there are still many issues regarding BIM, especially interoperability. Transferring information between different software using IFC format may cause huge problems related with information losses or wrong building element representation in different environments. There was a situation when model from Tekla was opened in Revit Architecture through IFC format and it appeared that foundations were in wrong position (Figure 14). However, the same model worked correctly in Revit Structures. Therefore, before using any software for the project it has to be tested in terms of behaviour of IFC models in different environments.

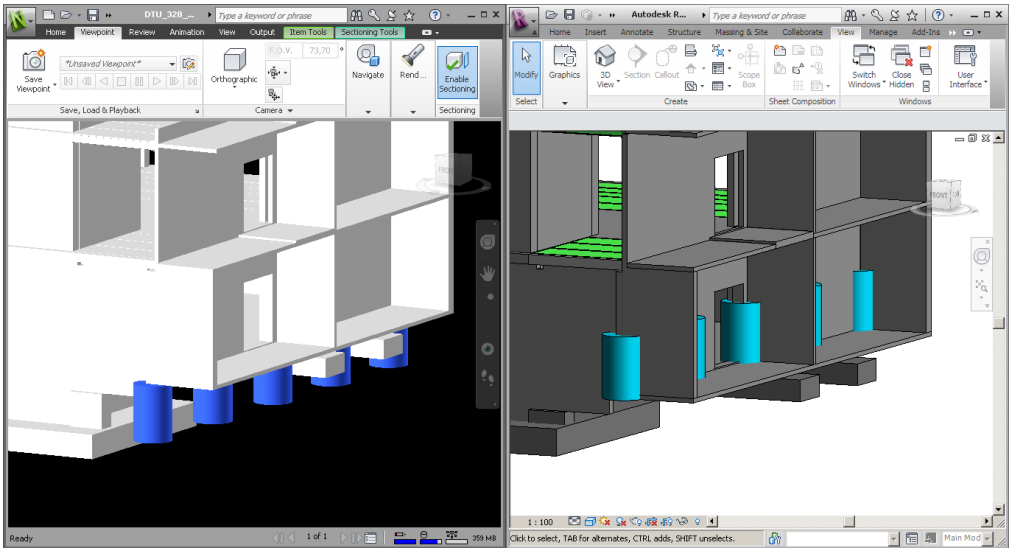


Figure 14 Same IFC model opened in NAVIS Manage 2012 (left – correct position of foundations) and in Revit Architecture 2011 (right – wrong position of foundation)

BIM based bidding process

There are attempts to make processes run more digitally. It applies for bidding process as well where perfect way to do it would be just sending BIM model to contractors as basis for the competition and receive bid price for the project. However, this is just a future. Reality is quite different. There are just small steps introducing BIM for bidding. Primary function of BIM models still remains 3D visualisation of the building for better understanding of the project.

Bidding by strict rules vs. flexibility

In many cases the best project price offer is received when bidding is based not on fully defined project but on cheapest solution. It means this is a case when design company is doing only overall design with building requirements and competing contractors provide efficient cheap solution which does not contradict stated requirements. This method can be used when client does not care what solution should be used. Also, when it is state projects, bidding material content have to follow EU rules which say that consultants cannot be too specific describing elements (vendor specific) and give advantage to particular company producing elements.

However, when client requires particular solution for the building structure or services it is the best when bidding material contains as detailed/specific information about the building as possible. Also in some cases when it is expected that after some period of time purpose of the building might change there is a need that building can adjust to different conditions which can be overseen by consultant. Even though it would be possible to include this requirement for flexibility in bid material it would be much harder to control that.

Early stage collaboration

Normally early stage collaboration between consultant and contractor is carried out in form of early bidding on rough project design. Main benefit for that is time saving due to absence of time buffer between design and construction which is bidding process (Figure 15).

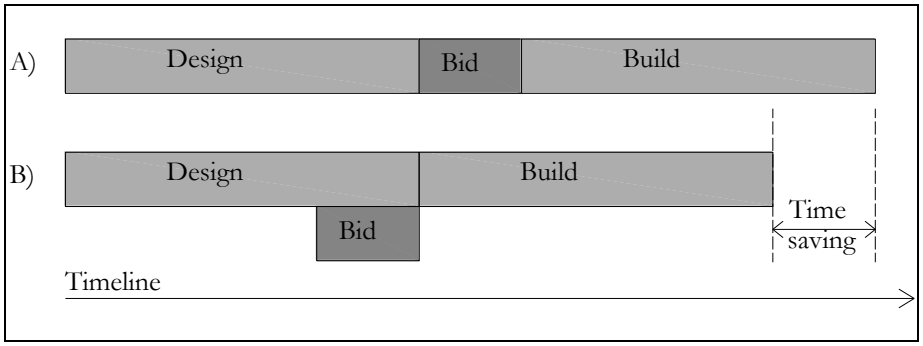


Figure 15 Time savings due to early bidding process: A) traditional Design-Bid-Build model; B) model with early bidding process along design

3.2.2. Bidding material from Contractor's perspective

This chapter is based on interviews with people from construction companies who have experience working in bidding process. Transcripts of interviews can be found in Appendixes C, D and E. In this

chapter it is described bidding process from contractor's perspective, experience and opinion about existing bidding practise, suggestions for improvement of bidding material content.

Description of the bidding process

Bidding process in construction industry is not something what is possible to describe in one strict way. There are many factors which influence the process; therefore, it differs from project to project.

First of all, there are many worldwide design/construction companies in Denmark which actively participate in tenders abroad. It can be Jamaica, Panama, Greenland, United States and other countries where projects are located. Usually, those countries have their own traditions of making competitions, preparing bidding documentation and have different expectations from companies participating in tendering process. Therefore, each international competition is a new challenge for participating company to make proper offer.

However, if considering Danish construction market only – it is not so simple either. Bid material received from owner or consultancy company may also differ. Sometimes full bill of quantity list is provided where the price for each line in the list is required to be set. Other clients forward material where quantities have to be calculated by prospective contractor. So these are two different ways of giving tenders.

Next important factor influencing bidding process is a scope of the project. It depends if tender is given in building site or in civil structures for instance. And tendering processes in two different areas are quite different.

Further on, it depends how early in the project development process construction company is involved. Sometimes it is very early stage where company can develop project with client, architect and consultant. In other cases fully finished by consultant project is received and nothing can be done to improve the project.

So bidding process within construction company differs from project to project and it is quite difficult just to do tendering process in one way as there are so many different projects, their sizes, scopes and a bidding material which are always different.

Nevertheless, despite all those differences Esper Christophersen, Section Manager for New Buildings and Concrete at MTHøjgaard, managed to describe usual bidding process strategy (Appendix C).

After bid material is received team taking care of bidding process makes an overview of the documents. Strategy session is held for identifying scope of the project dividing it into sub trades. Documents are also sent for legal analysis. Analysis of quality and safety aspects is carried out.

Torben Seemann, Estimator/Engineer at E. Pihl & Son A/S, says that in very beginning contract document is been analysed to see if bidding material is sufficient enough even to start bidding process. It is important to make sure that they are not bidding on project with unreasonable demands. In case of missing parts of the project queries related with raised issues are sent to the client. (Appendix D)

Stefan Brandt Johansen, Research and Development Engineer - BIM Manager at E. Pihl & Son A/S, says that they use a lot of resources to make sure that the team doing the tender for particular project is totally knowledgeable about the project, that they know very last piece of it, every room and every facade solution and so on. This helps to minimise risks related with uncertainty of the project. (Appendix E)

After project analysis strategic part of the process is following where methods of pricing in order to win the project are being discussed. Stefan mentions that if company want to differentiate from other bidders to particular project it has to find some areas within project material where it can offer the client something better, to do some value engineering and so forth. And that could be a scope of work. (Appendix E)

In larger projects when company has not enough resources analysis of possible sub trades is being carried. Here it is being decided which companies are trustworthy to be involved in the project with good competitive bids. Particular project material is being sent for chosen companies. (Appendix C)

When proposal is prepared it is submitted for competition.

Bidding material form and content

Today it is very rare for construction company to receive bidding material in paper documents. Usually this is done digitally. This way company can print material in as many copies as needed to support project evaluation and proposal preparation process.

Content of bidding material varies from project to project depending on the stage of the project, location (in case it is from country with totally different project development traditions), and the client decision. But normally bidding material content consists of project description, setup of drawings, bill of quantities for which price should be assigned and requirements of the project. All documents and drawings usually are in PDF format, and drawings sometimes are received in DWG format.

Lately, when 3D modelling tools become more used in construction industry digital 3D models of the building are included in bid material. It comes in IFC format or in popular 3D modelling software's native format. The purpose of it is usually just to help construction company better and quicker understand building geometry and complexity. However, this is not used widely.

Bidding material quality and project budget overrun

Interviewed people asked "*how often they experience rise of project price comparing to bid price"* answered instantly with no doubts – "*Always*". They agreed that success in meeting project budget requirements other than changes made by client depends a lot on the quality of the bidding material.

The thing is, that in order to provide reliable project price during tendering construction companies need to know about the project as much as possible so they can evaluate correctly all risks within further project development processes.

Stefan says, that many projects they receive today are not detailed enough to perform reliable price calculation, taking into account strong competition. When it is gone to building stage detailed "as-built" drawings appear. This may expose contractor to the situation when additional works have to be done which were not determined in bidding stage. Then the project is getting more expensive than it was predicted.

Esper also sees problem within low level of details available in documentation received for bidding. If contractors are bidding on price it means that they bid on what is drawn, and if it is not drawn - it is not included in the price. This is the way competitions work. What is more, often descriptions of the works/quantities are incorrect. As an example he describes situation when in the quantity list it was stated

that amount of reinforcement is 50 kg per cubic meter of concrete. However, when project was already in construction stage detailed design was received which stated that amount of reinforcement has to be 75 kg per cubic meter of concrete.

Esper also has noticed that design quality, at the same time bidding material quality, has decreased drastically over last few years. He refers this phenomenon to raised competition among design/consultancy companies which sets very sharp limits of time to do the design. Tight schedule and budget makes design companies "cut corners" and put less design engineering hours to do the project. It results in insufficient design leading to cost overruns of the project because it is not defined as well as it should be. Client ends up in the situation where the contractors send a lot of claims due to "holes" in the project. This, further on, reflects on final project price as well.

Required material for bidding process

To prepare reliable offer contractor need to know about the project as much as possible. To give bid price contractors make lots of internal calculations to evaluate cost of all the resources, labour work and equipment (crane, formwork e.g.). Therefore, all this evaluation cannot be done only based on list of quantities. It makes it crucial to understand how those quantities are distributed within the project. And this is where drawings and/or 3D models of the project play their role. Moreover, contractors may also proceed to bidding process for selection of subcontractors for particular works. For this reason bidding material supposed to be composed in the way it would be easy for contractor get familiar with the project and understand its complexity. On the other hand, contractors are not willing to receive huge amounts of documents, because this does not make bidding process sufficient either.

Detail level of quantity list

It is not good idea to make too detailed list of quantities. Instead, it is better to provide quantities of objects with description of their "recipes". As an example Esper mentions that to give the price for floor construction it is sufficient enough to provide floor area and then description of floor construction.

Work descriptions

Very often there are also some qualitative requirements for construction elements. Therefore specific description of objects should not be omitted. Examples of such description may be the need of joints to be waterproof, quality level of surfaces, description of material like special type of concrete which should include particular admixtures and so on. This information also determines price of works.

Drawings

Contractors may follow the list of quantities and assign price for each line of the list. But as this price is complex and is influenced by many factors like location or shape of the object it is important to have sufficient amount of drawings to determine where those quantities are located and how do they look like. For example, there is a difference in price between suspended ceiling in rectangular room and same ceiling in oval one (Figure 16). Cost of ceiling in extraordinary layout of room may rise up to 25%. Even though there is the same amount of material used to cover the ceiling price rises due to material leftovers and more time consuming labour works.

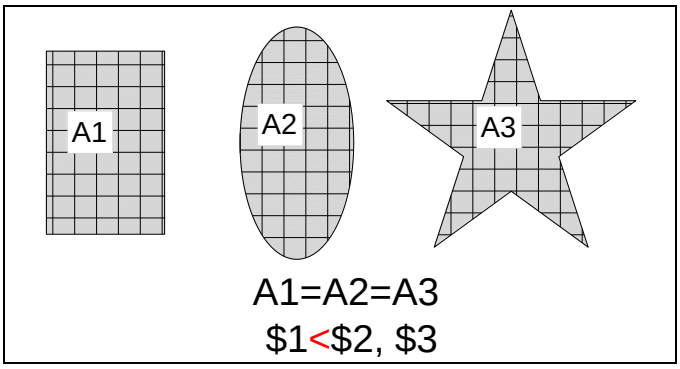


Figure 16 Room layout influence on installation of suspended ceiling price

Linking quantities and drawings

When contractors are looking at list of quantity they want to know where those quantities are located, visualize estimated object and evaluate difficulty in it (Figure 16, Figure 17). Therefore, they need to be able to know to which drawing(s) it relates. For this reason reference to drawings for each line of list of quantities (or at least for group of quantities) would be a huge help for estimators to determine better work price.

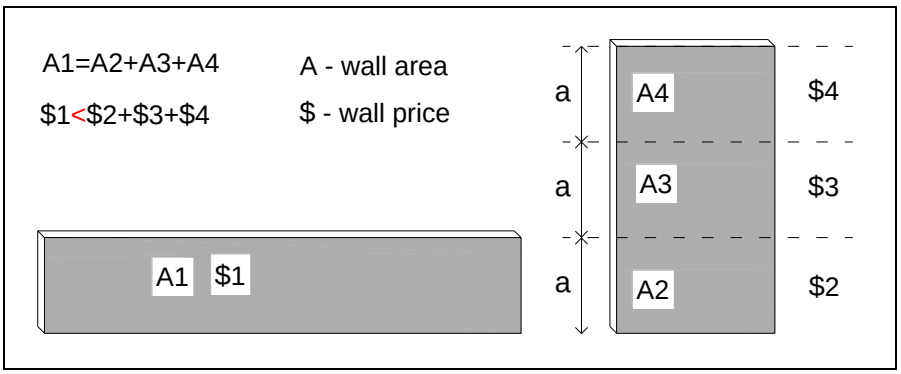


Figure 17 Work difficulty influence on the price

Location based quantity list structure

Structure of list of quantities plays important role for efficient project estimation process. Well structured list can be very useful for contractor as well as for client. All interviewees agreed that dividing list of quantities into groups according to their location like particular floors or building zones is a very powerful help (Figure 18). With this list structure contractor get faster insight of works to be done in different building zones. When the high-rise construction is built it cost much more to build column in top floors than in the bottom of the building. So it is important information to know that particular column is more expensive than other even though they are exactly the same geometry. Analysis of drawings together with such quantity list makes it easier to check for reliability of quantities provided in bid material (contractors always do their own QTO regardless if quantities are provided by designers or not). In case mismatches are discovered queries are sent to consultancy company. This may correct bid price and client would be aware of that as well. Moreover, it would be much easier for clients to analyse content of bid price provided by contractors. They would see the price of walls in different zones of the structure. In case bid price dissatisfies the client he can make proper decisions changing particular project parts.

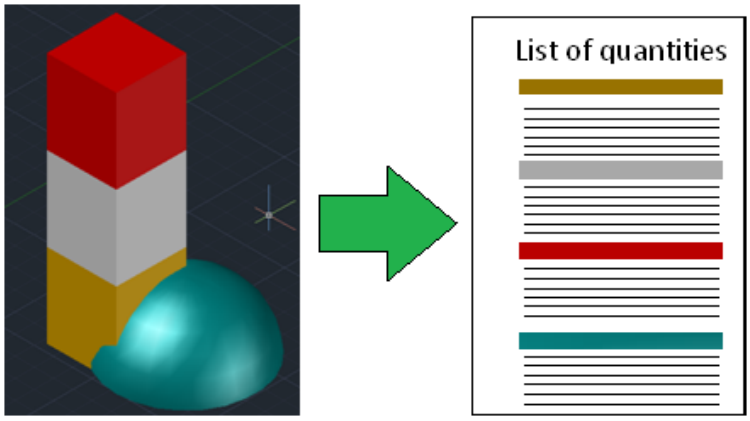


Figure 18 Location based structure of quantity list

Internal calculation of quantities

Regardless the fact that list of quantities is usually provided by consultancy company in the bidding process contractors always do their own material quantity measurements based on provided drawings. This way they get more familiar with the project and make double check minimizing "surprise" risk in planning of processes and budget.

Technique of calculation depends on traditions at the company, estimator's skills and format of drawings. More experienced seniors do their measurements straight from the paper drawings. During many years doing estimations they have developed their own technology of material quantity measurement and feel comfortable and confident with that. They usually do not put trust in computer aided quantity takeoff. Younger estimators in case of receiving DWG drawings use AutoCAD to perform measurements.

In some companies when 3D model is received, which is usually made in Revit or Tekla, quantities are extracted directly from those BIM tools.

Measurement rules

In Denmark there is a document provided by BIPS named "Opmaalingsregler 2008 Anvisning F111" which describes how quantities should be measured (9). However, those requirements are still limited in variety of measured objects. It is applicable only for simple projects.

All interviewed people from construction companies have confirmed that it is acceptable for them if there are different measurement methods used by consultancy companies doing the list of quantities (Figure 19). But the most important thing is to specify how they do it so contractors are aware of what those quantities listed in bidding material represent.

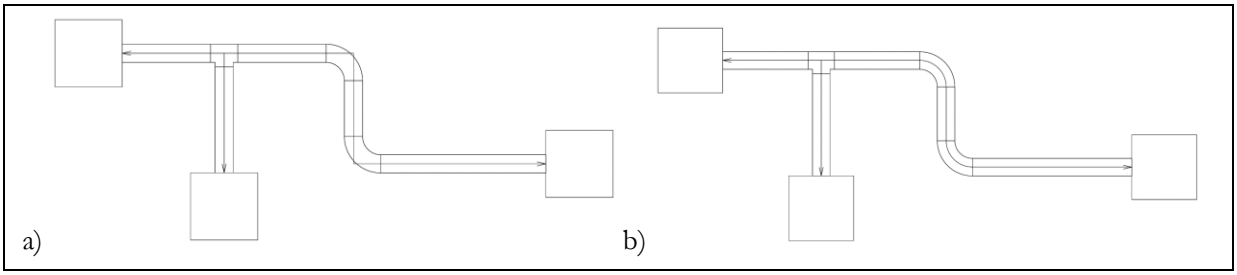


Figure 19 Different measurement methods (9)

There are different sub-contractors who do the pricing for particular works differently. One company making prefabricated walls needs to know what the net volume of concrete is and how many window/door holes it contains in order to calculate the price. Other company would prefer to know just volume of the wall including window/door holes. The cost of missing material in the holes simply is transferred for production of holes.

3D models

Receiving digital 3D model of the project together with bidding material is still not so common practise in Denmark. But contractors see a very huge value in them. It is very helpful especially in large/complex building projects or civil structures where it can take months to make an image of the project using just 2D drawings. When 3D model of the building is received it is very fast to put all the team together in the room and screen model using the projector and see all building parts, services. It is much faster to get the team that is doing the tender to understand the project. That is huge benefit.

Stefan had also mentioned that in some cases when they receive only 2D drawings and project is quite complicated they create their own 3D model of the building. The purpose of this model becomes not only visualization but they also use model to get material quantity takeoff.

Building Information Model based bidding

Building Information Modelling (BIM) technology is used more within design processes. Most of the contractors do not embrace this technology yet so much. Therefore, there is no practice or tradition established to include BIM in bidding material, as construction companies would not fully benefit from it if just using it only for visualization purposes.

There are many experienced seniors who are satisfied with existing situation and they are not willing to switch to computer aided estimation and construction. It also demands lots of investments and time for training the staff. Usually contractors want to stay on safe side with tested methods instead of taking risk applying new technologies to the processes.

All interviewed people were sceptical about the idea using BIM as material for bidding process and basis for quantity takeoff process.

First of all, the work scope of consultancy company and construction company is different. And consultancy companies are not willing to put lot of effort making BIM ready to use for contractor as they are not paid for that. Sometimes models come with errors and often they are not modelled in the way contractor wants it to be modelled in order to make the right estimate. As an example it can be process of extraction of quantities for painting the wall of the room. It is easy to do in Revit for example. But when there is a need to paint room only to suspended ceiling level it becomes difficult to control that. If consultant is doing BIM model which is not sufficient enough to use for contractor – contractor will have to make another one. It means that there will be 2 models made instead of 1. This way the total price of the project is getting higher and the one who is paying for that is client.

Esper assumes that if BIM model would be basis for bidding process it would be crucial for consultant and contractor to sit down and decide the rules how models should be made. It is important that everybody is doing it the same way. Otherwise, analysis of the model would take a lot of contractor's time,

probability making lots of mistakes in estimation rises, therefore, it would be not efficient method doing tendering.

Another issue with BIM based tendering is interoperability. Different companies use BIM tools from different vendors. And even though IFC format is proposed as a solution for interoperability – it is still not so reliable (Figure 14). Some of the software also has sophisticated tools capable assign useful information to model's objects. However, not all if it may be exported to IFC file and understood by other vendor BIM software.

However, there are companies which try to apply BIM technology also in construction and test it in bidding stage as well. Stefan says that in his company they explore different BIM tools and analyse how they can support processes within activities of construction company. They see a lot of potential in this area. Looking at the countries around Denmark, especially at Norway and Finland, he sees that tendering process on many large projects is much more controlled because clients in those countries are familiar with BIM technologies and demand from consultancy to use it. Stefan thinks that when clients in Denmark will realise the potential of BIM then in a couple of years a lot of projects will be bided out in tenders where 3D models will be used directly as a tool to extract quantities and understand the projects better. He thinks that government also should more encourage construction industry to use BIM by setting requirements to use this technology at least in state projects. And Danish government actually have already introduced Digital Construction initiative which requires that from 2007 state projects exceeding DKK 20 million 3D models have to be used in tendering process where contractors can extract needed information from the models (10). That is what Finland and in Norway has also done. That turned out to be a huge success because it influences the private market as well.

Torben also sees a lot of potential in BIM and he believes that it has great future. However, when this technology will be fully applied in practice depends on decisions of companies' owners who make strategies for business development.

Terminology

It would be much easier for contractor to analyse quantities if names of elements in project description and bill of quantities follow particular standard. In case if 3D models would be used for QTO it would be a lot of confusion if each company gives different names for same kind of element. It would be time consuming to extract all quantities and rename them in the way it is easy to understand for estimator. Torben thinks that following particular standards in terminology used in bidding material would be beneficial. However, it would be maybe easier to do achieve on Danish scale, but to make it work on international level is very complicated.

Estimation software

There are many different estimation software used by construction companies. Esper says all of them have their own advantages and disadvantages. But in their company among other software it has been decided to use Sigma which is widely used across the country. Stefan mentions that he sees a lot of potential in Sigma for doing BIM based estimation as it has integration to IFC format. However, as long as implementation of IFC in software is not better than it is today and there is no practise to prepare models for estimation process it is difficult to use all Sigma's potential.

Torben used to work in UK on a huge project where basically all the work was to be performed by subcontractors. There were around 130 subcontractors bidding on different project works and in order to make a good estimate Torben needed efficient way to prepare bidding material for different sub trades and make analysis of many proposals. At that time they used CANDY software which included whole bill of quantities and enabled him to arrange it in the way that they were ready to be sent for different sub trades. Received bills of quantities with prices were imported to CANDY where it was possible to perform price comparison from different subcontractors. This helped to make right decisions and estimations quickly.

Stefan also says that they use different estimation tools depending on the project. But they also look for the software which can bring whole package solution like VICO software where modelling tool is integrated with quantity takeoff, estimation, scheduling possibility and it can support bidding process as well.

Bidding by strict rules vs. flexibility

Stefan thinks that bidding by strict rules where price should be given in particular way would be very helpful for clients because received material from competitors would have same form and it would be easy to compare tenders. It could also influence the price of predefined solution as well which would decrease due to increase of competition among contractors. On the other hand, Stefan thinks that it would not give the best tendering process and clients would not be sure that they receive the best product. In projects where contractors have an opportunity to suggest their own ideas, optimise the design from the consultancy, deliver some value engineering or offer the client some other material, which are better and cheaper, it may be easier and cheaper for contractor and the client to build the project. Setting the price only following particular structure does not give best results.

Early stage collaboration

Early stage collaboration of consultancy and construction companies is not so common in Denmark. But when contractors get involved in design phase through early bidding process they can make estimations along project development process. Those estimations are more valuable and realistic, as pricing is done by the part which is going to build construction. Already in limited design stage contractors can influence design directions proposing cheaper and more efficient solutions.

Sometimes clients ask construction company for consultancy in particular projects. It is been trying solve different issues which are at the competence of construction company and come up with proposals to optimize the project.

To do an offer with an exact price without any risk for contractors, they need quite large set of data and information regarding the project. Therefore, the earlier contractors are involved in the project the better because then they can solve out issues regarding different risks and set better price for the project.

Looking at foreign countries like US, Finland or Norway it is possible to see that involvement of contractor in early stage of the project is often practice there. Stefan believes that in couple of years this practise will be more used in Denmark as well. In the long term it gives client a cheaper and a better project.

3.3. Software capability to support requirements of bidding process

Many software vendors actively advertise their products as a helpful tool to extract and organise material quantities of the project. However, during the interviews it has been discovered that even though some of the companies try to embrace BIM technology into the practice many other still do not put too much trust into software and prefer do things manually. Therefore, it has been decided to examine if there are any issues related with BIM based information takeoff for bidding material, how reliable it is and if BIM technology is ready to replace traditional paper document based bidding process with BIM based one.

3.3.1. About testing

There are many different 3D modelling applications used by different disciplines in project development process. In this chapter, it has been decided to make overview of chosen BIM tools regarding its ability to extract quantities form the model made by structural engineers. Usually modelling software includes QTO tool which enables extracting precise quantities of building elements created in same digital environment. This feature might help a lot to prepare bidding material for bidding process. However, when it comes to use of BIM technology – interoperability issue has to be considered. It is crucial that relevant information from 3D models can be transferred between different BIM applications used by other participants in the process. For this purpose IFC file format has been introduced which, however, coming out from the interviews, is not the perfect solution.

In this test part of the Master Thesis it has been decided to focus mainly on following issues:

- Capability of chosen BIM software to extract quantities needed by contractors for better understanding of the project and to provide more reliable bid prices
- Interoperability issue – how existing models used in practice behave after they are transferred between applications from different software vendors and how this behaviour can influence QTO
- QTO following IDM requirements

For tests it has been chosen to use following software:

- **Tekla Structures 16.1** – *"Building Information Modeling software that enables the creation and management of accurately detailed, highly constructible 3D structural models regardless of material or structural complexity. Tekla models can be used to cover the entire building process from conceptual design to fabrication, erection and construction management."* (11)
- **Solibri Model Checker v7** – *"out of the box software solution (Patent Pending) that analyzes Building Information Models for integrity, quality and physical safety. The system offers easy-to-use visualization with an intuitive walk-in functionality. With a single mouse click, the system X-rays the building model and reveals potential flaws and weaknesses in the design, highlights the clashing components and checks that the model complies with the building codes and organization's best practices."* (12)
- **Revit Architecture 2010 –** building design software which works the way architects and designers think, so higher-quality and more accurate architectural designs can be developed. Built for Building Information Modelling, Autodesk Revit Architecture helps to capture and analyze concepts and maintain vision through design, documentation, and construction. (13)

Test process is performed as follows:

- QTO in Tekla Structures
- Tekla Structures model behaviour in Revit Architecture (IFC)
- Tekla Structures model behaviour in Solibri Model Checker (IFC)
- Revit Architecture model behaviour in Solibri Model Checker (IFC)
- QTO following IDM requirements for bidding using Sigma Model Checker (IFC)

At first, overview of QTO possibilities in Tekla Structures is presented. Then, it has been decided to simulate situation when structural model made in Tekla Structures is sent to other participant in the project who uses Revit Architecture or Solibri Model Checker and see how model behave in these environments and how their behaviour can influence QTO regarding available element properties and their reliability. For the test structural model is used from real project. Unfortunately, Tekla Structures does not include tool of making floor levels to which elements can be assigned and it is not possible to check how floor level information is interpreted by Solibri Model Checker. Therefore, next test is performed using IFC model from Revit Architecture. For this test architectural model of the building is used which was made during Advanced Building Design course at DTU. Final test was performed to see if it is possible to make QTO from Tekla Structures model using Solibri Model Checker following IDM requirements.

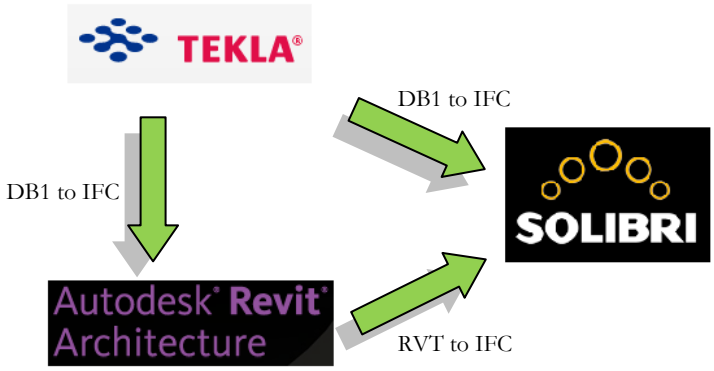


Figure 20 Performed tests on transferring models between chosen BIM tools

3.3.2. QTO in Tekla Structures

QTO process in Tekla Structures in this chapter is described only on overview level because detailed and technical explanation of how to perform QTO in the application requires deep knowledge about software capabilities, modelling process and quite complicated process of data collection to compose required information report.

In Tekla Structures it is possible to make various reports based on the information available in 3D models. Beside geometrical parameters of the elements like dimensions, areas or volumes, which are measured and calculated by software automatically, there are also many other predefined properties which can be assigned to the elements (Figure 21). What is more, in case there is a need to apply more parameters to building elements than it is available in the application – "User fields" can be used to apply any information about the element which is not available by default. For example, in case building elements

have to be classified by several classification systems – "User Fields" can be used for this purpose. In Tekla Structures there is no tool of making floor layers to which elements can be assigned. For this purpose "User Field" can be used as well.

There is a large number of standard report templates which are available for different kind of information takeoff including QTO (Figure 22). Quantities can be pulled out for selected building elements or entire model. The output of the report might be saved for preview in text editor or in excel sheet (Figure 23). In case QTO file is saved only in text file it easily can be imported to excel sheet.

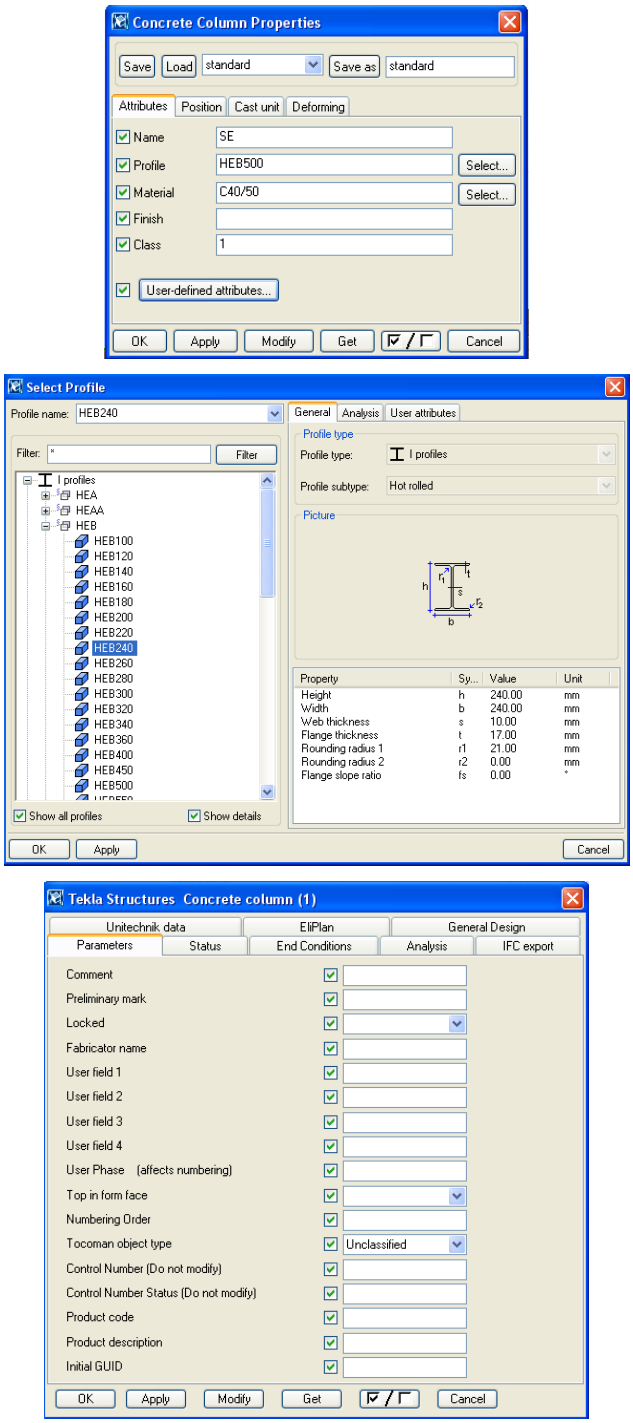


Figure 21 Some of the available to be assigned column element properties in Tekla Structures

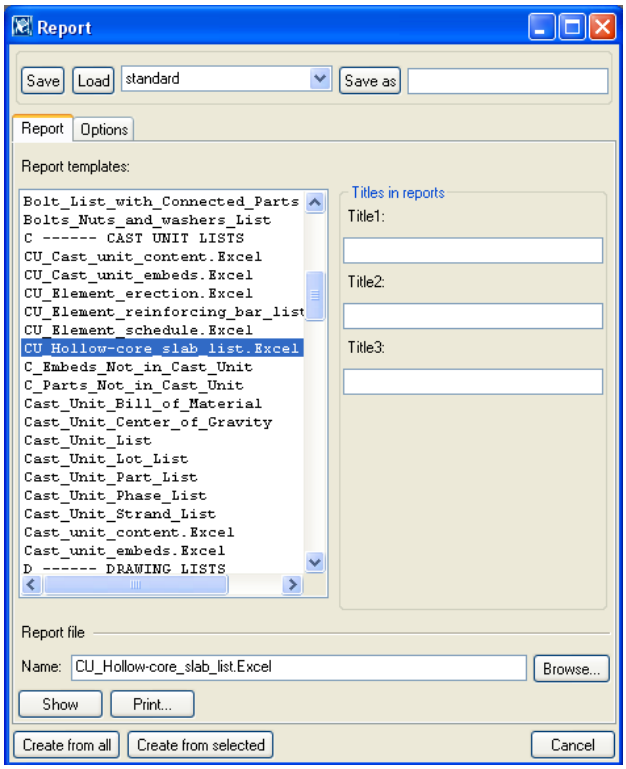


Figure 22 Report creating window with pre-defined templates in Tekla Structures

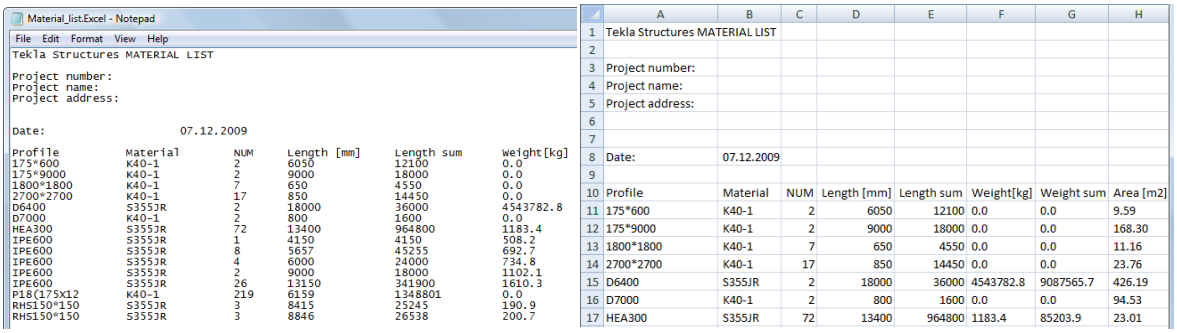


Figure 23 Extracted list of material quantities in text editor and in excel sheet

If parameters included in pre-defined report templates do not suit the purpose of the report they can be modified or new report templates can be created using Template Editor, which is separate application in Tekla Structures and can also run as a standalone program. With this application it is possible to compose information takeoffs of all the element parameters assigned in the model. Tekla Structures also can measure elements and calculate geometrical parameters in many different ways. For example there are over twenty area parameters to choose from in order to describe the element in the way it is required (Figure 24).

However, Template Editor is not an application which is easy to use. There are many different parameters involved in making the template which have to be very well understood (Figure 25). Also interface is not very user-friendly. In order to do make good own QTO templates study of the software and training with it is needed.

When it comes to export of the model to IFC file it is possible also to choose user defined fields parameters to be included in the IFC model. Not every BIM software application can read this information from IFC, however, some of them, like Solibri Model Checker, can.

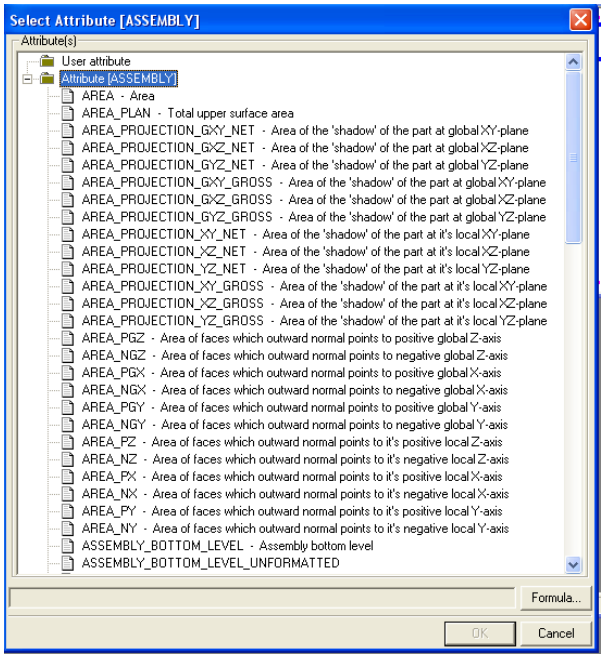


Figure 24 Available area parameters in Tekla Structures

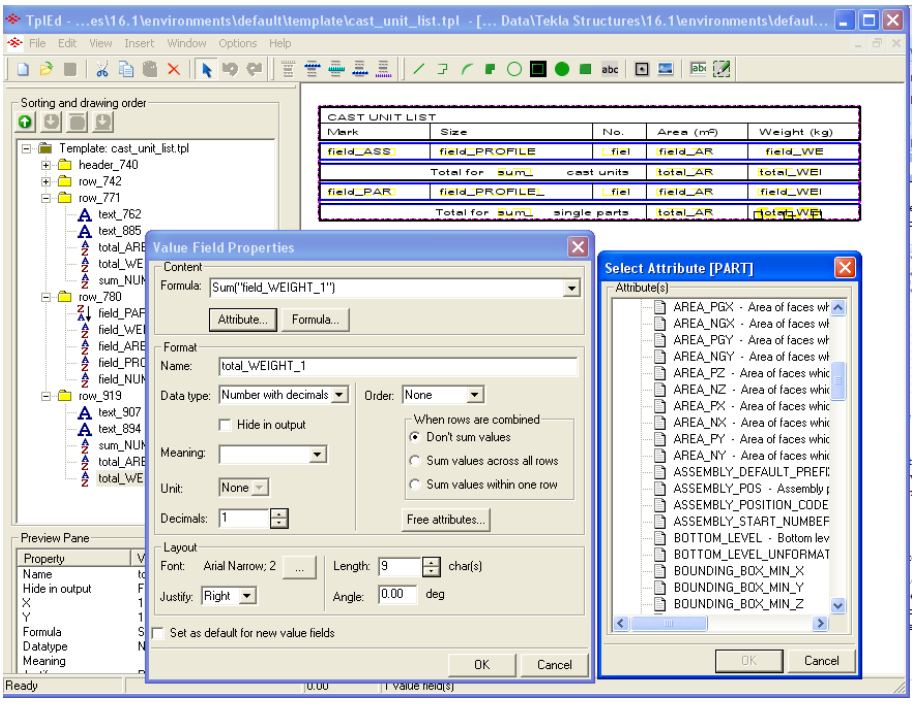


Figure 25 Template Editor for information takeoff in Tekla Structures

3.3.3. Tekla Structures model behaviour in Revit Architecture

For this test structural model of DTU Building 328 made in Tekla Structures and converted into IFC format is used. It is opened in Revit Architecture. While opening model in Revit error window popped-up

with a message about errors and warnings (Figure 26). Report on errors and warnings can be found under Appendix F. To open the model elements with errors have to be deleted by pressing "Delete Element(s)" button.

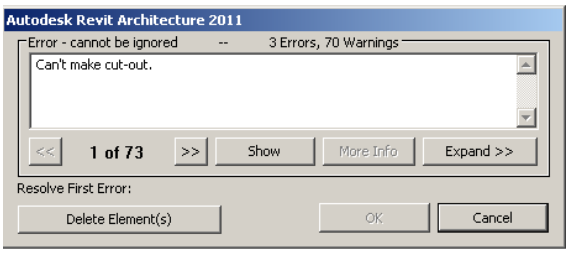


Figure 26 Warning window in Revit Architecture while opening IFC file exported from Tekla Structures

After model was opened several problems regarding the model have been discovered.

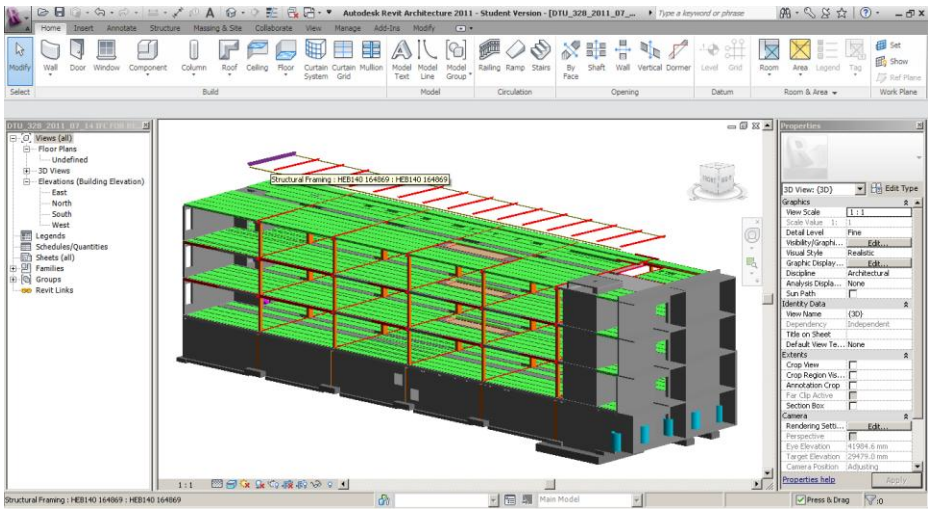


Figure 27 IFC model extracted from Tekla Structures in Revit Architecture

First of all, model had no floor layers, which is not a problem of file conversion to IFC format but it is because Tekla Structures has no feature of creation of such floor layers. Second, model was missing some construction elements - frame columns on the roof were not loaded (Figure 28). Third, foundation and some opening elements were represented in the way like they are mirrored against their upper surface (Figure 29).

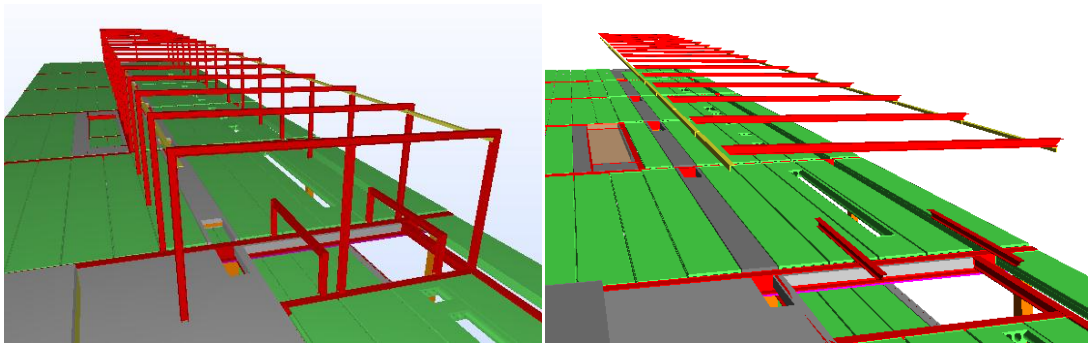


Figure 28 Missing IFC model elements in Revit Architecture: left – fully loaded model in Solibri Model Checker, right – model represented in Revit Architecture

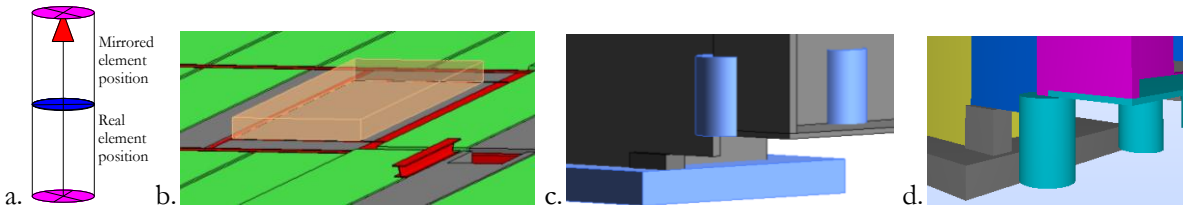


Figure 29 Mirrored elements of IFC model in Revit Architecture: a. element deformation scheme, b. mirrored opening object, c. mirrored foundation elements, d. correct foundation element placement (in Solibri Model Checker)

When it came to QTO it appeared that information about elements is quite limited and not informative enough (Figure 30).

Multi-Category Material Takeoff

Family	Type	Count	Level	Material: Name	Material: Area	Material: Volume
190*120						
190*120	190*120	3	Undefined	IfcSurfaceStyle #43155	0.145 m²	0.004 m³
3						
220*85						
220*85	220*85	1		IfcSurfaceStyle #633	2.804 m²	0.085 m³
1						
220*125						
220*125	220*125	1		IfcSurfaceStyle #633	4.735 m²	0.187 m³

Figure 30 Available information in QTO of IFC model in Revit Architecture

3.3.4. Tekla Structures model behaviour in Solibri Model Checker

To open Tekla structural model in Solibri Model Checker it was converted to IFC format file. File was successfully loaded to Solibri. After visual inspection of the model no geometrical problems were discovered (Figure 31). It seemed that all the elements are in right position. Looking at the "model tree" it can be seen that model contains only one floor to which all the elements of the building are assigned. This is due to fact that in Tekla Structures there is no tool of making floor layers and assigning elements to it. In the "model tree" building elements are grouped into components like Beams, Columns, Footings, Openings, Plates, Slabs and Walls. All the elements of the model are located in proper group of the model tree except precast concrete slabs which are represented as Beam component, which is the way it is modelled in Tekla.

It appears that IFC model opened in Solibri Model Checker contains a lot of information which can be used for generating detailed list of material quantities (Figure 32). Different components of the building have different element relevant properties.

It has been decided to look at parameters and quantities available for beam components of the building model and check if it is possible to make a list of quantities with information sufficient enough to do estimations. Main principle of making list of quantities is to include following information: element identification by component type and name, its material, relevant geometrical parameters and count of similar elements. Unfortunately, building elements used model are not assigned to different floors; therefore, list of quantities does not include information about element location.

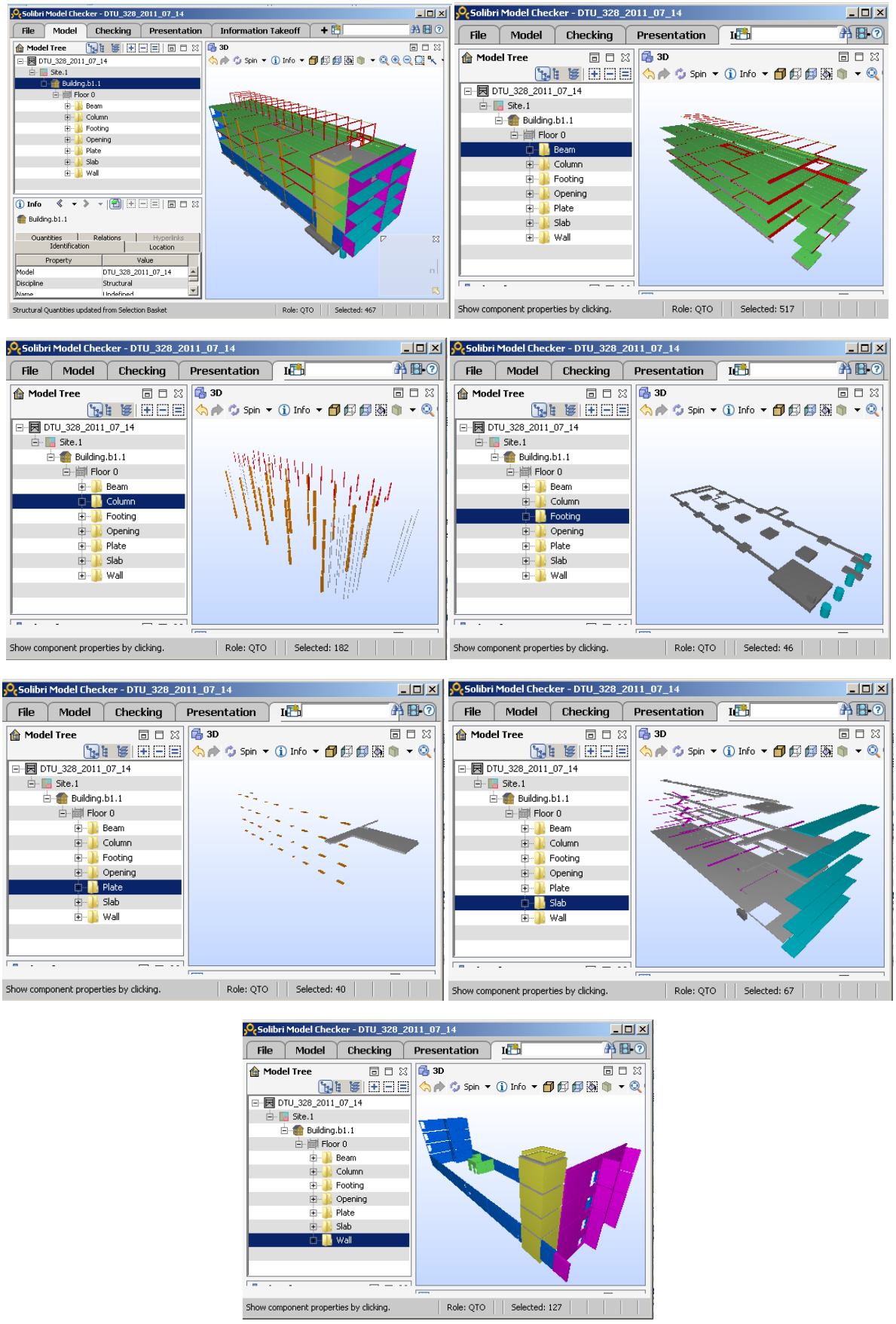


Figure 31 IFC model extracted from Tekla Structures in Solibri Model Checker

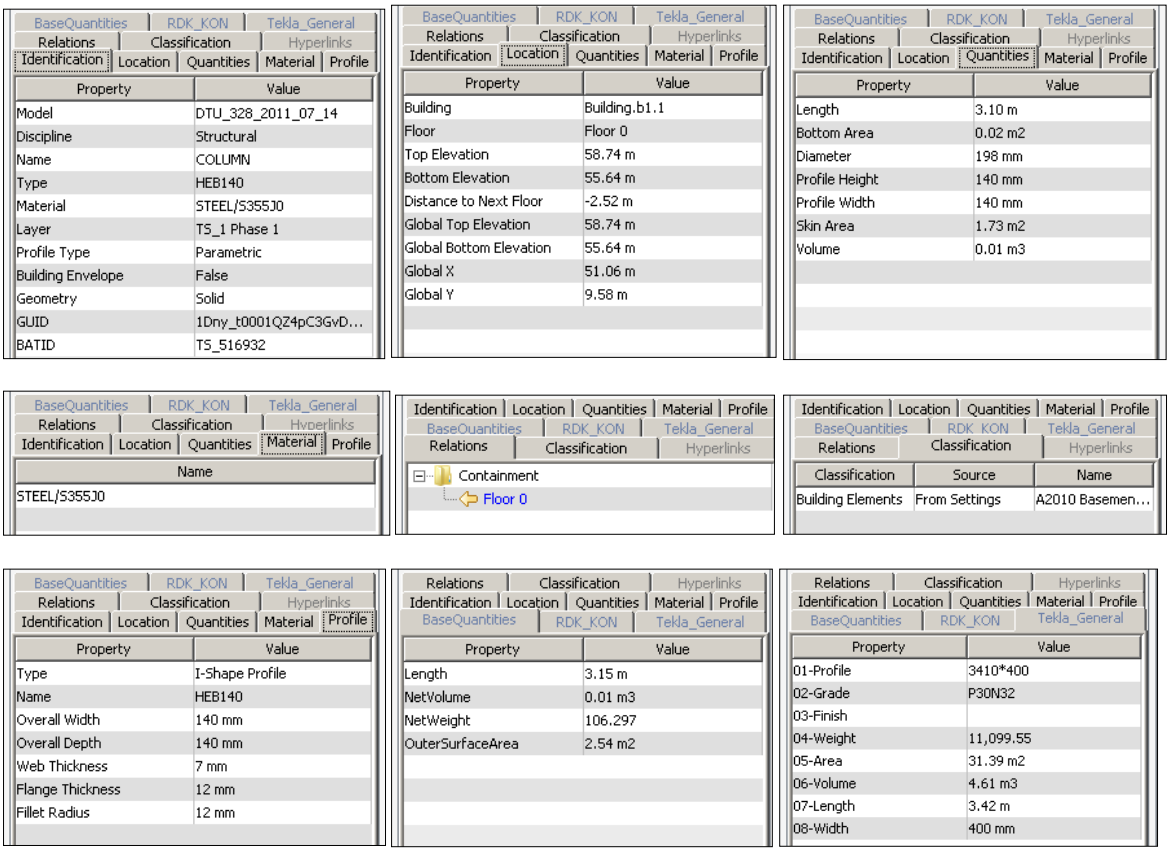


Figure 32 Available QTO information for column from IFC model made in Tekla Structures and opened in Solibri Model Checker

In Solibri there is so called Information Takeoff tool which enables making list of quantities of chosen elements. It is very useful tool when there is a need to analyse quantities or make quantity reports just of particular elements.

For this test it has been decided to analyse beam elements of the building model. The quantity list for beams was composed of the following available information relevant for QTO of beams:

- beam material
- name
- type (profile)
- linear geometrical parameters: width, height and length
- area
- volume
- count of similar elements

Note: totals of element quantities can be presented as well.

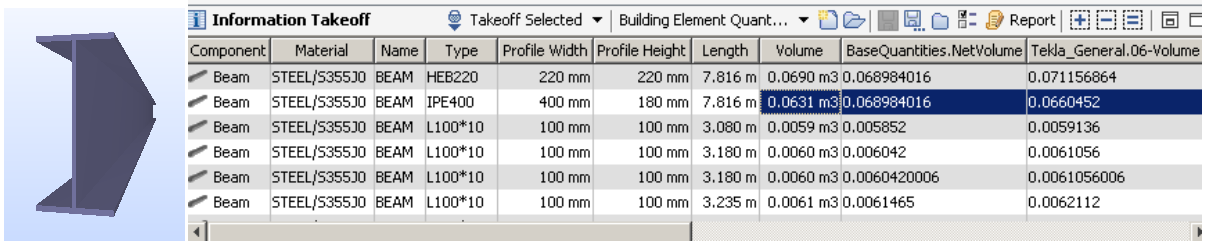
While preparation of quantity list for the beams it has been noticed that there are several properties of the element describing its volume. When quantities were extracted it appeared that in some cases values from different volume parameters were not the same. Therefore it is important determine/specify what those

quantities represent (Figure 33) and decide which parameter is needed or describes volume the best and should be included in the list of quantities.

Material	Name	Type	Profile Width	Profile Height	Length	Bottom Area	Tekla_General.05-Area	BaseQuantities.OuterSurfaceArea	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volume	Count
CONCRETE/P40N8	SLAB	PX27N	286 mm	270 mm	9.270 m	2.65 m2	15.151573	11.493	0.4374 m3	0.850986	0.43736548	1
CONCRETE/P40N8	SLAB	PX27N	745 mm	270 mm	9.270 m	6.91 m2	38.255411	11.493	1.0676 m3	0.850986	1.0676091	1
CONCRETE/P40N8	SLAB	PX27N	1.199 m	270 mm	9.270 m	11.11 m2	60.308499	11.493	1.7259 m3	0.850986	1.7258731	3
CONCRETE/P40N8	SLAB	PX27N	1.199 m	270 mm	9.270 m	11.11 m2	60.308499	51.994933	1.7259 m3	1.4393052	1.7258731	1
CONCRETE/P40N8	SLAB	PX27N	1.199 m	270 mm	9.270 m	11.11 m2	60.308499	54.665875	1.7259 m3	1.6336783	1.7258731	5
CONCRETE/P40N8	SLAB	PX27N	1.199 m	270 mm	9.270 m	11.11 m2	60.308499	60.308499	1.7259 m3	1.7258731	1.7258731	2
STEEL/S355J0	BEAM	HEB140	140 mm	140 mm	3.200 m	0.45 m2	2.576	2.576	0.0128 m3	0.01276632	0.0137472	2
STEEL/S355J0	BEAM	HEB140	140 mm	140 mm	6.650 m	0.93 m2	5.3549173	5.3549173	0.0272 m3	0.027168179	0.028577298	16
STEEL/S355J0	BEAM	HEB220	220 mm	220 mm	4.735 m	1.04 m2	6.0134545	6.0134545	0.0418 m3	0.041791142	0.043107473	1
STEEL/S355J0	BEAM	HEB220	220 mm	220 mm	7.816 m	1.72 m2	9.9263199	9.9263199	0.0690 m3	0.068984016	0.071156864	1
STEEL/S355J0	BEAM	IPE400	400 mm	180 mm	7.816 m	1.41 m2	11.466072	9.9263199	0.0631 m3	0.068984016	0.0660452	1
STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.080 m	0.31 m2	1.2012	1.2012	0.0059 m3	0.005852	0.0059136	2
STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.180 m	0.32 m2	1.2402	1.2402	0.0060 m3	0.006042	0.0061056	13
STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.180 m	0.32 m2	1.2402001	1.2402001	0.0060 m3	0.0060420006	0.0061056006	13
STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.235 m	0.32 m2	1.26165	1.26165	0.0061 m3	0.0061465	0.0062112	2
STEEL/S355J0	BEAM	L300*200*15	300 mm	200 mm	5.155 m	1.03 m2	5.1696752	5.1696752	0.0375 m3	0.037503536	0.037503536	3
STEEL/S355J0	BEAM	UPE270	270 mm	95 mm	1.400 m	0.13 m2	1.2488	1.2488	0.0068 m3	0.0067732	0.006272	2
STEEL/S355J0	BEAM	UPE270	270 mm	95 mm	9.350 m	0.89 m2	8.3401992	8.3401992	0.0452 m3	0.045235295	0.041887996	2
STEEL/S355J0	BRANDIS...	PL560*30	560 mm	30 mm	14.220 m	7.96 m2	16.8132	16.8132	0.2389 m3	0.238896	0.238896	5
STEEL/S355J0	BX001	SWTN320:...	500 mm	340 mm	14.220 m	7.11 m2	38.724	38.724	0.3242 m3	0.324216	0.324216	1
STEEL/S355J0	BX002	SWTN320:...	500 mm	340 mm	14.220 m	7.11 m2	38.724	38.724	0.3242 m3	0.324216	0.324216	1
STEEL/S355J0	BX003	SWTN320:...	500 mm	340 mm	14.220 m	7.11 m2	38.724	38.724	0.3242 m3	0.324216	0.324216	1
STEEL/S355J0	BX004	SWTN320:...	500 mm	340 mm	14.220 m	7.11 m2	38.724	38.724	0.3242 m3	0.324216	0.324216	1
STEEL/S355J0	BX005	SWTN320:...	500 mm	340 mm	14.220 m	7.11 m2	38.724	38.724	0.3242 m3	0.324216	0.324216	1

Figure 33 List of beam quantities

First object to be examined was chosen an ordinary IPE 400 steel beam. It has three volume parameter values which are different (Figure 34).



Component	Material	Name	Type	Profile Width	Profile Height	Length	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volume
Beam	STEEL/S355J0	BEAM	HEB220	220 mm	220 mm	7.816 m	0.0690 m3	0.068984016	0.071156864
Beam	STEEL/S355J0	BEAM	IPE400	400 mm	180 mm	7.816 m	0.0631 m3	0.068984016	0.0660452
Beam	STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.080 m	0.0059 m3	0.005852	0.0059136
Beam	STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.180 m	0.0060 m3	0.006042	0.0061056
Beam	STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.180 m	0.0060 m3	0.0060420006	0.0061056006
Beam	STEEL/S355J0	BEAM	L100*10	100 mm	100 mm	3.235 m	0.0061 m3	0.0061465	0.0062112

Figure 34 IPE 400 beam volume parameters in Solibri Model Checker

Geometrical parameters of chosen IPE 400 beam:

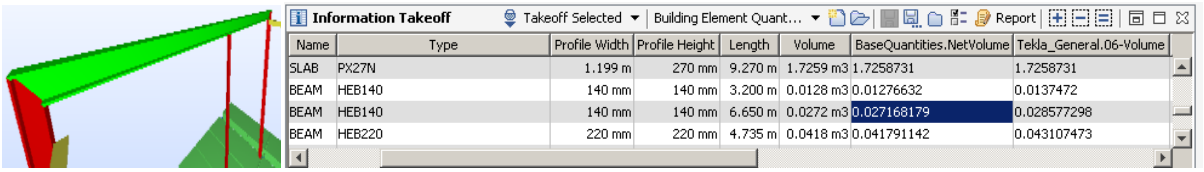
- Length: 7,816 m
- Cross section area: 84,5 cm^2 (14)

Manually calculated beam volume is:

- Volume: 7,816 x 84,5 x 10^{-4} = 0,0660452 m^3

Expected beam volume matches "Tekla_General.06-Volume" parameter (Figure 34) which comes from Tekla Structures; other values: "Volume" parameter – 5 percent lower and "BaseQuantities.NetVolume" – 1 percent higher.

There is also another interesting case where HEB 140 beam is a part of steel frame and its ends are cut by 45 degrees (Figure 35).



Name	Type	Profile Width	Profile Height	Length	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volume
SLAB	PX27N	1.199 m	270 mm	9.270 m	1.7259 m3	1.7258731	1.7258731
BEAM	HEB140	140 mm	140 mm	3.200 m	0.0128 m3	0.01276632	0.0137472
BEAM	HEB140	140 mm	140 mm	6.650 m	0.0272 m3	0.027168179	0.028577298
BEAM	HEB220	220 mm	220 mm	4.735 m	0.0418 m3	0.041791142	0.043107473

Figure 35 HEB 140 beam volume parameters in Solibri Model Checker

Geometrical parameters of chosen HEB 140 beam:

- Length of the beam (length of beam's top shelf): 6,650 m
- Cross section area: 43,0 cm^2 (14)

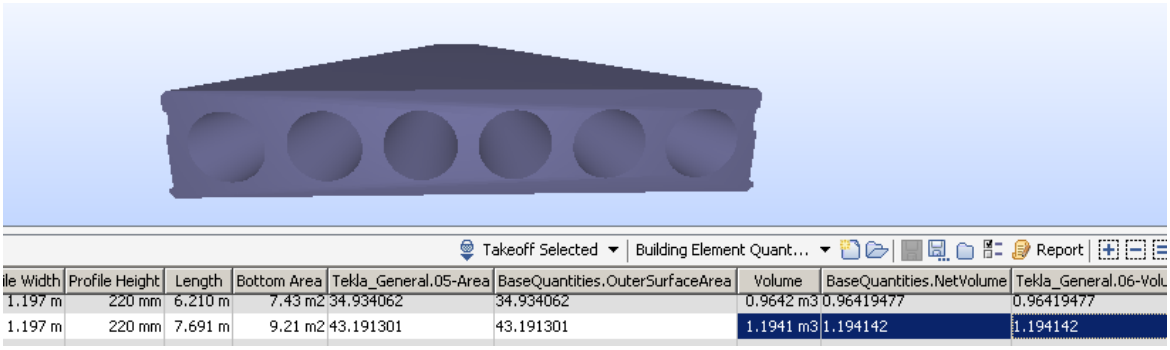
Manually calculated beam volume is:

- Gross volume: 6,650 x 43,0 x 10^{-4} = 0,028595 m^3
- Net volume: (6,650 – 0,14) x 43,0 x 10^{-4} = 0,027993 m^3

Expected beam gross volume of the beam almost matches "Tekla_General.06-Volume" parameter which comes from Tekla Structures (Figure 35). Expected net volume value is about 2 percent lower than gross value. Other volume values available in the model are about 5 percent lower than gross value.

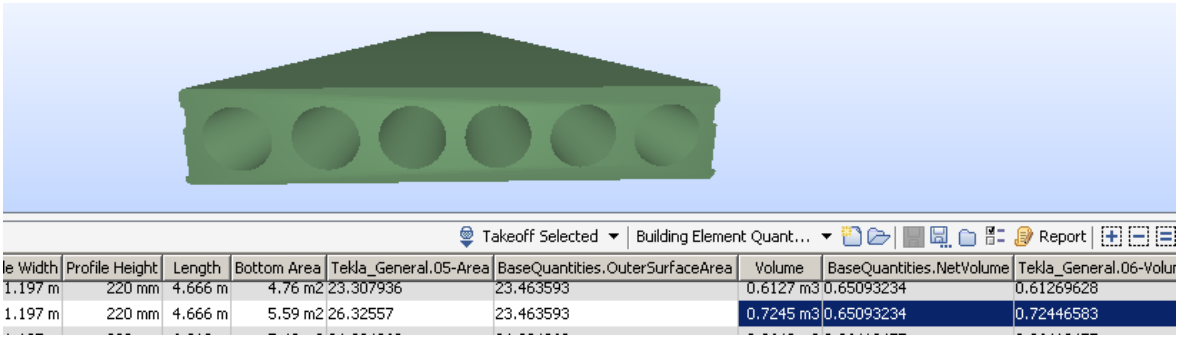
It has been noticed that volumes of concrete beams are quite accurate and that all 3 volume parameters has similar value. Unlike concrete beams, volumes of precast concrete slabs, which belong to beam category, have to be examined. For some of precast concrete slabs all 3 volume parameters are the same, for other – parameters differ (Figure 36). It is difficult to find the reason for that. But it has been decided to compare available values in Solibri Model Checker with ones calculated manually.

a.



ile Width	Profile Height	Length	Bottom Area	Tekla_General.05-Area	BaseQuantities.OuterSurfaceArea	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volu
1.197 m	220 mm	6.210 m	7.43 m2	34.934062	34.934062	0.9642 m3	0.96419477	0.96419477
1.197 m	220 mm	7.691 m	9.21 m2	43.191301	43.191301	1.1941 m3	1.194142	1.194142

b.



le Width	Profile Height	Length	Bottom Area	Tekla_General.05-Area	BaseQuantities.OuterSurfaceArea	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volu
1.197 m	220 mm	4.666 m	4.76 m2	23.307936	23.463593	0.6127 m3	0.65093234	0.61269628
1.197 m	220 mm	4.666 m	5.59 m2	26.32557	23.463593	0.7245 m3	0.65093234	0.72446583

Figure 36 Different volume values available in Solibri Model Checker for the same type of precast concrete slabs

Comparison is performed based on data of slab shown in Figure 36 b.

Geometrical characteristics of the slab:

- Width: 1,197 m
- Height: 220 mm
- Length: 4,666 m
- Diameter of horizontal holes in the slab: 150mm

Manually calculated beam volume is:

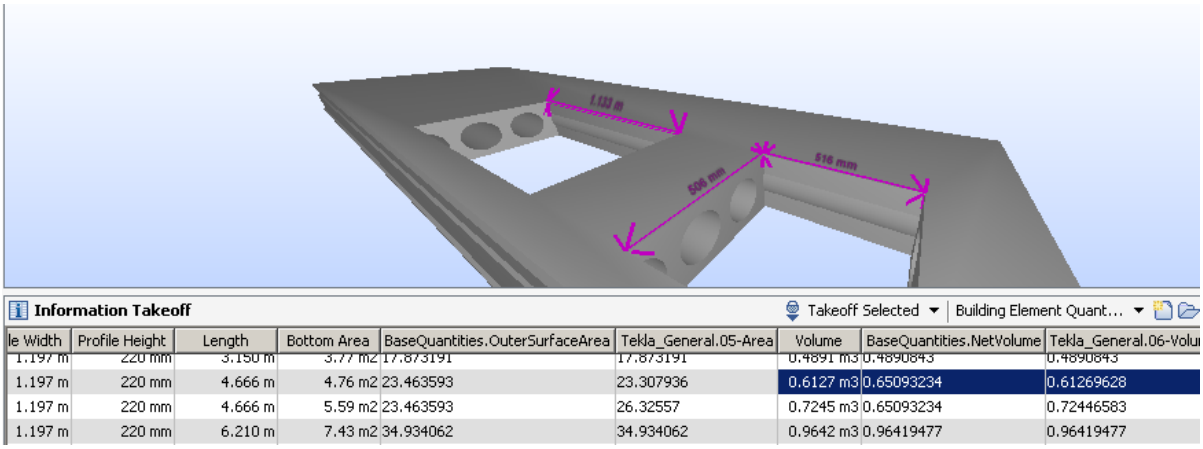
- Net volume: 1,197 x 0,220 x 4,666 – 6 x ($0{,}075^2$ x 3,14 x 4,666) = 0,7342 m^3

Net volume of the slab calculated manually is almost the same as value from "Volume" and "Tekla_General.06-Volume" parameters (Figure 36 b). "BaseQuantities_NetVolume" value is about 11 percent lower than calculated one therefore cannot be used for list of quantities.

There is also one same slab as just examined but with the holes in vertical direction (Figure 37). Manually calculated net volume of such slab is:

- Square holes: 1,13 x 0,5 m and 0,5 x 0,5 m
- Net volume: 0,7342 – (1,63 x 0,5 x 0,22 – 3 x $0{,}075^2$ x 3,14 x 1,63)= 0,5836 m^3

Comparing manually calculated value with values provided in Solibri Model Checker it can be seen that holes have been taken into account in "Volume" and "Tekla_General.06-Volume" parameter (Figure 37). "BaseQuantities_NetVolume" value did not change comparing to previously examined slab without vertical holes.

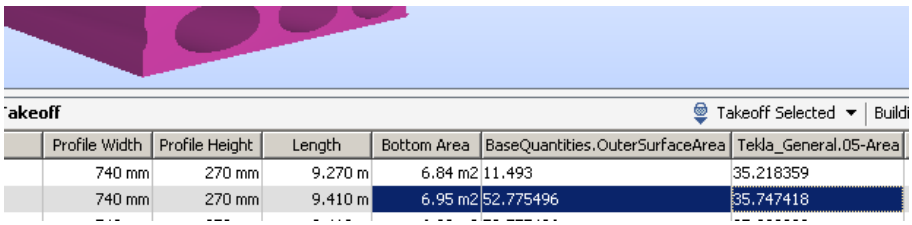


le Width	Profile Height	Length	Bottom Area	BaseQuantities.OuterSurfaceArea	Tekla_General.05-Area	Volume	BaseQuantities.NetVolume	Tekla_General.06-Volu
1.197 m	220 mm	3.150 m	3.77 m2	17.873191	17.873191	0.4891 m3	0.4890843	0.4890843
1.197 m	220 mm	4.666 m	4.76 m2	23.463593	23.307936	0.6127 m3	0.65093234	0.61269628
1.197 m	220 mm	4.666 m	5.59 m2	23.463593	26.32557	0.7245 m3	0.65093234	0.72446583
1.197 m	220 mm	6.210 m	7.43 m2	34.934062	34.934062	0.9642 m3	0.96419477	0.96419477

Figure 37 Hollow core slab with vertical holes in Solibri Model Checker

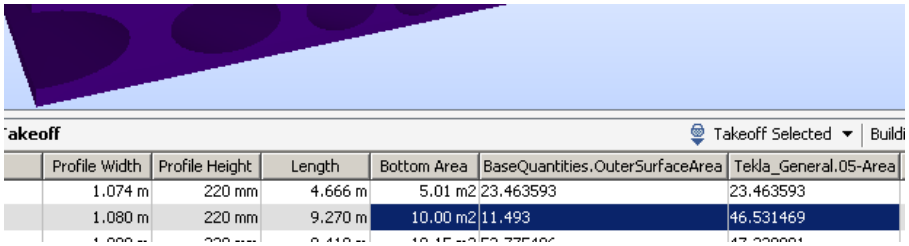
Looking at other quantities than volume, for example surface area, – similar issues are discovered. There are 3 values in square meters representing the quantity of the slab. First one is "Bottom Area" of the slab which gives correct values of the element's bottom net area (Figure 37, Figure 38). Other two area parameters "BaseQuantities.OuterSurfaceArea" and "Tekla_General.05-Area" are quite odd at the first sight. Comparing two same type slabs (Figure 38) it can be noticed that for the first slab value of one area parameter is much higher than other, for the second slab – it is opposite.

a.



Profile Width	Profile Height	Length	Bottom Area	BaseQuantities.OuterSurfaceArea	Tekla_General.05-Area
740 mm	270 mm	9.270 m	6.84 m2	11.493	35.218359
740 mm	270 mm	9.410 m	6.95 m2	52.775496	35.747418

b.



Profile Width	Profile Height	Length	Bottom Area	BaseQuantities.OuterSurfaceArea	Tekla_General.05-Area
1.074 m	220 mm	4.666 m	5.01 m2	23.463593	23.463593
1.080 m	220 mm	9.270 m	10.00 m2	11.493	46.531469

Figure 38 Surface area parameters of two different hollow core slabs in Solibri Model Checker

Geometrical parameters of the slab (Figure 38 a):

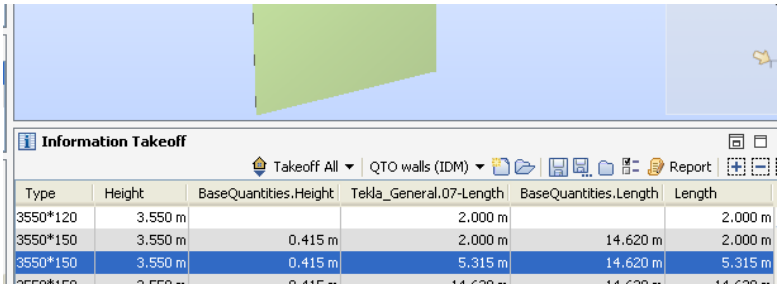
- Width: 740 mm
- Height: 270 mm
- Length: 9,410 m
- Diameter of holes: 200 mm

Manually calculated area values:

- Bottom area: 0,74 x 9,41 = 6,96 m^2
- Outer slab area (envelope): 2 x (0,74 + 0,27) x 9,41 + 2 x 0,74 x 0,27 = 19,41 m^2
- Total slab surface area (including holes): 19,41 + 3 x 0,2 x 3,14 x 9,41 – 6 x 3,14 x $0,1^2$ = 36,9 m^2

Comparing manually calculated areas of the slab with provided ones in Solibri (Figure 38 a) it can be seen that "Tekla_General.05-Area" represents total slab surface area including surface of the holes. However, it is difficult to determine what the value of "BaseQuantities.OuterSurfaceArea" parameter presents.

It has been decided to check on wall parameters as well, especially on wall length and height which have to be included in QTO for bidding process following IDM requirement. For walls, same as for beams, in Solibri Model Checker there are several options to choose geometrical parameters of the elements. However, it has been noticed that values from "BaseQuantities" are not reliable (Figure 39, Appendix G). Therefore, height value should be used from set of parameters from "Quantities"; length value can be used from "Quantities" or "Tekla_General" (Appendix G).



Type	Height	BaseQuantities.Height	Tekla_General.07-Length	BaseQuantities.Length	Length
3550*120	3.550 m		2.000 m		2.000 m
3550*150	3.550 m	0.415 m	2.000 m	14.620 m	2.000 m
3550*150	3.550 m	0.415 m	5.315 m	14.620 m	5.315 m

Figure 39 Different wall height and length parameters in Solibri Model Checker

Other issues than element quantities also have been discovered which had to be fixed during the modelling process. It has been noticed that names of elements do not follow particular naming system. For example, some of beams are named just as "Slab" or "Beam" and others has particular coding like "RIIIR" or profile name "HEB220". This makes list of quantities less organised.

Some of the elements have different names even though they have exactly the same geometrical parameters, made of the same material and located on the same floor. This should be avoided unless there are some specific differences between the elements.

3.3.5. Revit Architecture model behaviour in Solibri Model Checker

For this test building information model made in Revit Architecture is used which contains floor levels with elements assigned to them. The main objective of this test is to inspect elements' behaviour in Solibri Model Checker regarding their location and ability to extract location based quantities.

Model in IFC format from Revit Architecture was successfully loaded in Solibri Model Checker (Figure 40). Visual inspection of the model did not reveal any problems regarding changes of geometrical shape, element location or position.

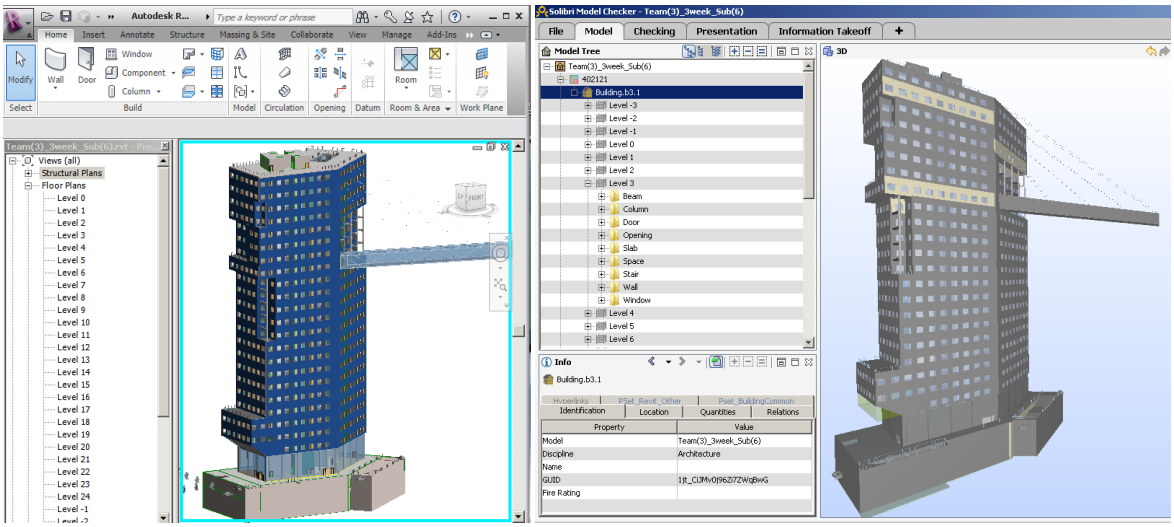


Figure 40 Examined BIM model: a - in native Revit Architectural environment, b - in Solibri Model Checker environment

To identify if all elements are assigned to the same floor as in Revit Architecture, all elements assigned to particular floor were isolated and visualized separately from the other elements in other floors. After examination of all floors it appeared that all the beams and some of the walls are assigned to the lower level than it was done in Revit Architecture (Figure 41). The common thing about these elements is that their boundaries were slightly corrected manually (while modelling in Revit Architecture) in order to achieve desired design: beams were offset down by 60 mm, and some of the wall parts were extended down to cover the slab going above terrace. Comparing view of elements belonging to 14th floor in Revit Architecture with the same view in Solibri Model Checker (Figure 41) it can be seen that three walls and beams from 15th floor are assigned to 14th floor. It is assumed that this problem is because of these unusual modifications of the elements and deeper analysis has to be performed in order to identify technical problem of this issue.

Unfortunately, location based quantity takeoff of such building model in Solibri Model Checker is not reliable as elements contain misleading information about their location in the building.

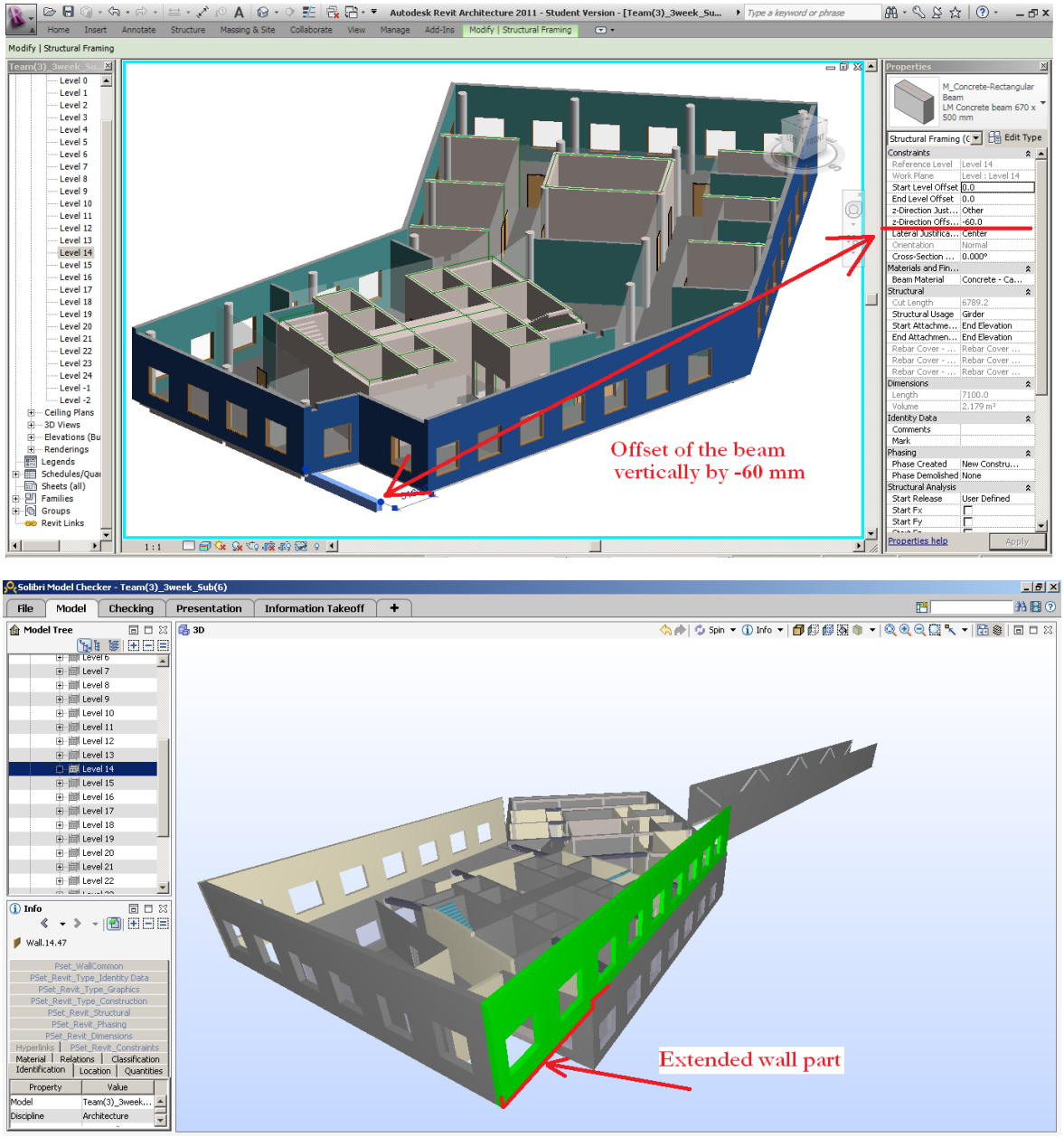


Figure 41 Floor no. 14 in Revit Architecture and in Solibri Model Checker.

3.3.6. QTO in Solibri Model Checker following IDM requirements

In this chapter it is described how to perform QTO in Solibri Model Checker v7 of structural columns, beams and slabs modelled in Tekla Structures following IDM requirements (Appendix A) and save it in excel sheet so later it could be used for estimation process.

Loading the model

1. Open Solibri Model Checker v7
2. Under "File" tab choose Role preferences for "QTO" (Figure 42).

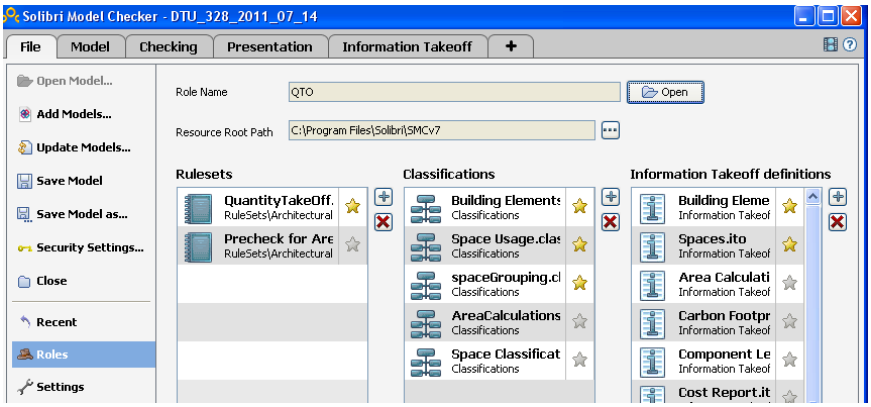


Figure 42 Role settings in Solibri Model Checker v7

3. Load the IFC model in Solibri Model Checker (Figure 43).

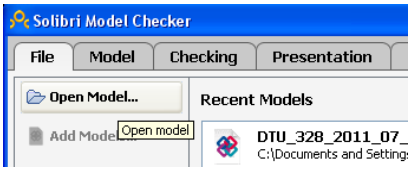


Figure 43 Opening the model in Solibri Model Checker v7

4. In popped-up window choose Discipline "Structural" (Figure 44).

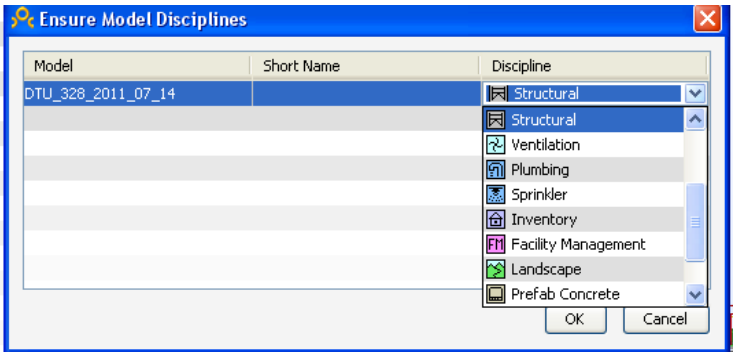


Figure 44 Selection of model discipline to be loaded in Solibri Model Checker v7

5. Once model is loaded visual inspection for the model integrity has to be carried out. If needed automated check of the model can be performed based on defined rules. In case there are minor problems which can influence material quantities model has to be fixed.

QTO of Columns

To make QTO for columns particular "Information Takeoff definition" has to be created.

1. "Information Takeoff" tab has to be opened (Figure 45).

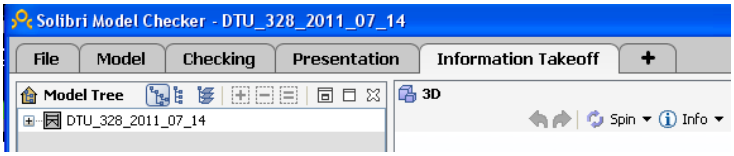


Figure 45 Information Takeoff tab in Solibri Model Checker v7

2. In Information Takeoff window information definition for QTO of columns has to be created by clicking on "New Information Takeoff Definition" icon (Figure 46). In appeared window name for created information takeoff definition has to be given, Discipline "Structural" and Component "Column" chosen (Figure 47). Press OK.

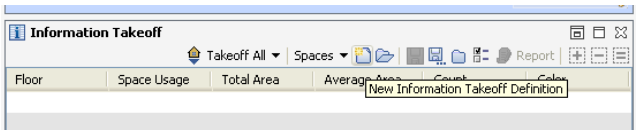


Figure 46 "New Information Takeoff Definition" button in Solibri Model Checker v7

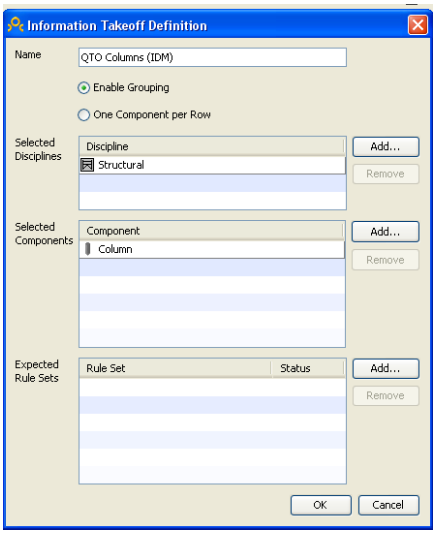


Figure 47 Information Takeoff Definition window

3. In Information Takeoff window several table columns with properties are previewed by default. They have to be changed and arranged according to IDM requirements. In the table below IDM requirements for column properties to be included in QTO are presented. These have to be created in Solibri Model Checker.

Table 3 Column properties for QTO required by IDM

Type: (SE, S)	What type is involved, in-situ, prefabricated or steel with or without console, etc.
Height	Which height has the given column
Dimension	Ø300 or 300x300 etc.
Classification:	DBK or other classification.
Number of elements	The number of columns at given price.
Description	Description of object construction

First of all, table columns of list of quantities might be deleted and desired ones created. To remove column click right mouse button on table column and choose "Remove Column" (Figure 48).

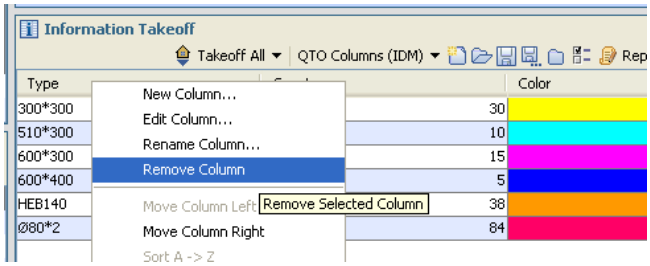


Figure 48 Removing table columns from information takeoff table

4. To add table column in list of quantities right click on "Information Takeoff" window and choose "New Column..." (Figure 49). Window appears where parameters of the table column have to be defined.

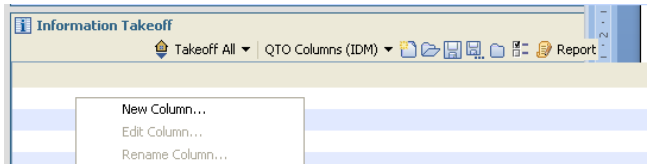


Figure 49 Creating new table column in information takeoff table

5. To describe the "Type" of the element according to IDM – "Name" or "User Field" parameter can be used. It is just required that one of them follows "Type" description from IDM. While creating new table column window appears where table column parameters have to be set as: "Identification" as a Column Type, in Identification field "Name" has to be chosen and table column name should be given as "Type" (Figure 50). Press OK.

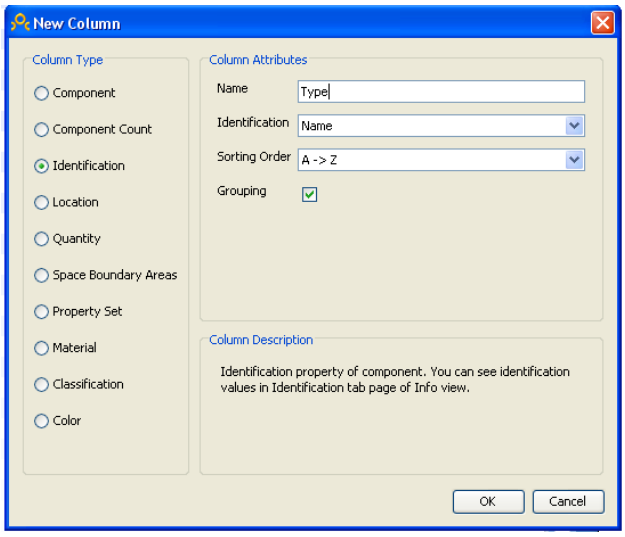


Figure 50 Table column parameters for "Type" property of column element according to IDM

Note: It is crucial that names for elements in Tekla Structures are given in the way that they follow description of column "Type" property in IDM!

6. To add "Height" parameter of the element new table column has to be created with properties: Column Type "Property Set", Property Set Name "Tekla_General", Property Name "07-Length", Format "Length", Grouping "checked" and Name "Height" (Figure 51). Press OK.

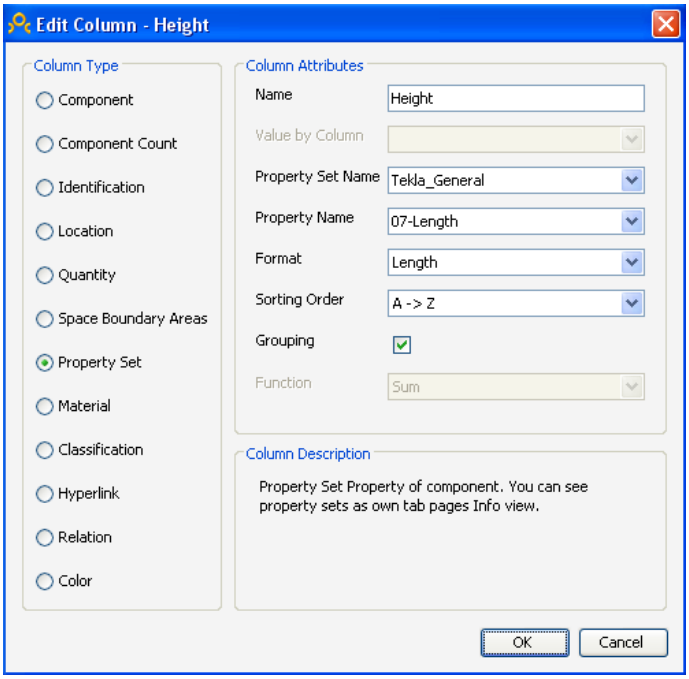


Figure 51 Table column parameters for "Height" property of the column element

> Note: height value represents maximum height of the element regardless how element's endings are cut.

7. To add "Dimension" parameter to the list of quantities – table column with parameters as shown in the figure below has to be created (Figure 52).

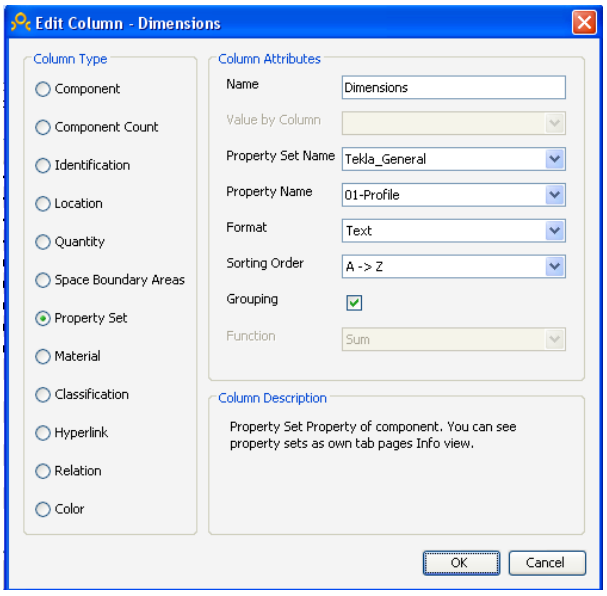


Figure 52 Table column parameters for "Dimension" property of the column element

8. Adding classification column in the table would be as easy as previous ones. But it is required then that elements are assigned with proper classification information already in the modelling process in native BIM application and exported into IFC. However, building element classification information might be not available in the model or elements might be classified by different system than it is required. In this case classification of the elements can be performed in Solibri Model Checker.
   To do this Classification window has to be opened (Figure 53).

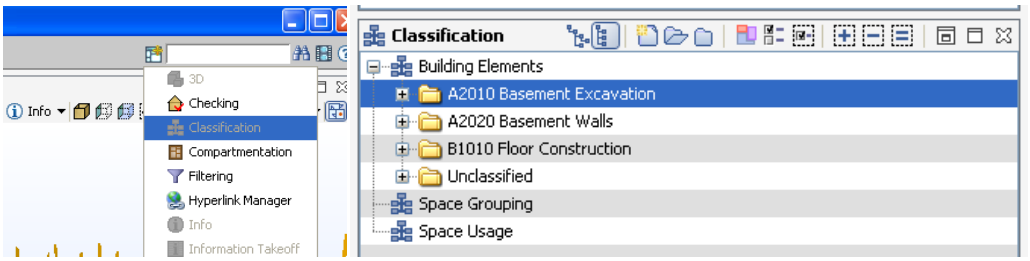


Figure 53 Opening Classification window in Solibri Model Checker v7

Here, several classification systems are already provided which classify model objects based on their properties (Figure 54). If needed, it is possible to add and/or modify classification criteria properties and give particular naming or coding.

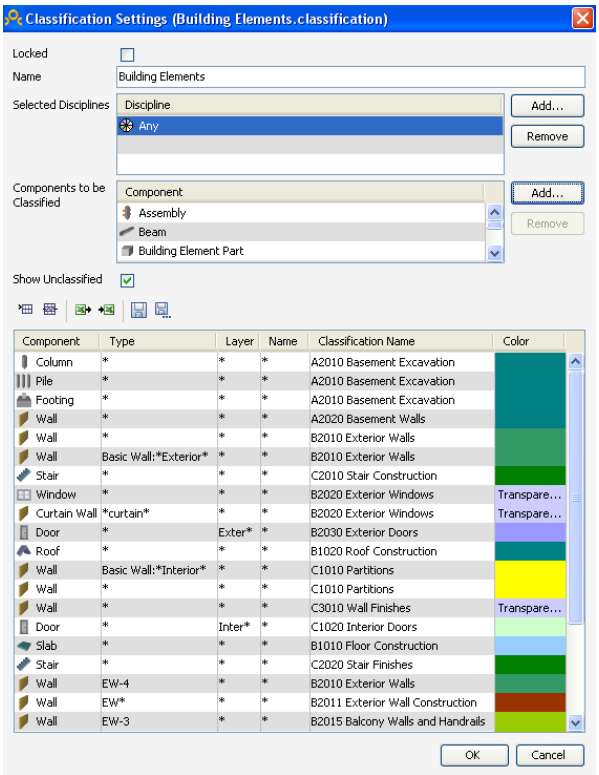


Figure 54 Typical parameter settings for automated classification of building elements in Solibri Model Checker v7

It is also possible to create own classification list based on parameters of the elements. In this case it is important that parameters which differentiate all elements are well known and examined.

Own classification system is created by clicking on "New Classification" icon in Classification window (Figure 55). Then program asks to give a name for classification and to choose component type for which classification is applied.

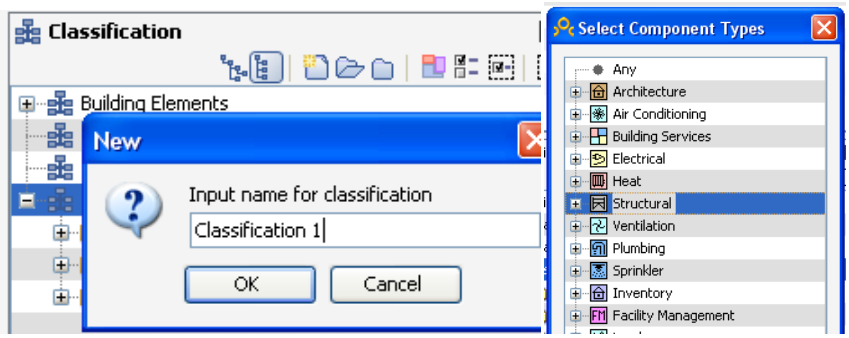


Figure 55 Creating new classification system in Solibri Model Checker v7

Automated assignment of elements to classification system is done in several steps. First of all, setting window for automated classification is opened by right click on created classification system and choosing "Settings..." (Figure 56).

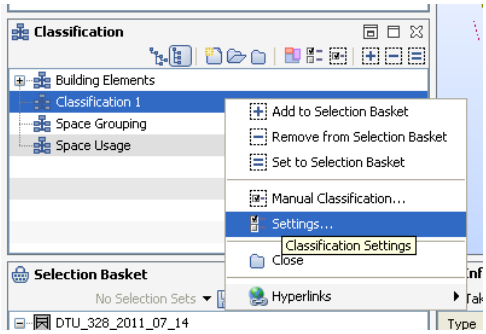


Figure 56 Opening settings window for created classification system

In opened Classification Settings window it is defined which elements with particular properties are automatically assigned to created category of classification (Figure 57).

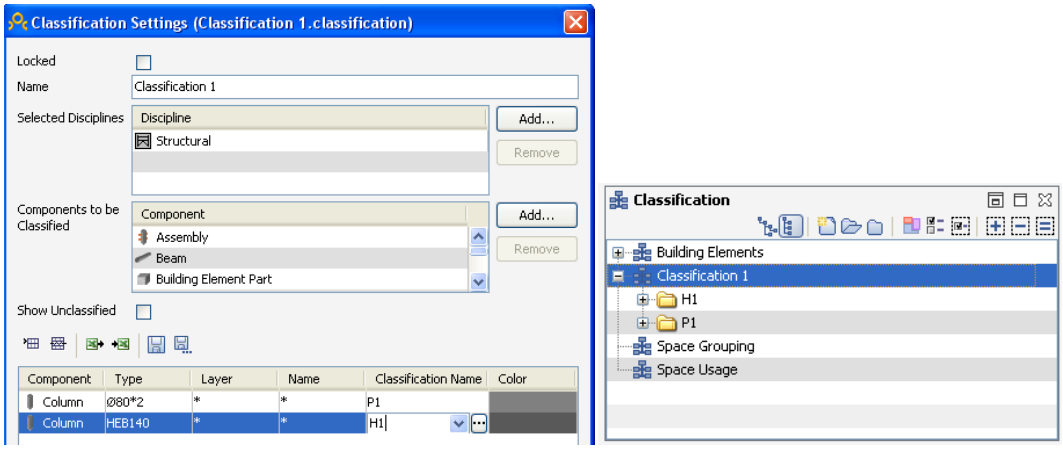


Figure 57 Definition of element properties on basis of which elements are assigned to particular category of the classification

There is also second option to assign elements to created classification system. It can be done manually by selecting elements and assigning them to particular category for which name is given (or chosen from existing ones). First of all, elements which are to be assigned to particular category of the classification have to be selected (added to Selection Basket – feature in Solibri Model Checker). When elements are added to the Selection Basket following actions have to be done: right click on created classification in Classification window and click on "Manual Classification..." (Figure 58).

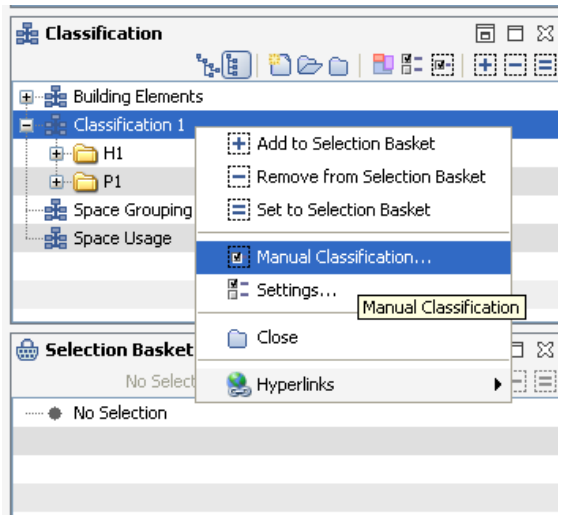


Figure 58 Opening of Manual Classification window

In popped-up window "Selection Basket" has to be chosen from Selection options and name for the category in classification system given (or chosen from existing one) (Figure 59).

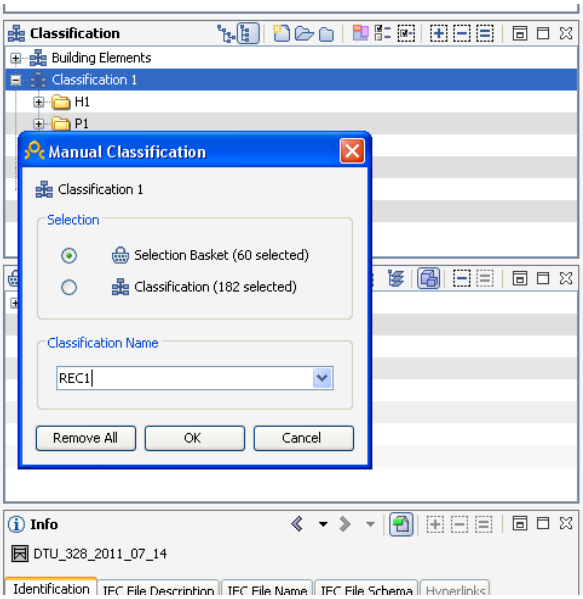


Figure 59 Manual element assignment to created classification window

This way classification system can be created in Solibri Model Checker. To add classification column in the list of quantities created column has to follow parameters as it is shown in Figure 60.

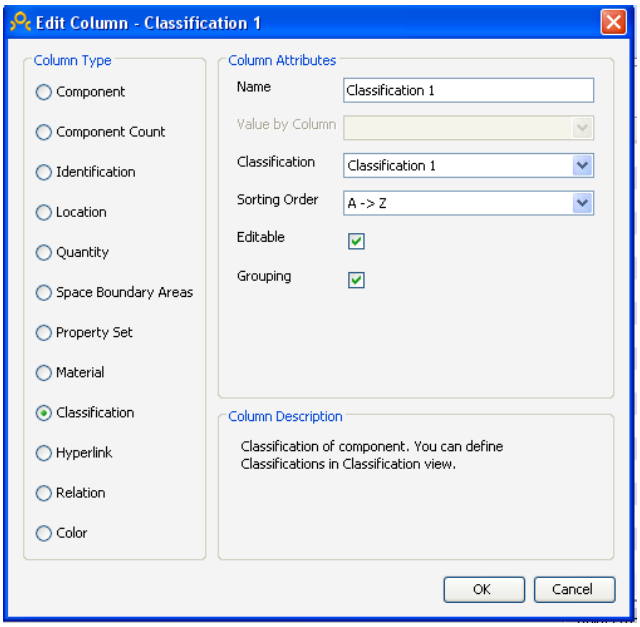


Figure 60 Table column parameters for "Classification"

9. "Number of elements" is added to the list of quantities by creating a column in the table with parameters as shown in the figure below.

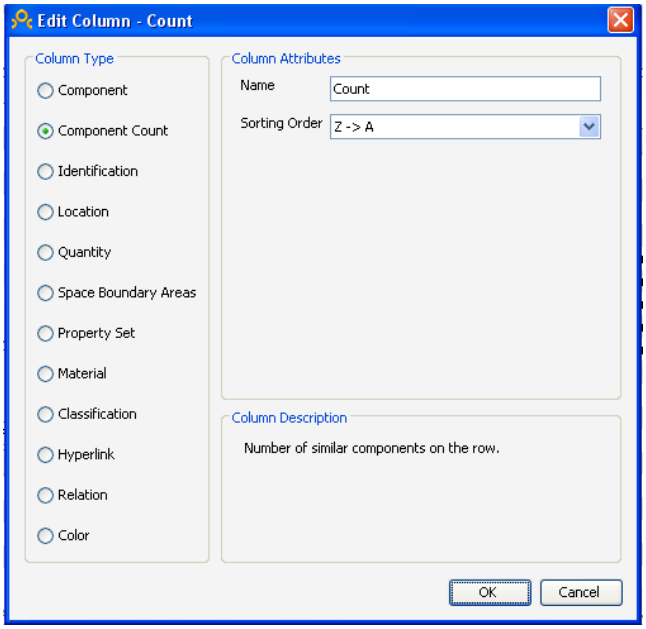


Figure 61 Table column parameters for "Number of elements"

10. "Description" information can be added to the list of quantities based on the model information as long as these descriptions are applied to the elements in Tekla Structures and exported with IFC. Otherwise, descriptions can be added manually in already exported excel file.
11. Export of list of quantities to excel spreadsheet is done by pressing "Report" icon in the Information Takeoff window. In popped-up window name of the file has to be given. Excel sheet is created with press of the "Save Report..." button. Location for the file is chosen.

QTO of beams

To make QTO for beams "Information Takeoff definition" for beams has to be created.

Note: Prefabricated slabs in Tekla Structures are represented as beam components. Therefore, two information takeoff definitions have to be created in Solibri Model Checker: one with IDM defined parameters for beams and one IDM defined parameters for slabs. When list of quantities is exported to excel sheets elements which do not belong to particular list have to be deleted manually.

1. "Information Takeoff" tab has to be opened (Figure 45).
2. In Information Takeoff window information definition for QTO of beams has to be created by clicking on "New Information Takeoff Definition" icon (Figure 46). In appeared window name for created information takeoff definition have to be given, Discipline "Structural" and Component "Column" have to be chosen (Figure 62). Press OK.

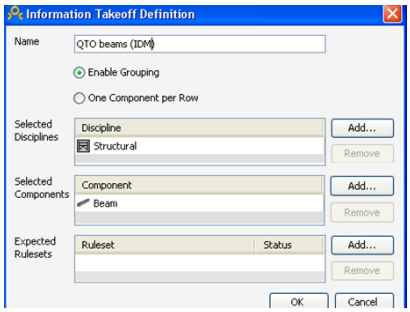


Figure 62 Information Takeoff Definition window with parameters selected for QTO of beams

3. In Information Takeoff window several table columns with properties are previewed by default. They have to be changed and arranged according to IDM requirements. In the table below IDM requirements for column properties to be included in QTO are presented. These have to be created in Solibri Model Checker.

Table 4 Beam properties for QTO required by IDM

Type (BE, SB)	What type is involved, in-situ, prefabricated or steel with or without console, etc.
Length	Which length has the given beam
Dimension	Which dimension has special bar or square.
Openings/holes	In the case of special holes or system holes.
Classification	DBK or other classification.
Number of elements	The number of type beams as given price.
Description	Description of object construction

First of all, table columns of list of quantities might be deleted and desired ones created. To remove column click right mouse button on table column and choose "Remove Column" (Figure 48).

4. To add table column in list of quantities right click on "Information Takeoff" window and choose "New Column..." (Figure 49). Window appears where parameters of the table column have to be defined.
5. To describe the "Type" of the element according to IDM – "Name" parameter has to be used from Solibri Model Checker. While creating new column of the table – window appears where table column parameters have to be set as: "Identification" as a Column Type, in Identification field "Name" has to be chosen and table column name should be given as "Type" (Figure 63). Press OK.

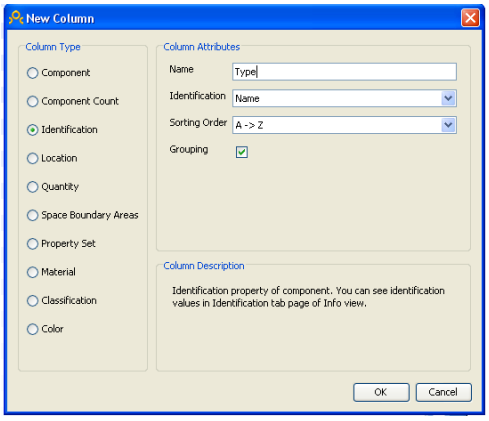


Figure 63 Table column parameters for "Type" property of beam element according to IDM

> Note: It is crucial that names for elements in Tekla Structures are given in the way that they follow description of column "Type" property in IDM!

6. To add beam length parameter to list of quantities table column with parameters shown in the figure below has to be added.

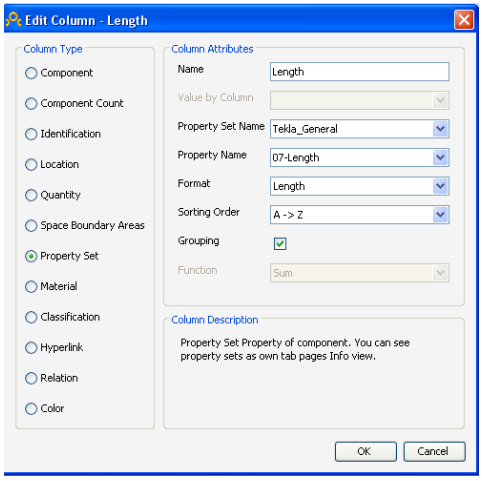


Figure 64 Table column parameters for "Length" property of beam element according to IDM

Note: length value represents maximum length of the element regardless how element's endings are cut.

7. To add beam cross section dimension to list of quantities table column with parameters shown in the figure below has to be added.

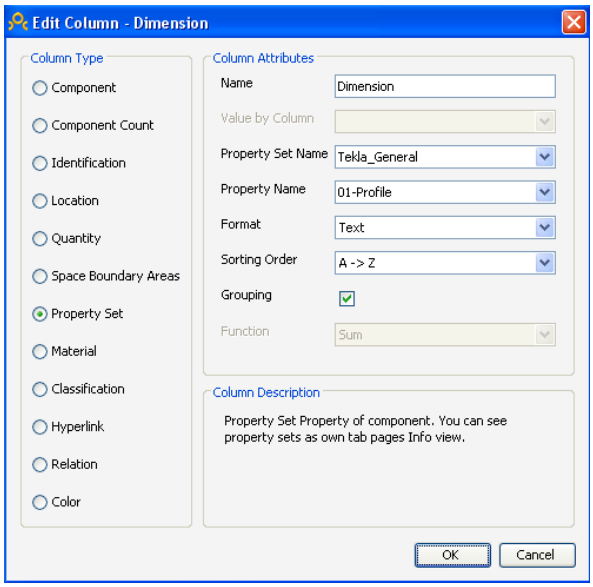


Figure 65 Table column parameters for "Dimensions" property of beam element according to IDM

8. Number of holes or any recesses in the beams has to be inspected and counted manually. There is no such function in Solibri Model Checker to give this information.
9. Classification of the beams is done in the same way as it is done for columns.
10. "Number of elements" is added to the list of quantities by creating a column in the table with parameters as shown in the figure below.

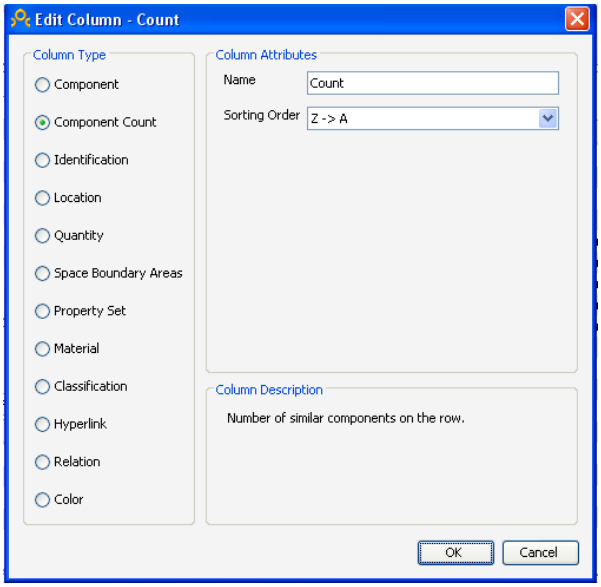


Figure 66 Table column parameters for "Number of elements"

11. "Description" information can be added to the list of quantities based on the model information as long as these descriptions are applied to the elements in Tekla Structures and exported with IFC. Otherwise, descriptions can be added manually in already exported excel file.
12. Export of list of quantities to excel spreadsheet is done by pressing "Report" icon in the Information Takeoff window. In popped-up window name of the file has to be given. Excel sheet is created with press of the "Save Report..." button. Location for the file is chosen.

QTO of walls

In the table below IDM requirements for column properties to be included in QTO are presented. These have to be created in Solibri Model Checker.

Table 5 Wall properties for QTO required by IDM

Type (VE, V)	What type is involved, in-situ, prefabricated or sandwiches etc.
Height	Which height has the given wall
Openings/holes	Number of openings/holes
Classification	DBK or other classification.
Total length	It is the total length of the given price
Description	Description of object construction

1. New Information Takeoff definition has to be created for QTO of walls. This is done the same way as it is described for column or beam (Figure 45, Figure 46 and Figure 47).
2. "Type", "Opening/holes", "Classification" and "Description" parameters are added to the list of quantities the same way as it is done for columns and beams.
3. Created table column defining "Height" of the wall should have parameters as it is shown in the figure below.

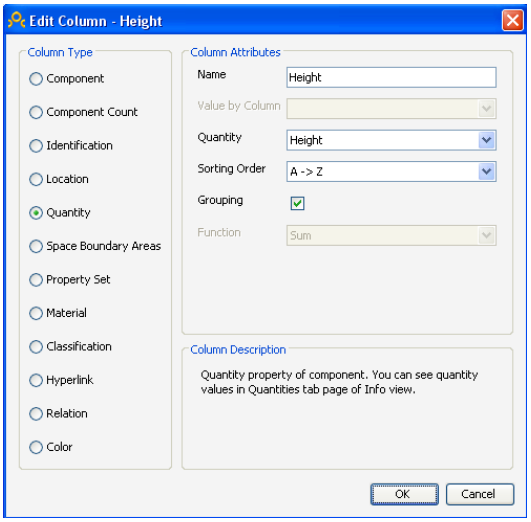


Figure 67 Table column parameters for "Height" of the wall

4. Created table column defining "Total length" of the wall should have parameters as it is shown in the figure below.

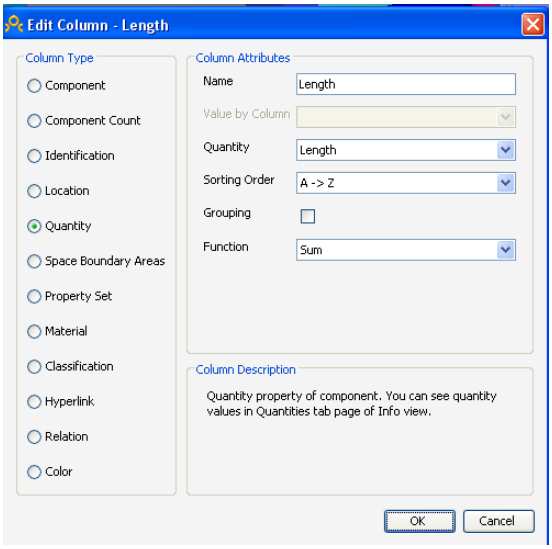


Figure 68 Table column parameters for "Total length" of the wall

3.4. Test results

The aim of performed tests was to answer the question if there are any serious issues related with BIM based information takeoff for bidding material, how reliable it is and if BIM technology is ready to replace traditional paper based bidding process with BIM based one.

Tekla Structures is 3D modelling software where it is possible to assign lots of different information to the elements. This is very useful especially when there is also a tool available which enables to extract that information for different purposes including QTO. With Tekla Structures it is definitely possible to make very good various QTO reports which can be designed and structured in the way it is required by users of the reports. However, to create templates for the QTO documents proficient skills in using the software is required. Tekla Structures exports basic parameters of the element to IFC model, but if there is a need to include more information in IFC it can be done by changing export settings and selecting required parameters to be exported.

Tests on interoperability issues have shown that different software applications still have problems in converting BIM models to or reading from IFC format files.

Tested structural model of the building made in Tekla Structures was loaded in Revit Architecture. It has shown serious problems: not all building elements were loaded into the application, location of some elements was changed and there was limited information about the elements to make list of material quantities sufficient enough for estimation process.

The same model loaded in Solibri Model Checker has shown better results. All building parts were loaded correctly and there were no problems with elements' geometry representation. Elements contained lots of information which could be used to generate informative list of material quantity. However, to make good list of quantity some issues have to be considered already during the modelling process in Tekla Structures. Names of the elements in tested model did not follow particular system. Some of the beams were called just "Beam", others were given its profile name or they were named by some code. Some of

the elements with identical geometrical and material parameters were given different names. This means that these elements appear in different lines/position in the list of quantities instead of being grouped.

In Tekla Structures there is no such possibility to create floor layers to which building elements can be assigned. However, it is possible to add user defined parameter which can be assigned to each element and represent its location in the building for example. But what is more important is that user defined parameters in Tekla are transferrable through IFC format and available in Solibri Model Checker. This makes it possible to include "floor" parameter in list of quantities and make location based QTO. In tested model structural engineer was mainly focused on modelling the elements for own purposes and possibility to use user defined field to assign location to the element was not considered.

As it has been mentioned Tekla Structures model opened in Solibri Model Checker through IFC format contains lots of information. Beside available linear parameters of the elements there are several parameters describing volume and area. In most cases all same type parameters (area or volume) for each element have different values. Therefore, before doing the list of quantities it is crucial to examine what those values represent and use needed ones. It is important to be aware of how elements are measured, does the area of the slab for example includes areas of the holes in it or not.

In the test, where Revit Architecture model has been used to examine if assigned elements to particular floor levels preserve that information in Solibri Model Checker, it appeared that some of the building elements were assigned to different floor level than they were assigned originally. This problem excludes possibility to generate list of material quantities grouped by floor.

Last test was performed to check if it is possible extract QTO following IDM requirements from IFC Tekla Structures model loaded in Solibri Model Checker. This test has shown that all the geometrical parameters can be extracted from the model. In order collect descriptive properties specified by IDM (type, classification or description of the elements) there is a need to assign this information during modelling process in Tekla Structures. Also it is important to make sure that required information is included in exported IFC file. In case classification or description information is missing – it can be assigned manually: classification in Solibri Model Checker and descriptions in exported excel spreadsheet. Openings in the elements have to be counted in Solibri Model Checker manually and added to excel spreadsheet. Even though this process is not automated, using 3D model to visualize selected object and count number of recesses is quite simple.

The overview how Solibri Model Checker can support extraction of material quantities from IFC model exported from Tekla Structures is presented in Table 6 (for columns), Table 7 (beams) and Table 8 (walls). Note, that it is important to make sure that required parameters are exported to IFC model.

All in all, tests have shown that BIM tools can help extract material quantities very quickly which may improve efficiency of preparation of bidding material process. However, to generate reliable list of quantity with sufficient amount of information there is a need to develop high quality models which have to be initially modelled with concern about information required for QTO and to use software which is able to read and manipulate information from the model.

Table 6 Solibri Model Checker capability to support QTO of columns from IFC Tekla Structures model following IDM requirement

Parameter	Description of parameter	Solibri Model Checker capability to support QTO from IFC Tekla Structures model following IDM requirement
Column		
Type: (SE, S)	What type is involved, in-situ, prefabricated or steel with or without console, etc.	 Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures under field "Name" or user defined field.
Height	Which height has the given column	 Parameter can be extracted automatically in Solibri Model Checker. It comes from Tekla Structures model as a "Length" parameter.
Dimension	Ø300 or 300x300 etc.	 Parameter can be extracted automatically in Solibri Model Checker. Element´s cross section geometry can be defined from "Profile" field available from Tekla Structures.
Classification:	DBK or other classification.	 Manual Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. User defined field can be used for this purpose. Second option is to assign this parameter to the elements in Solibri Model Checker.
Number of elements	The number of columns at given price.	 Parameter can be extracted automatically in Solibri Model Checker.
Description	Description of object construction	 Manual Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. Otherwise it have to be done manually already in excel sheet report.

Table 7 Solibri Model Checker capability to support QTO of beams from IFC Tekla Structures model following IDM requirement

Parameter	Description of parameter	Solibri Model Checker capability to support QTO from IFC Tekla Structures model following IDM requirement
Beam		
Type (BE, SB)	What type is involved, in-situ, prefabricated or steel with or without console, etc.	 Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures under field "Name" or user defined field.
Length	Which length has the given beam	 Parameter can be extracted automatically in Solibri Model Checker. It comes from Tekla Structures model as a "Length" parameter.
Dimension	Which dimension has: special bar or square.	 Parameter can be extracted automatically in Solibri Model Checker. Element´s cross section geometry can be defined from "Profile" field available from Tekla Structures.
Openings/ holes	In the case of special holes or system holes.	Manual Calculation of holes/cuts/ recesses in elements can be done manually in Solibri Model Checker.
Classification	DBK or other classification.	 Manual Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. User defined field can be used for this purpose. Second option is to assign this parameter to the elements in Solibri Model Checker.
Number of elements	The number of type beams as given price.	 Parameter can be extracted automatically in Solibri Model Checker.
Description	Description of object construction	 Manual Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. Otherwise it have to be done manually already in excel sheet report.

Table 8 Solibri Model Checker capability to support QTO of walls from IFC Tekla Structures model following IDM requirement

Parameter	Description of parameter	Solibri Model Checker capability to support QTO from IFC Tekla Structures model following IDM requirement
Wall		
Type (VE, V)	What type is involved, in-situ, prefabricated or sandwiches etc.	 Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures under field "Name" or user defined field.
Height	Which height has the given wall	 Parameter can be extracted automatically in Solibri Model Checker. "Height" parameter measured by Solibri Model Checker can be used.
Openings/holes	Number of openings/holes	Manual Calculation of holes/cuts/ recesses in elements can be done manually in Solibri Model Checker.
Classification	DBK or other classification.	 Manual Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. User defined field can be used for this purpose. Second option is to assign this parameter to the elements in Solibri Model Checker.
Total length	It is the total length of the given price	 Parameter can be extracted automatically in Solibri Model Checker. To get sum of lengths of all walls "Length" parameter measured by Solibri Model Checker can be used.
Description	Description of object construction	 Parameter can be extracted automatically in Solibri Model Checker. It is required that this parameter (following its description) is assigned to the element in native model environment Tekla Structures. Otherwise it have to be done manually already in excel sheet report.

4. Discussion

4.1. Communication

There are several means of communication people use to share information. They can do it simply by using speech, written texts or visual material. All those manners serve to explain receiver the information sender has in mind which enables receiver to give adequate respond.

Pictures and drawings are main form of communication in construction industry. They carry lots of information which is difficult or even impossible to explain in words. Combination of well-prepared drawings together with written texts is a powerful tool which can make communication process extremely efficient.

There are many disciplines involved in construction industry. Good communication between them is a key factor determining success of the project. Each discipline has its own tasks to solve at different project stages and is focused on particular part of the project. To establish fluent information flow along the processes it is crucial to make sure that every participant is aware of information content required by next process actor to solve next tasks.

Bidding process is in focus of this thesis. The aim is to discover which information is required by contractors to be included in bidding material to provide reliable bid price of the project. For this reason interviews with people from construction industry involved in bidding process were conducted. Based on testimonials of their experience improvements for bidding material preparation strategy is suggested.

4.2. Overview of bidding process and bidding material content

Most of construction projects in Denmark follow traditional business model similar to design-bid-build concept (Figure 3). It means that unlike in design-build model, where close collaboration between construction and design is established, consultant and contractor is separated by bidding process where communication about the project is carried out only by set of bidding material documents. This means that project success regarding the budget depends on quality of these documents and how well bidding contractor understands the project based on those documents.

Contractors put a lot of effort and resources to analyse bidding material to learn about the building project in order to evaluate all the risks they may face during construction. In case material is not well defined some additional hidden risks and works may appear during erection of the building which results in undesirable increase of project price (Figure 69, A).

There is a huge competition in construction industry. In order to win the project companies usually need to give lowest bid price proposal. It applies for consultant as well as for contractor. However, these two actors have different ways to reach this goal. Consultancy companies competing for the project in order to lower the bid price limit the design process time and capacity, which means that there will be huge probability that project will be done in hurry, not well defined, with many omissions and errors. Contractors have their own methods to win the project and do business. First of all, contractors usually receive particular form of bid material which needs to be filled with prices for different works. This way it is easier for consultant/client compare proposals. However, in this case contractors are bidding only on

information provided in bidding material. Even though company may predict that there will be additional works done on site it most likely will be not included in bill of quantities submitted to the client. It is assumed that all contractors are bidding under the same conditions based on the information available in bidding material. Therefore, no additional costs are added to proposal in order not to give advantage to competitors and only unit price for extra work might be mentioned. What is more, contractors sometimes even lower the bid price to the level which does not give desired profit but ensures success in the competition. Due to "holes" in the project material contractors may abuse the situation and recoup the losses by sending claims to the client/consultant in construction phase and even make bigger profit than expected.

Based on the interviews it can be stated that there are several ways to receive reliable bid price. They are different by assignment of responsibilities for calculation of work to be done. First way is to deliver contractor detailed and well prepared documents about the project (Figure 69, B). Consultant takes responsibility for accuracy and quality of material provided to contractors. This method demands more time to spend on development of detailed design ready for estimation and preparation of well structures bidding material. This way, contractors would spend less time on project material analysis and would be able to provide more reliable bid price as the design would be more understandable and would have less errors. However, when project material includes all the details, contractors do not have opportunity to suggest more efficient design with lower bid price and better quality of the building. Even if the project is done following the budget it does not always give the best result on final product.

Therefore, second option is to make not very detailed design of the project and just specify requirements for different parts of the building (Figure 69, C). This way, contractors will be able to suggest their own best solutions and efficient techniques to do the project. In such bidding process competitors would bid not only on price but also on cheap and efficient solution to meet bidding requirements. Bid price in this case is much more reliable as contractor gets more familiar with the project. In this case responsibility of quality of material quantity calculation is transferred to contractor; therefore, price is more constant during construction phase as contractor will not send claims related with wrong quantities.

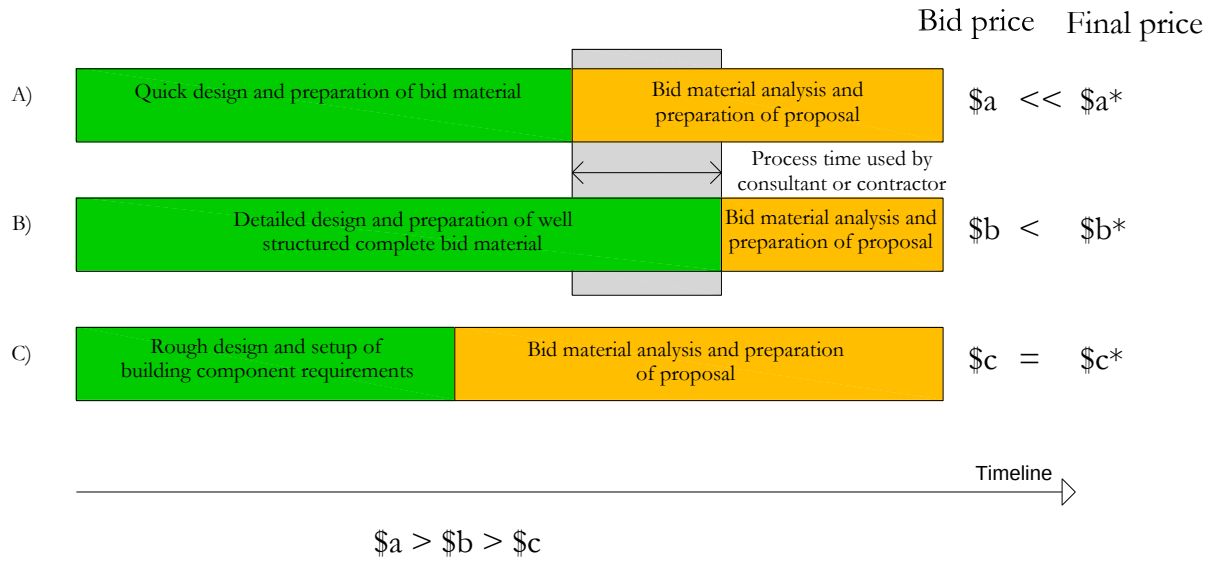


Figure 69 Comparison of different design-bid-build approaches in pre-construction phases

Preparation of convenient bidding material with correct quantities of works is time demanding process. It is important to describe the project and works in the way contractors get full and correct overview of the building. There are many different projects starting with simple ordinary housing buildings and ending up with complex sophisticated architectural design buildings. Therefore, bidding material content and form cannot follow the same template for all the projects. During the interviews it was revealed that it is not so important to follow particular form of bidding material. But documents must clearly describe what works need to be done, where and when it needs to be done, what are the quantities, what do these quantities represent (the way of measurement (Figure 19, Figure 70)) and what is the quality required. All this information should be composed in the way that it is easy to analyse specifications, quantities and drawings all together. It is not enough to estimate the works based only on bill of quantities. All information provided in each specification or bill of quantities have to be related to drawings where that information applies and vice versa.

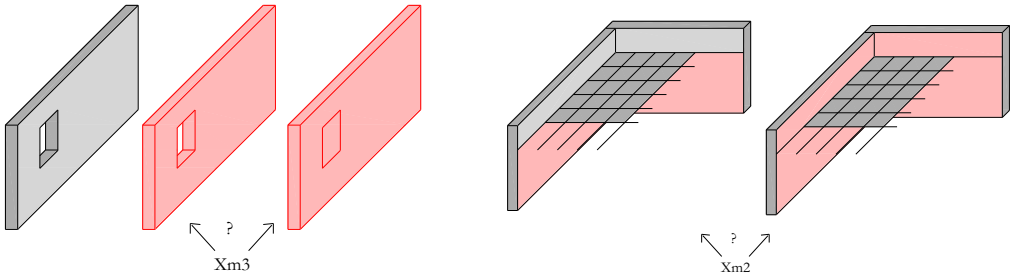


Figure 70 Different representation of quantities

There is an initiative to develop Information Delivery Manual which describes the set information which has to be included in bidding material. It also specifies what element properties have to be included in list of material quantity. Advantage of such Information Delivery Manual is that preparation of bidding material for all projects by all consultants would be carried out in same way by same rules and contractors would know exactly what to expect from bidding material so they can spend less effort on project analysis. But there is a risk that some project might be too complex to be well defined by bidding material following same IDM requirements. Therefore, IDM should provide different templates for different complexity projects.

Building Information Modelling technology becomes a topic widely discussed in construction industry. Many BIM software vendors actively advertise their products as an effective tool handling various processes within design and construction. The problem is that construction industry is very inert in terms of appliance of new technologies like BIM. It is resistant to changes. Any change for business scheme is a risk which companies are not willing to take. Moreover, experienced employees feel comfortable being experts within existing routine and do not feel the need to learn new working techniques. Nevertheless, success of international companies who have embraced BIM in their processes gives inspiration for Danish companies to start own initiatives applying BIM in their daily practice.

There are many issues to be considered before using BIM at bidding process. First of all, there is no single BIM tool which can handle all the processes within the design. There are different software applications which are used to solve different tasks during project development. To use BIM technology for preparation of bidding material there is a need to ensure that from very beginning of the project development – modelling process is carried out with concern (aim) to use model for quantity takeoff at

bidding stage. Models used for extraction of quantities need to be of sufficient detail level and quality. If in early stage only conceptual design is made, before bidding stage it has to be almost in as-build stage to reflect real quantities used in construction (Figure 71).

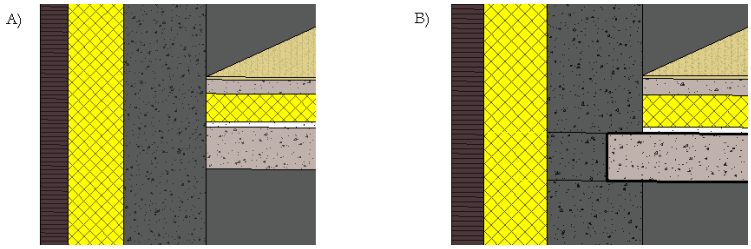


Figure 71 Example of slab, which has to be supported on walls, representation in BIM model: A) wrong representation of slab, software will calculate less material than it will be used during construction; B) correct representation of slab, exact material quantities will be obtained

BIM model made in the way as it is shown in Figure 71 A would be sufficient only for bidding process where bidding material contains rough design of the project with particular requirements for material and its quality (Figure 69 C). Contractor would have, in this case, to propose solution for connections between construction elements, develop more realistic model (Figure 71 B), extract precise material quantities and make realistic cost estimation.

Switching from paper based bidding process to BIM based one may not be an easy task. There are still many interoperability issues and problems which have to be investigated and solved. There are some companies who try to extend practice of using BIM technology. However, it is still not enough to switch to BIM based bidding process on big scale. Nevertheless, despite all those problems with interoperability, performed test on QTO following IDM requirements is Solibri Model Checker using IFC model from Tekla Structures has shown that it is possible to create reliable IFC based list of material quantities which can be used for estimation process. But it is just important to determine which software can exchange sufficient amount of information, to learn about the way particular software treats models and assign proper information to the elements already in modelling stage.

In today's situation, despite the fact that construction companies do not use all the advantages of BIM, including the model in bidding material package is still a very good supplement for contractors. It might not be used for QTO, but in many cases it would help them to understand building just exploring 3D models much better than just using the drawings alone. Another advantage of submitting 3D models to contractors is that they would get more familiar with using model previewers and step by step switch to full use of BIM with all its advantages.

4.3. Suggestions for improvements in bidding material preparation strategy

Each more complex task requires a good strategy in order to achieve desirable results. The same also applies to bidding process the success of which is evaluated by accuracy of bid price comparing to final project price. Bidding process is mainly based on communication between consultant and contractor through set of documents. Therefore, the main objective of bidding process strategy is obtainment of well defined project material which enables competing contractors precisely estimate the project.

Interviews with professionals form construction industry participating in bidding processes have revealed that there are some areas where improvements in preparation of bidding material can be made. Therefore, existing problems were highlighted and suggestions for better preparation of bidding material are presented.

Problems

1. Different way of measurements and calculation of material quantities by consultant and contractor
2. Wrong calculation of material quantities: quantities do not represent the works to be done
3. Poor connection between bidding documents: descriptions, list of quantities and drawings
4. Interoperability issue using BIM tools
5. Too low determination of companies to implement BIM in practise

Suggestions

It is important for design company to understand, that contractor participating in tendering process is bidding only on works mentioned in bidding material. Therefore, bid material should be prepared in the way that it gives contractor a good understanding of the project. Consultants are representatives of the client and they have to make sure that client is satisfied with the final product and the budget. This requires putting effort not only in doing the good design of the building but also it requires some effort to prepare the project for bidding stage.

These are the suggestions for improvement of bidding material preparation strategy which could help contractors provide more reliable bidding price:

1. Consultant usually asks contractors evaluate project by giving the price for quantities of different building elements and materials. The price per material/element unit may vary due to different factors like material quality or element complexity. Therefore, all this information has to be provided in bidding material so contractors know what are they bidding on:
    - Material/element description: quality, characteristics, "sandwich recipe"
    - Measurement rules: it has to be described how elements are measured, if the quantity of deck, for example, includes both slabs and casting or these are calculated separately (Figure 13), if quantity of materials to cover the roof is based on roof area or exact quantities are calculated (Figure 72) if the holes in element are included in calculated quantities or not (Figure 70, Figure 73), it has also to be decided which unit would represent the material quantity the best (m, m^2, m^3 or pcs etc.)
    - Special conditions have to be specified as well if there are any.

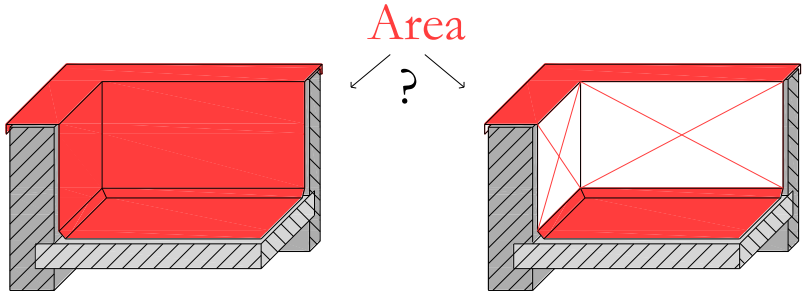


Figure 72 Definition of quantities for roof finishes

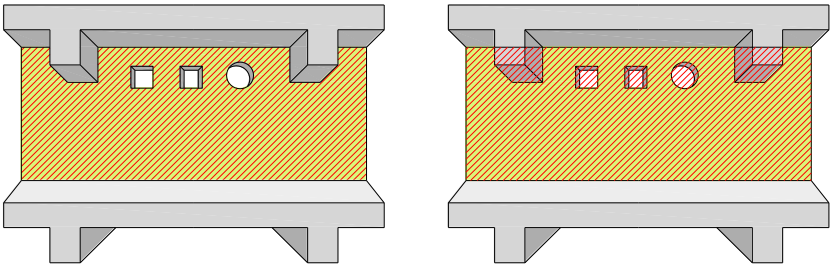


Figure 73 Different ways to measure quantity of wall: left – excluding holes and cuts; right – including cuts and holes

2. Methodology to obtain needed quantities has to be developed. This includes the need to explore 3D modelling software capabilities to extract desired quantities automatically and to decide which calculations have to be performed manually. Also methodology for modelling process has to be established which would describe the way building elements have to be modelled, what information building model and its elements have to contain (terminology which is suitable for bidding, element location assignment etc.) which would be useful for quantity takeoff process
3. The purpose of material quantity list, drawings and descriptions in bidding process is to introduce the project to contractors, to make sure that there is enough information about the project to make reliable estimate. However, contractors often find it difficult analyse these documents all together to get a picture of the project. It is difficult to relate data from quantity list for example with drawings and estimators have to put a lot of effort in order to "solve the puzzle". It becomes even more confusing if there is a mistake in one if the document. In many cases it involves lots of assumptions which makes bid price less reliable. Therefore, bidding material has to help contractor to get familiar with a project through consistent and well-structured bid material. These are the suggestions which would make bidding material more organic and suitable for project analysis:
    - Development of location based list of quantities, where materials are grouped by the location like floors, different activity zones or parts of the building (Figure 18)
    - Another useful solution for this issue is references. They could be used in list of quantities and refer quantities to particular drawings where they are located. It helps estimator to evaluate all issues related with element complexity and easily check the quantities
4. Companies should more actively look for possibilities to use BIM as a basis for bidding process. It is known that there are many problems with interoperability, but those problems have to be identified and addressed to software developers. There have to be close collaboration with software developers who are interested to provide reliable solutions and make business of it. At first, tests could be carried out beside ongoing project, problems inspected and solution found. At the time when it is discovered that BIM does not bring major risks for the quality of the processes it can be applied in practice.
5. Reliability of bid price depends a lot on bidding material quality production of which might demand lots of effort from consultant. In case consultant is bidding on the project he may not afford that. Therefore, it is worth to consider other bidding models between consultant and

contractor which enables contractor learn about the project and bid on it without significant effort for consultant to prepare bidding material. Knowing that contractors are interested in understanding the building as well as possible it is worth to consider involving them at early design phase where they get familiar with a project and even can propose efficient solutions based on construction practise.

It might seem that there is a lot of work for consultants to do before bidding process. However, they would benefit from that as well. First of all, it gives better and more reliable bidding process. Second, the process would give better opportunity to identify mistakes if there are any. Third, it would be easier for consultant to analyse proposals and see how prices are distributed throughout the project. Fourth, prepared material can be used for construction phase when monitoring construction processes.

BIM implementation barriers and promotion

Lately development of information technologies has boosted a lot. It penetrates almost all fields of people's life. It is also expected that IT will not bypass construction industry as well. It is almost commonly agreed that BIM technology is a future of the building industry. However, there are many factors which slow down development process in this direction.

First of all, many companies are fully satisfied with existing practice and are not willing to risk implementing technology especially when it is known that there are many issues to be solved within BIM. Moreover, there are not enough successful cases of BIM implementation. Big changes in the processes usually cause decrease of initial productivity. Implementation of BIM technology is expensive because of need of training and software. There are many actors involved in project development process and not everyone might have necessary skills or willingness to develop models of required quality. It makes it difficult to establish legal background for responsibility assignment and risks. There is too much different software available in the market; it is difficult to choose the software which would be compatible with software used by all the partners.

There are different ideas how BIM can be implemented in practice. It depends on many factors like scope of activities or structure of the company. It is not enough just to buy the software. Before making any big decisions on implementing BIM serious analysis has to be performed about how company can benefit from technology the most. Construction industry is quite inert applying new technologies; people are satisfied with existing practices even though there is a potential to do things more efficient. For this reason software developers should be more active advertising BIM tools and presenting new possibilities and advantages of BIM. Educational institutions should also more contribute making BIM more popular. More courses about the BIM have to be involved in study programmes and software developers should support universities with the software and provide consultancy service.

There is also very good Danish government Digital Construction initiative which requires that state projects of particular budget have to be developed using BIM technology (10). Bidding process in such projects is also BIM based. So designers/consultancy is forced to develop high quality models which would enable contractors to extract needed information from the models. This way, successful practices can be developed which would serve as an example and inspiration for old-fashioned companies.

5. Conclusion

The aim of this Master Thesis was to investigate existing practise of building material quantity list preparation process for bidding stage between Danish consultancy and construction companies and to identify weaknesses in bidding process which influences reliability of bidding price. Investigation process was based on interviews conducted with project managers and estimators who are involved in bidding process. Building Information Modelling role in the process was in focus of the thesis therefore questions regarding this technology were emphasized during the interviews.

Interviews have revealed that almost every construction project more or less goes over budget. There are several reasons for that. First of all, final project price, comparing to bid price, might increase due to changes applied by client during construction phase. Second, mistakes made during design phase are quite expensive when building is already in construction process. And third source of project price increase is misunderstanding in communication between consultant and contractor in bidding stage. Changes applied by the client in construction phase are not of such concern as client is paying for these modifications. However, other two problems have to be solved.

It appears that mistakes in the project and low bidding material quality are result of insufficient amount of time available for consultancy to do the design and prepare project for bidding process. This is due huge competition between consultancy companies who are forced to shorten the time for design process in order to minimise the price for their service and win the project. List of material quantity very often lacks of sufficient information to make reliable estimation or available information is differently interpreted by consultant and contractor. Due to "holes" in the project material contractors may abuse the situation and recoup the losses by sending claims to the client/consultant in construction phase and even make bigger profit than expected.

As a solution for existing problems two way outs from the situation are suggested. First one is related with change of bidding process model and second is addressed to the content of bidding material.

It is worth to consider other than Design-Bid-Build business models which would make contractors more familiar with building project and which would enabled them providing more reliable price before construction takes place. It can be done by simply involving contractors to collaborate already in design phase. Another option changing existing bidding practise is to transfer responsibility for detailed design and quantity takeoff to contractor. It means that consultant would make rough design of the project and prepare set of building requirements and contractors would have to provide detailed design and price for quantities calculated by themselves. This way contractor would not send claims for wrong material quantities as in such model it becomes his own responsibility and project price is most likely remain constant along whole construction process.

Second way out to be considered is finding efficient methods in preparation of bidding material. First of all, proper/right information for bidding documentation have to be determined in order to obtain reliable bidding price of the project. It has to be done in collaboration of both construction and consultancy companies. When required information is determined there is a need to find effective way for production and gathering of this information. BIM technology definitely has to be a part of this process. Examined Tekla Structures software is a very good example of BIM tool which can support this process. It allows assignment of lots of different information to the elements in the model which can be extracted with few

clicks of the mouse button. There is just a need to create high quality models with required information assigned to the elements and make report templates with particular parameters needed for QTO.

In this thesis BIM based bidding process was also considered. From conducted interviews it can be concluded that construction industry is still not ready for such huge changes in bidding process. Tests performed on interoperability have shown that some BIM software has difficulties in converting to or reading from IFC file format and contractors reasonably do not fully trust this technology. However, other test has shown that it is possible to extract quantities from Tekla Structures model in Solibri Model Checker at least following IDM requirements for QTO for bidding process. It means that it is possible to use BIM in bidding process. But first of all, it is important to determine which software can exchange sufficient amount of information. Second, it requires deep knowledge about the way particular software treats the models. Third, already in modelling stage proper information have to be assigned to models which would enable to prepare well structured and consistent list of material quantities.

All in all, there is a room for improvements in construction bidding process. BIM has a huge potential in construction industry. Companies just have to be more determined to explore all the advantages of this technology and step into the modern future.

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APPENDIXES

Appendix A Information Delivery Manual for QTO in design

Note: - This is not complete version of IDM; it is still in development stage

- This document has been translated from Danish language using Google Translator

- Document in Danish is provided in the end of this appendix

Instructions for the extraction of quantities of supply

This guide describes the purpose, procedure and specification for how the amount of withdrawals can be made for the provision of advice to the contractor by profession and main contracts.

It is a condition that developed ICT sales contracts in which the client establishes requirements for the choice of volumes, including volume of direct extraction from the design used in building models.

Purpose

The purpose of this guide is to form an overall estimate of the quantities that can be usefully extracted from each discipline models and what that should be entered manually. The guide will give a precise definition of the processes which should occur with volume extraction.

The purpose of the volume of withdrawals is as follows:

• The contractor must prepare a quote for the concrete construction project, based on the amount of charge from the adviser

• Ensure that the risk of error for volumes is minimized.

• Provide overview of process and responsibility in connection with the tender amount

Reading guide

Delivery Overview

Delivery is between the consulting party for each offer computes the tendering contractors.

The following are the roles and supplies this guide covers briefly described:

Roles

Client

• The developer describes the need for ICT requirements through ICT performance specifications of the ICT arrangement. The developer has overall responsibility for tendering and tender on the construction issue.

• The client will review the tender documents and evaluate the offer from the bidding contractors.

Counsellor

• Specialist teacher for individual disciplines have overall responsibility for the subjects and hence also for all the processes that must occur in connection with quantitative extraction.

• Specialist teacher for individual disciplines responsible for the preparation of building and descriptions that define the requirements for the individual building. The descriptions include all technical information regarding the used building parts, and the description must be related discipline model, drawings and offer list.

• CAD course coordinator is responsible for developing discipline model of the individual subjects. This person has thus also responsible for the drawings. The volume of extracts from discipline model has CAD course coordinator responsible for model building are done so that the amount of withdrawals made in accordance with the applied and intended measurement rules for this course.

Discipline model developed according to the design schedule, starting with the given conditions. Discipline model elements will be named in order to be prepared volume extraction. When discipline model reaches the desired level, will be prepared drawings and extracted the quantities that apply to offers list. Addition will provide a precondition memorandum describing the measurement rules which were used to calculate quantities.Bips gauging rules when needed.

CAD course coordinator will perform mængdeudtrækket to tender lists. Extraction will be divided in relation to subjects and building. The focus will be on how producers need.Specialist teacher is responsible for being done QA on the total material.

Construction 1 and 2

• Tilbudsberegneren responsible for pricing and pricing.

Tilbudsberegneren divides the tender documents in the individual subjects, and distribute contract documents to subcontractors / suppliers under division into subjects. The subcontractors / suppliers provide the basis of the material each price. Tilbudsberegneren will collect all the price data from subcontractors / suppliers and assemble the material for a single tender list (volume) with complete price and compose a note prerequisite for all pricing.

By agreement with the developer reviewed and validated volume calculations based on the submitted Tender Project, eg on the basis of building part descriptions and drawings (2D DWG / PDF).

Deliveries / Transactions

Tender

• Building Second Descriptions; ICT output specification section 4.3 paragraph. Second

• Drawings (2D DWG / PDF); ICT output specification section 3.4.1 paragraph. First (Drawing Production)

• Offer list (quantities); ICT output specification section 4.4 paragraph. First

• Assumption Memo (Surveying Rules eg bips F111 and F111a)); ICT output specification section 4.4 paragraph. First (Offer Lists by volume)

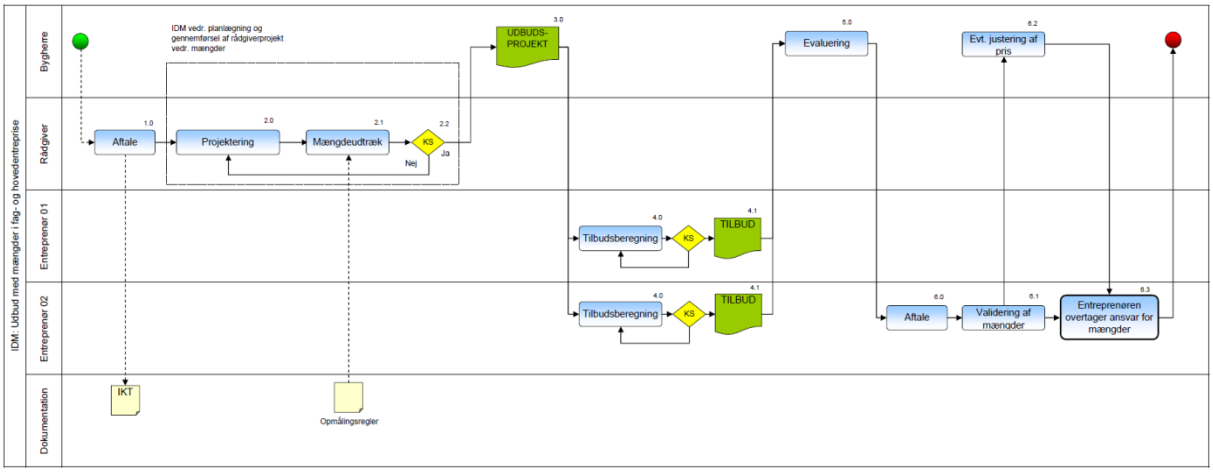
• 3D building model (3D DWG / IFC or the original model), ICT output specification section 4.3 paragraph. 4th

Offers

• Offer list (volumes) completed by price

• Prerequisite Memo according to pricing.

Process description



Specification of processes	Description
[1.0] Agreement	An agreement between client and consultant team. Be drawn up an ICT sales contracts for the service.
[2.0] Planning	Consultant team projects based on ICT Agreement and specific IDM (?) Project.
[2.1] Amount of Extract	Based on the measurement rules out volume extractions from discipline models.
[2.2] Quality Assurance	Performed quality assurance on the overall tender
[3.0] Supply Project	Advisor Team delivers supply project to the client. The project includes following: Building Second Descriptions, drawings / models offer list with quantities, the measurement rules, and documentation of assumptions.
[4.0 and 4.1] Calculation Offers and Deals	The client sends the project to supply to a number of contractors. Entrepreneurs draw offer on the basis of supply project from the consultant. NB: There is an offer on the basis of volumes from the team's advisor supply project.
[5.0] Evaluation	The developer shall evaluate the bids.
[6.0] Appointment	An agreement with the winning contractor.
[6.1] Validation of volumes	The winning contractor examines and validates the volume calculations.
[6.2] Possibly. adjustment / negotiation of new price	If found discrepancy between volume calculation, which was the basis for the offer and contractor validation, an adjustment / negotiation of new price.
[6.3] The contractor assumes responsibility for the volume calculation	Contractor takes over now the full responsibility for the quantities which underlie the agreement with the developer.

Specification of data objects

For the data from the objects can be used correctly in the volume list, it is important to the overall structure is defined. This should do that when we know the correct information will be coupling between objects and offers lists be Hook. If there are things which are not in the building you go up in levels.

Level 1: Subjects

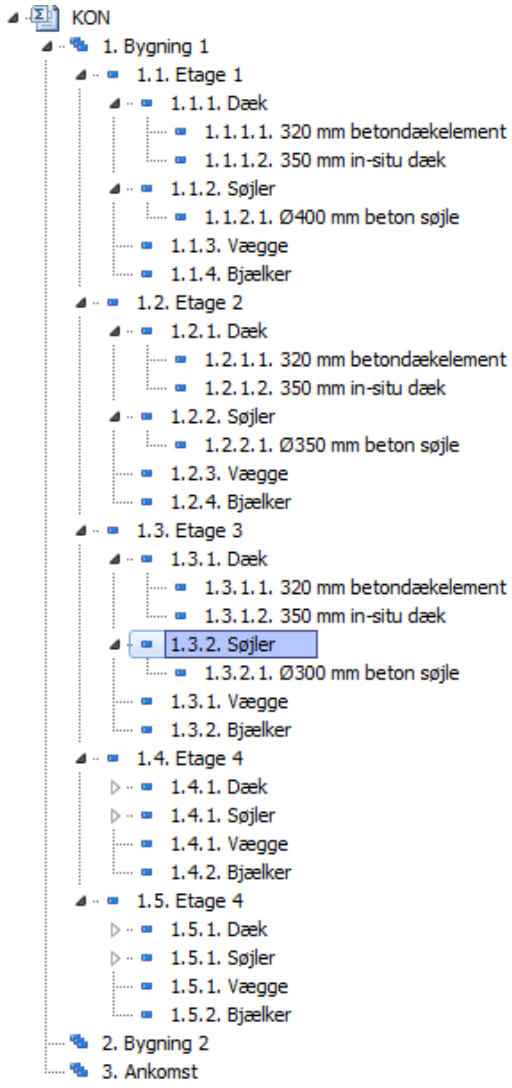
Level 2: Building, Block, Area, Section

Level 3: Floors, blocks

Level 4: Building Second Type

Level 5 - and how far one goes down: Contents of building part

See example:


KON
1. Bygning 1
1.1. Etage 1
1.1.1. Dæk
1.1.1.1. 320 mm betondækelement
1.1.1.2. 350 mm in-situ dæk
1.1.2. Søjler
1.1.2.1. Ø400 mm beton søjle
1.1.3. Vægge
1.1.4. Bjælker
1.2. Etage 2
1.2.1. Dæk
1.2.1.1. 320 mm betondækelement
1.2.1.2. 350 mm in-situ dæk
1.2.2. Søjler
1.2.2.1. Ø350 mm beton søjle
1.2.3. Vægge
1.2.4. Bjælker
1.3. Etage 3
1.3.1. Dæk
1.3.1.1. 320 mm betondækelement
1.3.1.2. 350 mm in-situ dæk
1.3.2. Søjler
1.3.2.1. Ø300 mm beton søjle
1.3.1. Vægge
1.3.2. Bjælker
1.4. Etage 4
1.4.1. Dæk
1.4.1. Søjler
1.4.1. Vægge
1.4.2. Bjælker
1.5. Etage 4
1.5.1. Dæk
1.5.1. Søjler
1.5.1. Vægge
1.5.2. Bjælker
2. Bygning 2
3. Ankomst

Specification of data objects				
Area	**Building part**	**Quantity**	**Description of amount**	**Manual or on the basis of BIM**
Tender				
Requirements for objects, Architectural Model				
Requirements for objects Structures	Walls	Type: (VE, V)	What type is involved, in-situ, prefabricated or sandwiches etc.	
		Height: (h)	Which height has the given wall	
		Choke: (UDS)	Number of recesses	
		Classification:	DBK or other classification.	
		Tot length: (LBM)	It is the total length of the given price.	
		Description:	Object must describe the construction and description	
	Columns	Type: (SE, S)	What type is involved, in-situ, prefabricated or steel with or without console, etc.	
		Height: (h)	Which height has the given column	
		Dimension: (D)	Ø300 or 300x300 etc.	
		Classification:	DBK or other classification.	
		Number: (Stk)	The number of columns as given price.	
		Description:	Object must describe the construction and description	
	Beams	Type: (BE, SB)	What type is involved, in-situ, prefabricated or steel with or without console, etc.	

		Length: (L)	Which length has the given beam	
		Dimension: (D)	Which dimension has special bar or square.	
		Choke: (UDS)	In the case of special holes or system holes.	
		Classification:	DBK or other classification.	
		Number: (Stk)	The number of type beams as given price.	
		Description:	Object must describe the construction and description	
	Foundations	Type: (PF, SF, PLF)	What type is the case of point foundation (PF), strip foundation (SF), plate foundation (PF), etc.	
		Dimension:(D)	This is the height * width * depth	
		Classification:	DBK or other classification.	
		Number: (Stk)	The PF is the number of foundations that give appreciated.	
		Tot length:	When SF is running meter as given price.	
		Area:	The PF is the m2 as given price.	
		Description:	Object must describe the construction and description	
	Pickets	Type: (P)	What type of pole is talking about.	
		Dimension: (D)	The pile cross-sectional dimension	
		Classification:	DBK or other classification.	
		Tot length:	Pile total length incl. if necessary. of length	

	Tyre constructio n	Type: (DE, TE, D)	What type these are: Ground, prefabricated hollow core concrete, in-situ cast concrete decks, roof decks, etc. element.	
		Classification:	DBK or other classification.	
		Area:	Amount calculated as m2. The syllabus covers both gross and net amount, ie. w / o holes and recesses.	
		Choke: (UDS)	In the case of special holes, system holes, drilled holes etc..	
		Description:	The object must be described in the building and description	
	Staircase	Type: (TRE, TR)	What type is involved	
		Classification:	DBK or other classification.	
		Quantity:	The number specified by type and extent	
Requirements for objects, installations	Geometric object			
Offers				

Specification of coordination points

Tender	There must be consistency between the project drawings, discipline models, building descriptions, quotations list and memo condition. Applied classification must be continuous and shall be traceable to both discipline models, offers lists and building bitter marriages. The system used for building tender lists must be consistent with other project tender documents.

Vejledning for udtræk af mængder ved udbud.

Denne vejledning beskriver formål, procedure og specifikation for hvordan mængdeudtræk kan udføres i forbindelse med udbud fra rådgiver til entreprenør, ved fag- og hovedentrepriser.

Det er en forudsætning, at der er udarbejdet et IKT-aftalekompleks hvori bygherre fastsætter krav om anvendelse af udbud med mængder, herunder direkte mængdeudtræk fra de i projekteringen anvendte bygningsmodeller.

Formål

Formålet med vejledningen er, at danne et overordnet overblik over hvilke mængder, som med fordel kan udtrækkes fra de enkelte fagmodeller, samt hvilke som bør indtastes manuelt. Vejledningen vil give en præcis definition af hvilke processer og som bør forekomme i forbindelse med mængdeudtræk.

Formålet med mængdeudtræk er følgende:

- Entreprenøren skal udarbejde et tilbud på det konkrete byggeprojekt, med afsæt i mængdeberegning fra rådgiveren
- Sørge for at risikoen for fejl vedr. mængder minimeres.
- Give overblik over proces og ansvar i forbindelse med udbud med mængder

Læsevejledning

Leveranceoversigt

Leverancen foregår mellem den rådgivende part til den enkelte tilbudsberegner for de tilbudsgivende entreprenører.

I det følgende er de roller og leverancer denne vejledning omhandler kort beskrevet:

Roller
Bygherre
- Bygherren beskriver behovet for IKT-krav via IKT- ydelsesspecifikationer i IKT-aftalekomplekset. Bygherren har det overordnede ansvar for udbud og tilbud på byggesagen.
- Bygherren vil granske udbudsmaterialet samt evaluere tilbuddet fra de bydende entreprenører.

Rådgiver
- Fagledelsen for de enkelte fagdiscipliner har der overordnede ansvar for fagene og dermed også for alle de processer, som skal forekommer i forbindelse med mængdeudtræk.
- Fagledelsen for de enkelte fagdiscipliner står for udarbejdelsen af bygningsdelsbeskrivelserne, som definerer kravene til de enkelte bygningsdele. Beskrivelserne indeholder alle tekniske informationer angående de anvendte bygningsdele, og beskrivelsen skal hænge sammen med fagmodellen, tegninger og tilbudslisten.
- CAD-fagkoordinatoren er ansvarlig for udarbejdelse af fagmodellen på det enkelte fag. Denne person har dermed også ansvaret for tegninger. Ved mængdeudtræk fra fagmodel har CAD-fagkoordinatoren ansvar for at modelopbygningen er udført således at mængdeudtræk sker i overensstemmelse med de anvendte og forudsatte opmålingsregler for dette fag.

Fagmodellen udarbejdes iht. projekteringstidsplanen, med udgangspunkt i de givne forudsætninger. Fagmodellens elementer vil blive navngivet så der kan udarbejdes mængdeudtræk. Når fagmodellen når det ønskede niveau, vil der blive udarbejdet tegninger og udtrukket de mængder som er gældende for

tilbudslisten. Dertil vil fremkomme et forudsætningsnotat som beskriver de opmålingsregler som er blevet benyttet til opgørelse af mængder. Bips opmålingsregler kan benyttes efter behov.

CAD-fagkoordinatoren vil udføre mængdeudtrækket til tilbudslisterne. Udtrækket vil blive opdelt i ift. fag og bygningsdele. Der vil være fokus på hvad producenterne har behov for. Fagledelsen er ansvarlig for at der bliver udført KS på det samlede materiale.

Entreprenør 1 og 2

- Tilbudsberegneren har ansvaret for prisberegning og prissætning.

Tilbudsberegneren opdeler udbudsmaterialet i de enkelte fag, og fordeler udbudsmaterialet til underentreprenører/leverandører i henhold til opdelingen i fag. Underentreprenører/leverandører giver på baggrund af materialet hver sin pris. Tilbudsberegneren vil indsamle alle prisdata fra underentreprenører/leverandører og sammensætte materialet til en samlet tilbudsliste (mængder) med udfyldt pris og sammensætte et forudsætningsnotat for hele prissætningen.

Ved aftale med bygherren gennemgås og valideres mængdeberegningerne på baggrund af det fremsendte Udbudsprojekt, fx på basis af bygningsdelsbeskrivelser og tegninger (2D DWG/PDF).

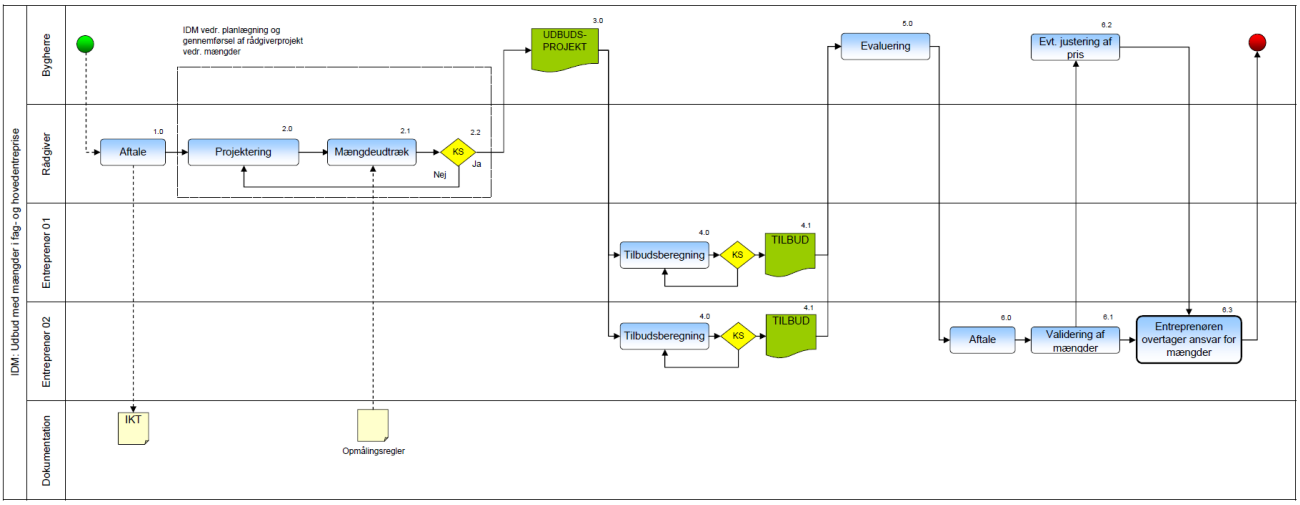
Leverancer / Transaktioner
Udbud

- Bygningsdelsbeskrivelser; IKT-ydelsesspecifikation punkt 4.3 stk. 2.
- Tegninger (2D DWG/PDF); IKT-ydelsesspecifikation punkt 3.4.1 stk. 1. (Tegningsproduktion)
- Tilbudslisten (mængder); IKT-ydelsesspecifikation punkt 4.4 stk. 1.
- Forudsætningsnotat (Opmålingsregler fx bips F111 og F111a)); IKT-ydelsesspecifikation punkt 4.4 stk. 1. (Tilbudslister med mængder)
- 3D bygningsmodel (3D-DWG/ IFC eller original model), IKT-ydelsesspecifikation punkt 4.3 stk. 4.

Tilbud

- Tilbudslisten (mængder) med udfyldt pris
- Forudsætningsnotat iht. prissætningen.

Procesbeskrivelse



Specifikation af processer	**Beskrivelse**
[1.0] Aftale	Der indgås aftale mellem bygherre og rådgiverteam. Der udfærdiges et IKT aftalekompleks for ydelsen.
[2.0] Projektering	Rådgiverteamet projekterer med udgangspunkt i IKT aftalen og specifik IDM(?) projekt.
[2.1] Mængdeudtræk	Med udgangspunkt i anvendte opmålingsregler udføres mængdeudtræk fra fagmodeller.
[2.2] Kvalitetssikring	Der udføres kvalitetssikring på det samlede udbudsmateriale
[3.0] Udbudsprojekt	Rådgiverteamet afleverer udbudsprojekt til bygherren. Projektet indeholder bl.a. følgende: Bygningsdelsbeskrivelser, tegninger/modeller, tilbudsliste med mængder, anvendte opmålingsregler, samt dokumentation for anvendte forudsætninger.
[4.0 og 4.1] Tilbudsberegning og tilbud	Bygherren sender projektet i udbud til x antal entreprenører. Entreprenørerne udfærdiger tilbud på baggrund af udbudsprojekt fra rådgiveren. NB: Der gives tilbud på baggrund af mængderne fra rådgiverteamets udbudsprojekt.
[5.0] Evaluering	Bygherren foretager en evaluering af de indkomne tilbud.
[6.0] Aftale	Der indgås aftale med den vindende entreprenør.

[6.1] Validering af mængder	Den vindende entreprenør gennemgår og validerer mængdeberegningerne.
[6.2] Evt. justering/forhandling af ny pris	Såfremt findes uoverensstemmelse mellem mængdeberegningen, som lå til grund for tilbudet og entreprenørens validering heraf, foretages en justering/forhandling af ny pris.
[6.3] Entreprenøren overtager ansvaret for mængdeberegningen	Entreprenøren overtager nu det fulde ansvar for de mængder som ligger til grund for aftalen med bygherren.

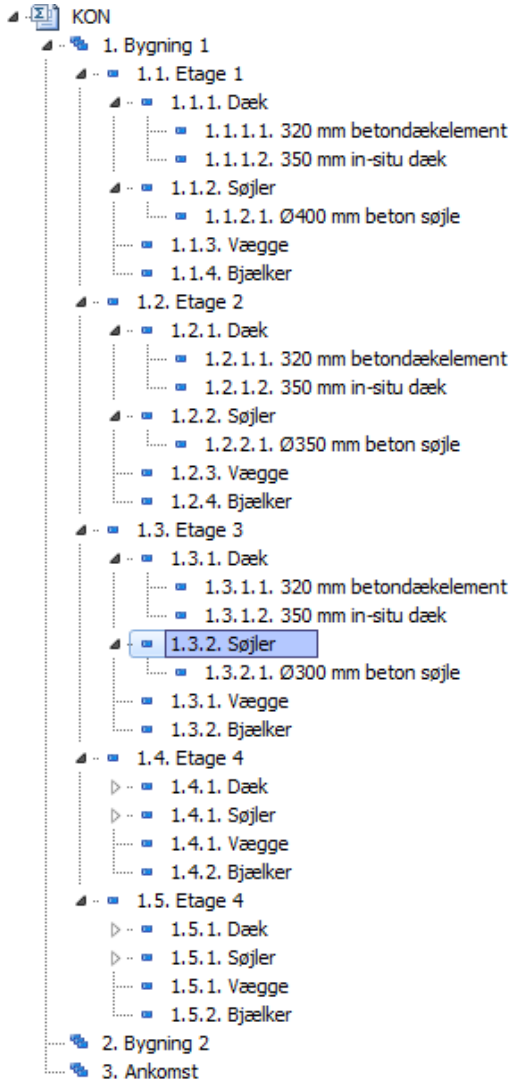
Specifikation af dataobjekter

For at dataene fra objekterne kan benyttes korrekt i mængdelisten er det vigtig at den overordnede struktur er defineret. Dette skal gøre at når der kendes de korrekte informationer vil koblingen mellem objekter og tilbudslister være sammenkoblige. Hvis der er ting som ikke er med i bygningen går man op i niveauer.

Niveau 1: Fag

- **Niveau 2**: Bygning, Blok, Område, Afsnit
  - **Niveau 3**: Etager, blokke
    - **Niveau 4**: Bygningsdelstype
      - **Niveau 5** – samt hvor langt man går ned: Indhold af bygningsdel

Se eksempel:


KON
1. Bygning 1
1.1. Etage 1
1.1.1. Dæk
1.1.1.1. 320 mm betondækelement
1.1.1.2. 350 mm in-situ dæk
1.1.2. Søjler
1.1.2.1. Ø400 mm beton søjle
1.1.3. Vægge
1.1.4. Bjælker
1.2. Etage 2
1.2.1. Dæk
1.2.1.1. 320 mm betondækelement
1.2.1.2. 350 mm in-situ dæk
1.2.2. Søjler
1.2.2.1. Ø350 mm beton søjle
1.2.3. Vægge
1.2.4. Bjælker
1.3. Etage 3
1.3.1. Dæk
1.3.1.1. 320 mm betondækelement
1.3.1.2. 350 mm in-situ dæk
1.3.2. Søjler
1.3.2.1. Ø300 mm beton søjle
1.3.1. Vægge
1.3.2. Bjælker
1.4. Etage 4
1.4.1. Dæk
1.4.1. Søjler
1.4.1. Vægge
1.4.2. Bjælker
1.5. Etage 4
1.5.1. Dæk
1.5.1. Søjler
1.5.1. Vægge
1.5.2. Bjælker
2. Bygning 2
3. Ankomst

Specifikation af dataobjekter				
Område	**Bygnings-del**	**Mængde**	**Beskrivelse af mængde**	**Manuelt eller på baggrund af BIM**
Udbud				
Krav til objekter, Arkitektmodel				
Krav til objekter, Konstruktioner	Vægge	Type: (VE,V)	Hvilken type er der tale om, In-situ, præfabrikeret eller sandwich osv.	
		Højde: (h)	Hvilken højde har den givne væg	
		Udsparing:(Uds)	Antal af udsparinger	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Tot længde:(Lbm)	Det er den totale længde i som der gives pris på.	
		Beskrivelse:	Objektet skal beskrive i bygningsdelsbeskrivelsen	
	Søjler	Type: (SE,S)	Hvilken type er der tale om, In-situ, præfabrikeret eller stål med eller uden konsol osv.	
		Højde: (h)	Hvilken højde har den givne søjle	
		Dimension:(D)	Ø300 eller 300x300 osv	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Antal:(Stk)	Det er antal søjler som der gives pris på.	
		Beskrivelse:	Objektet skal beskrive i bygningsdelsbeskrivelsen	
	Bjælker	Type: (BE,SB)	Hvilken type er der tale om, In-situ, præfabrikeret eller stål med eller uden konsol osv.	

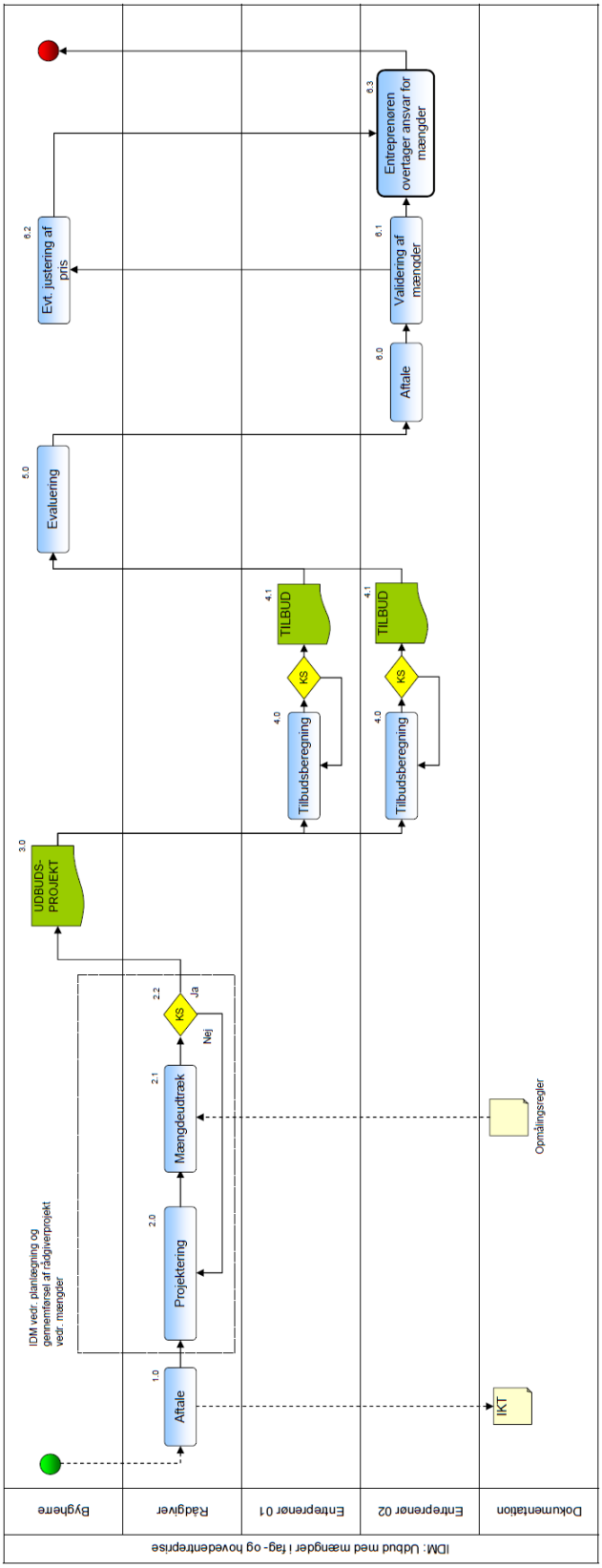
		Længde: (L)	Hvilken længde har den givne bjælke	
		Dimension:(D)	Hvilken dimension har bjælken speciel eller kvadratisk.	
		Udsparing:(Uds)	Er der tale om specielle huller eller system huller.	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Antal:(Stk)	Det er antal af type bjælker som der gives pris på.	
		Beskrivelse:	Objektet skal beskrive i bygningsdelsbeskrivelsen	
	Fundamenter	Type: (PF,SF,PLF)	Hvilken type er der tale om punktfundament (PF), stribefundament (SF), pladefundament (PF) osv.	
		Dimension:(D)	Der er tale om højde*bredde*dybde	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Antal:(Stk)	Ved PF er det antal fundamenter som der gives pris på.	
		Tot længde:	Ved SF er det lbm som der gives pris på.	
		Areal:	Ved PF er det m2 som der gives pris på.	
		Beskrivelse:	Objektet skal beskrive i bygnings-delsbeskrivelsen	
	Pæle	Type: (P)	Hvilken type pæl er der tale om.	
		Dimension:(D)	Pælens tværsnitsdimension	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Tot længde:	Pælens totale længde inkl. evt. overlængde	

	Dækkonstruktion	Type: (DE, TE, D)	Hvilken type er der tale om: Terrændæk, præfabrikeret betonhulda	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Areal:	Mængde opgøres som m2. Der opgives både brutto- og nettomængde, dvs. m/u huller og udsparinger.	
		Udsparing: (Uds)	Er der tale om specielhuller, systemhuller, borede huller mv.	
		Beskrivelse:	Objektet skal beskrives i bygningsdelsbeskrivelsen	
	Trappe	Type: (TRE, TR)	Hvilken type er der tale om	
		Klassifikation:	DBK eller anden form for klassifikation.	
		Antal:	Antallet specificeres fordelt på type og omfang	
Krav til objekter, Installationer	Geometrisk object			
Tilbud				

Specifikation af koordinationspunkter

Udbudsmateriale	Der skal være overensstemmelse mellem projektets tegninger, fagmodeller, bygningsdelebeskrivelser, tilbudsliste og forudsætningsnotat. Anvendt klassifikation skal være gennemgående og skal kunne genfindes i både fagmodeller, tilbudslister og bygningsdelebeskvielser. Det anvendte system for opbygning af tilbudslister skal stemme overens med projektets øvrige udbudsmateriale.

Bilag: Procesbeskrivelse i fuldt format



Appendix B Interview with Morten Darø Tranholm (Rambøll)

Date: 2011 10 04

Location: Rambøll Headquarters

Interviewed person: Morten Darø Tranholm, Project Director, Rambøll

Intervieweig person: Daniel Rogisnki, Master student in Civil Engineering, Technical University of Denmark

I know that you have made 3D building model in Tekla which you have used to calculate material quantities for bidding process. You had some issues with that. What were they?

Normally when you do measurements of the amounts as a contractor you just take a drawing and ruler and you measure things. So, the way we did it we looked for instance for deck element and when you look at the surface area of the deck elements you do not have the small casting along the edges. Therefore, the area will be slightly less and in fact it will be something like 5 to 10 % which is when you look at the prices quite a lot. So they have to do extra comparing to what they have measured. We probably should give them amounts but also a list how the amounts were calculated with Tekla so they could take that into consideration. It is just bidding contract did not include 3D model of Tekla. We just did it old fashion way.

So contractor received quantities but did not receive description how those quantities were calculated, is it right?

Yes. That was the problem. We did not describe how we calculated them. We gave them quantities but then during contracting phase they have to verify their quantities. And they found that their quantities were higher than ours. And that was for the deck only.

So what is the solution for that?

I think you should make memo saying that for instance columns are measured this way, and if it is a skew surface the average dimension is taken. Just to say that our quantities are calculated this way.

Also if you have decks for instance which are not rectangular you also need some rules how you calculate that. You could say also something about complexity of geometry based on your Tekla model. You could tell how many types of deck elements you have used. But in many cases the details about how you put your decks will change during construction phase. But you should have the list saying exactly how these measurements are done.

There are some documents that define those (measurements) on the overall basis but if it is not detailed enough...

There is a BIM software developer VICO which provides document describing what parameters different type elements include and how those parameters are calculated or measured.

As consultancy engineers we could measure things in all of kind ways that we want. But what would be really nice what does contractor says, how he like it to be done to give exact price.

But you are also interested in obtaining exact price as you represent matters of the Client.

Definitely. In the end we are making budgets, then we make bidding process and we get all the offers. And we want our budget to be close to their offers. The most important is that we do it the same way the contractor does it. Because then we can compare our budget with our old prices what we know from other bid.

I think it would be very nice if contractors have an opinion said: for walls we want the quantities be calculated exactly like this.

But I think there is a risk that you get almost an information overflow from these 3D models. Because as you see you can make all kind of quantities and you can make it very detailed but if they do not use it - it makes just distorted picture and you actually get the wrong files.

The perfect way would be if we hold industry to agree: this is the way it should be done. That would enable us to make the most accurate price both as consultant and as contractor.

What do you think about detail level of the project, how it is today?

Probably sometimes we lack some details. But when we have tendering process we should be able to pretty sure estimate the project.

Do you extract quantities from Tekla or you do it with other programs?

You can do it from Tekla.

The way we do it in Denmark is quite different than they do it in England. The way they do it is that they have specialist who do only calculation of the prices later on project also in consultancy.

And what we do here is that the guy making the project also makes the price. So we are not specialists in doing these prices.

Would you like to have same system like in England that you do the design and you have guy in the team who does quantity and price calculation?

I am not quite sure, because the guy who gets the project may not know whole details. I think I would like that fewer people made the prices. So where you have a very small department with few people who always are involved in pricing and quantity takeoff and who would support the people who actually do the project. But I think it is actually very important to have people who actually did the project. Many times there will be details which will be missed if it is just will be made by someone who just calculates quantities.

Using different software in the process may cause many problems with interoperability even using ifc format. Have you experienced any?

Ifc is not perfect format. Many programs have problems writing to ifc and reading it. On one project we had an incident when we made an ifc model from Tekla and sent it to the architects. They imported that in Revit Architecture. The problem was that all the foundations had shifted so that the top side and the bottom side had changed place. But the strangest thing was that I tried to import it to Revit Structures and it worked ok.

I think that before you want to use new software before you start modelling you have to do tests on all the parts you want to introduce. And every time you introduce a new type of element in the structure you need to know how it is exported. And I think you could actually do it and it would take just little time to do it. You cannot just go modelling and then see what happens.

What information do you receive before you start modelling process?

We receive just floor plans. What we do is that we do all the structural parts and send it to the architect where the architect does not do any of concrete or steel or anything. So if he wants to move the door or window he has to call me: please move it and send me an ifc.

Can you show what element properties are available in Tekla and if you can make reports in them directly from Tekla?

These are all properties you can get on slab. All those numbers you can extract to a table. Furthermore, we have "user fields" where we are able sort building elements. So I can define this slab as "1" in user field, which would represent first floor.

What about the layers in Tekla, does it have them?

No it does not. This is a manual way of creating floors by assigning elements to chosen "user field" coding.

What about the name of all elements? Do they follow some standard or you name it manually the way you need it?

You can name it according to your needs. We just give names which make sense not following particular standard.

Here in the model I can see beam which is of unordinary profile. How you define this beam in bill of quantities?

When we make quantities we say we have this type of beam which looks like this and this. And then how many meters are of this beam.

In many cases we cannot decide what kind of beam we have to use because there are different suppliers of beams which look different. So we just draw one kind of beam and say that the beam has to be of these geometrical properties and it has to sustain particular load. But exactly what beam you want to use you can choose whatever you like.

Another thing is that in state projects you have to follow EU rules to prepare bidding material. This means that you cannot be too specific describing elements so you do not give advantage to particular company producing elements.

So contractor have to perform detailed design calculations for proposed elements?

Even though we have done structure calculations for this building, the detailed calculations have been done by the manufacturer. It is pretty used model in Denmark.

I can see that in this model are some clashes. Why did not you fix them?

At some point we just stopped using this model. What we have been using it for is overall drawings, plain drawings of the floors, not the detailed drawings. Detailed drawings are just been made in AutoCAD.

Do you give references to drawings in bill of quantities?

We do say basically just look at the drawing.

What would be your suggestions to improve bidding process in terms of bidding material content?

I think that looking forward the most important thing is to make things run more digital. The nicest thing would be just to make a really good 3D model and send it to contractor and let him draw the quantities. That would be the best I guess.

Date: 2011 10 24

Location: Rambøll Headquarters

Interviewed person: Morten Darø Tranholm, Project Director, Rambøll

Intervieweig person: Daniel Rogisnki, Master student in Civil Engineering, Technical University of Denmark

Can you describe the process of preparation of bidding material?

What we do is that we have 3 parts of tender documents which are drawings, sometime 3D model, descriptions telling how to build, it is like a report which tells what should be a reinforcement in concrete, how elements should be painted, what should be fire protection and all the things that are not in the drawings but tell about the quality of the structure. As a supplement to that we have the overall description of the project which tells how all entrepreneurs will act.

Who is making those descriptions?

The people who do the calculation of construction do description.

When you are sending 3D model for bidding, what format it is?

It varies.

What is the purpose of sending 3D model?

Sometimes especially for installations what they get is 3D model which is kind of a sketch telling "you have to do this, and these are your geometrical limitations". Then they have to go and change the model using their products in their offer. I know that for some project we delivered Tekla model where it is

given concrete geometry and entrepreneur put all the reinforcement to the model. It is not many companies who can do it yet but things are going that way.

How often do you receive claims form contractors in construction phase for more material used than it was stated in bidding material quantity list?

I think it happens very often. There was the project when quantities were taken from our 3D model for bidding material were not the same as measured with a ruler from the drawings.

Often there are some adjustments also in the bidding process when we get claims from contractors.

How do you define what to include in the bidding material and what do you expect to receive from contractors?

Normally we make a list where we pined out different elements and then they need to put the prices on that. And also you should make a category "adjustments" where you can say if there will be more of reinforced concrete what would be the price for that. What we try to do is to try to include so much that it is possible to build the building.

Have you ever received any queries from contractors during the bidding stage about any information which required for better evaluation of the project and price?

What they get is usually enough to give a price. But often it tends to that if something is not 100% solved after we make a contract we talk about it and say how it is solved and in many cases their price is based on the cheapest solution which is often not enough.

During the bidding process they (contractors) you can ask questions. But is not often I would say that they ask everything they are in doubt of and then they just take assumptions.

What is usual level of detail of list of quantities, you do not list every screw used in the building?

It varies from project to project to project. I think in most cases for decks for instances we get square meters and what kind of slab it is. And then we have drawings to get more specific.

In deck construction there are gaps between slabs which have to be filled with concrete. Do you include quantities of concrete to fill those gaps?

No. What we normally do is that you have one price for casting the elements. You have one price for putting them (slabs) in place inclusive the small castings and reinforcement around.

What is a level of details of drawings included in bid material?

It is almost the same as used in construction phase. It has to be pretty close, because if you make details afterwards it will cost more money.

How quantity list is structured for bidding process? Is it sorted by location or element type?

It is usually sorted by element. But it depends on the size of the structure. Sometimes you could have a subdivision in beams at first level, second level and so on.

Why would you do that?

Most of the beams on first level might be the same, but on the next level they might be different. Or you may have beams on the ground and then you might have beams on the roof for instance.

What about the case when you have same beams on all levels, it might cost more to construct beam on 10th floor than on 1st one?

I would say it would cost the same as you use same crane. But if you have a really tall building we might do that (to make list of beam quantities for different levels).

What methods and techniques do you use for calculation and measurement of quantities?

If we have a Tekla model we try to extract as much as possible. Revit is also quite good.

So you do not use ruler any more?

Some people probably do on smaller projects.

Do you specify in bid material how those quantities are calculated?

I do not think so. We just give them quantities.

Are there any particular rules for calculation and measurement of building element quantities?

I think there is a try in making those rules for structures anyway, but they are not very specific. If you have not rectangular deck you will have a problem defining the length. It is not problem to say it in square meters but in length... And that would be a problem also for columns and beams for instance.

In case when you have to calculate wall area to be painted until suspended ceiling level, is it possible to extract these quantities from models or it gives surface area of whole wall?

I am pretty sure that Revit could do that and I think architects do that.

If we make a contract we give some quantities and say this is our building and they give a price for each quantity. And then we go to contract negotiations and they take over the responsibility for the amounts. So they will go home and calculate all quantities. Then they will find that it is this amount plus a bit more. And it goes as a supplement to the contract. That is often how this process goes. And what you want is that this part eventually disappears.

Do you receive information during bidding process that there are more quantities that it is stated in bill of quantities? If so do you update bid material for all contractors?

Yes, you can do it during the process. But mostly they are not going to ask that especially if there is more. Then they just give a price and say "by the way, you have 100 square meter walls more, you know our price for square meter wall". Then we have discussion whether they are right or not and they sometimes get some extra money.

Do contractors reveal this information after they win the project?

I think most of them. Either they ask a question during the bidding process so that everybody has to go with new quantities.

How widely BIM is used in the company, what is the purpose of using it and how do you benefit from that?

I think we use it now for 70 to 80 percent of our projects. I think a lot of it is not to make errors. The coordination between different subjects is hoped to be better when you do it in 3D model. For bidding process we use BIM to pull put the quantities and so far that is basically it.

You could use it also to make automatic descriptions. So that when you have a concrete column you automatically get description of that. And I know that Revit can do that. Many architects use that.

What problems do you face using BIM?

I think that transferring information between different software is a huge problem. Because when you go to IFC you lose amount of information. No matter from what software it comes from. In a perfect BIM world you would just have one format which everybody uses.

How detailed and accurate models should be to make quantity takeoff? Is it enough to model building so that for example floor construction is presented as an element which boundaries are touching the wall or you need to model it in the way that concrete slab actually penetrates the wall as it is in real building?

We mostly use quite detailed models and in most cases you is needs to be as more detailed as possible.

You have mentioned that contractors participating in bidding process usually have to follow strict form of evaluation documents and they just need to provide prices for stated works. But what do you think about project development process when consultant makes rough design, determines set of requirements for the building and let contractors bid not only on a price but also on solution and quality?

I think that in many cases you get best prices on just giving the solutions, when the contractor has to provide solution. So you just do the overall. In this case you would want the structure where you do not

really care about what solution is used. But if you really care about the solutions which should be used then you have to make it as detailed as possible before giving it to contractor. But if you just want a house and you do not really care what are the solutions used you get better price.

I will give you an example. We have worked for medic industry. We normally make buildings which are very flexible so we put some extra reinforcement which does not cost a lot. And 10 years after we made a building we always can make all kinds of new holes and make another use of it. If you as contractor just to make a solution they would make optimal solution just for that. So you cannot change it (building arrangements) and you lose flexibility. In terms of quality you it is better when you design solutions yourself. You could put that into tendering documents as well (requirement for flexibility) but then it is a bit harder.

So I think when you have standard building where you know you need to use standard solutions the best is to let contractor to make a solution, but if you have something which is very complex it is better design yourself.

Do you have experience inviting contractors for bidding in early design phase? What was the reason for that and what benefits you get from that?

1. Time, you save time. You make early bid and then you make a price. You can get started a bit quicker because while you make a contract and you look at things you do not have that middle buffer to it where you have to calculate the price. I think the time is the main issue here. But you do not design and build at the same time. You can do bidding along the design process.

Appendix C Interview with Esper Christophersen (MTHøjgaard)

Date: 2011 09 21

Location: Technical University of Denmark

Interviewed person: Esper Christophersen, Section Manager of New Buildings and Concrete, Construction Department at Øresund, MT Højgaard a/s

Intervieweig person: Daniel Rogisnki, Master student in Civil Engineering, Technical University of Denmark

Can you describe the process where you perform estimation for bidding?

When we receive bid material we usually sit down and try to get an overview of it divided into sub trades. Then we will have strategy session where we also try to get an overview of the scope of the project. Then we have a strategy where we send out documents to legal analysis, we send out the project as a whole to analyse quality safety aspects. We have our own department that do that part. Then we sit down and decide who is in the competition, what type of pricing do we have to do here to win the project. That is more strategic part of it. We also see which sub trades we want to bid this onward to, because if we have a larger project usually we will have some sub trades coming in, some of the work we do ourselves, but almost in every project there is a little bit of sub trades. We decide who we want to bid, who do we trust, who do we think can come with good bids, competitive bids. Then after that we sit down and of course we start asking these different companies whether they want to bid and someone say no, but hopefully most of them say yes and find some alternatives, send the bidding material out. At the same time we sit down and sort of do the work on the things what we are going to bid on like our own homework, we sit down and do a takeoff of quantities. And even there is included quantity list, we still sit down and try to evaluate whether the quantities fit with a project as a whole as we can see it, what is included in single quantities. If we take concrete foundation, for example, how much formwork it is for a cubic meter of concrete?

So you perform that calculation yourself, or you get it in the bidding material already?

It depends on the quantity list. Some include the formwork site, or they actually say they do not include formwork site, but they include contact surface of the concrete, and a cubic meters and also reinforcement level.

Does this kind of information satisfy you?

Then there have to be description along with it, there have to be some details so I can see when they say: there is this much reinforcement - is there any reinforcement that sticks out so it makes connection to a wall. Are there any waterproofs in the joints, is there anything special we have do to in the joints, do we have to sandblast or pressure wash the joints to ensure waterproofing. Is there anything included in this relatively simple amounts of quantities that have to be taken into consideration. If formwork is curved that changes quite a bit the pricing. Is there special type of concrete? Does it have any sort of admixtures I need to consider, is it exceptionally strong? So there have to be a lot of description, and we have to have something that I can look at and see: when I pour this concrete how much of work is that going to contain.

What is usual bidding material content you receive in competitions? Is it just a list of quantities and drawings or other than that?

They will usually come with description of the work. The problem is that a lot of time it is just a copy-paste from previous projects, what they think it might be a good idea (ironic). The design engineers, they are limited by the fact that they have a limited amount of time to design project for bidding, so they cut corners. And most design companies today have to bid on design work so they also have really sharp prices. So they do not have extra design engineering hours to do more work than necessary.

Now we are in sort of an opinion thing. I see that design quality is falling drastically the last couple of years, because of this pricing. And it means that there are a lot of cost overruns in the project, because projects are not defined as well they should be. When that happen you end up in the situation where the

contractors send a lot of claims, because the project is not defined well enough and there are lots of holes in project so there is a hole in price set.

How often do you experience rise of the project price comparing to bid price?

Every time.

How much this price increases?

We did a large office building contract for over 150 mln DKK, and on that contract we have used 9 months to talk with building owner. And we have done a lot of things. The cost overrun on that was 800 000 DKK. And he (owner) wished some extra into the house. Other than that there were no extras. So theoretically we have built the house to the bidden price.

But we also have a large project where are the concrete and earth works. Contract was for 38,5 mln DKK and right now we have sent claims for 31 mln (DKK). And actually we fully expected that we burst for all of it. But the project was of such low quality, that when you doing the bidding you just could not figure out what complexity is. And we started the work and found out that we have to do some pours onside and some steel frames. But steel man had not put any supports on so all over the sudden we are doing pours and steel frames where we had to figure out we had to do this – the form works. But now we actually had to do support because it is up several floors above and you could not see that. So we said I would expect that steel framework is done then it can carry the load that I can pour in, otherwise you should have said that there has to be extra support into the pour is done. And I cannot guess that. And things like that.

So, I would say that if we talk about our internal project, which we build for my colleagues in house, 7 to 8 % is a normal for this type of concrete work. If it is done on a total building it is maybe about 3 to 5 %, it depends on complexity of the building an how good the bidding material was. But again it is about the quality of the material what we receive.

When you make your proposal do you follow the material list structure to give the price of each element or you have your own list you follow?

If they include the list we always follow that. But if we do not find a list or it is not fairly adequate or it had lots of faults, then we are usually under the process because then we start asking questions. As soon we have send this out to our subcontractors we have an evaluation of the legal things and safety and quality, we start our own quantity take out or analysis of those quantities. We start asking question under the process, how do we relate to this, this detail is missing, could we get a copy of that, how do we interpret this? There can be different things.

What about the names of elements presented in bidding material, should they have specific name or coding, or they maybe have to follow specific standards?

It would be a lot easier if followed some standards. It should be relatively simple within Danish terminology: Composite "Bielke" – Beam, or RB concrete beam which is just rectangular beam, or KB which is with console. Those things give you better understanding of the project; it makes it easier for contractor to analyse.

How important is specification of location of those quantities?

Where are these quantities? And that can be a thing actually. You do not want to make quantities so long; it cannot reach 3000 pages. But you also want to know which quantities belong where. You would like to know if you have different buildings or wings attached to the same building, is it wing A, B or C, where those quantities belong. If there is basement under the 1, is that where these concrete quantities belong? What about foundation quantities right there?

So you prefer get quantity list to be sorted by different building section? As an example, could be it quantity list grouped by floors? Is it better than just stating how many same type elements we have in whole building at once?

Yes. Because you have better chance to be able to control or identify any faults in that. Do we understand this correctly? Is there only 4 000 tons of beams in this building? When I look at it there should be 20 000 tons of beams. Whatever. If it is just whole building you sort of loose the track.

If you can see the basement, and there is something defined there – how does it look like? Then you can see the next floors.

I would say in Denmark where we use to build 5 floors buildings you maybe take a basement which usually would have a different construction system than the other floors. It might be done by either onsite pour or as a different type of concrete elements than the ones up in above ground. The mean floor might be also different. It might be a bit higher; it might be open so you get more light. So the floors that deviate you should separate, but if you have 4 -5 floors what are copy of each other then it is probably not a problem, because you can easily mentally divide here the quantities by five and that is one floor. So that is easy. But if you have these three different basic units what are different from each other... sometimes a lot of time today you have a lot of main floors of identical columns and beams and some stabilizing stair walls and then maybe above that floors you even have actually facade walls, where in the main floor you have to get a lot of light in, in office building.

How important is the shape of element you have to build or perform work on? For example, in the bidding material you have requested to paint ceiling of particular size in square meters. However, it appears that ceiling is in shape of the star, how do you evaluate it from bidding material?

That is why you have to have those drawings.

In bidding material quantity list do you have a reference to the drawings which are present at each line of the list so you can see location of particular item or location of work to be done?

If they can under the bidding reference to drawings there would be lots of time spent. If you had for 1 to 5 as one group then you have to report 5 different drawings and that might not always be practical. In that sense then you would refer to architectural drawing or something. And people would know they have to look in there. But actually for contractor it would be great, because then you can see whatever is on that time I bid on, whatever is on that drawing what I bid on... what about all the other drawings that might also show some other things and then you may be technically exclude those drawings.

So if it requires so many drawings and time to analyse quantities referred to drawings, maybe bidding list could be followed with small drawing representing for instance shape of element from the list, so estimator can see that shape and if it is extraordinary he/she should deal with this position more carefully?

I think that would be very easy. Then you know which area you are related to. When you have a small figure of the shape then you can say: this area I mean here. And then people may say: OK that is what they are talking about, that is the area of that funny shape there. So those square meters will be 25% more expensive than the other square meters. And then they can price that. It is always about being able to relate the quantities to the project.

Which software do you use for estimation?

Right now we use Sigma mostly. But there are a lot of different programs out there, and we have inside MTH lots of different programs that we use also, but the standard is Sigma.

Why Sigma? Other software is not sufficient enough?

Sigma was a political decision. We needed to find one system and they sit down in a work group and they decided that it is going to be Sigma. It has advantages and disadvantages as any system. It is not my favourite, but we gave decided that we want to have the same system across the whole country.

Do you receive bidding material as electronic version or physical paper documents?

Very rarely we receive paper documents. We always receive it electronically. But we always get them printed out, because a lot of people who are doing the bidding on e practical work like my concrete bidders... My youngest bidder is 57 years old, and my oldest bidder is 65. They use computers but they measure up on drawings. They do not work well with measuring quantities or looking at quantities on the screen.

In what format you receive drawings?

It is in pdf.

What about 3D models?

We have received some Revit models. And I have used that on some projects. And some of my not so much of my bidding people or estimation people, but some my people are getting better using Revit viewers to sort of analyse the structure, because it is organic forms and to get understanding of how things connect and how they are formed. It is quite helpful.

And when I say it the younger guys, I am still talking under 50, so it is not because you have to be 30 or, but I think it helps that when you are a lot younger you are more used to looking at screens for reading and that training that comes with is much more accessible makes it easier as time goes by, more and more use of broad applications and computers.

What do you think about passing only BIM model in bidding process so you can extract quantities yourself?

The only problem I would have with that is that it demands that all design engineers and all design architects sit down with a group of contractors and say: when we make a Revit program how do we define objects. Revit is made of bunch of objects. What names do we give for objects and how do we define the objects? So if you want to do quantity take out then you can go and say: I want all walls. What do I get when I get walls? Do I get the windows? And then you have to go and say: Windows or Doors are called "Walls air". We actually found out that when you just have a wall with a window, the window is nothing – it is a hole, it does not exist in theory. But in practical, you actually, if you have to make a window, you have to have a formwork on both sides of a concrete. So you have a full formwork. So you have to start callings the doors' or windows' holes as "Wals air", so you make an air object. So it is non solid object but it is named in Revit model. So you can extract a quantity of it and add to the amount of wall. Because when you go and purchase concrete precast walls you pay full price for a window hole. The problem is that lot of design engineers know that. They just do not think about it. Because the people who are doing design drawings they are only concerned about the objects to see what is solid. But so when they come to the quantities of concrete walls excluding the windows, we cannot actually go out and get bids for concrete precast elements' suppliers on that, because they want to know how many windows and doors there are. So we are missing these quantities. So when they provide us quantities of wall in area of contact surface it is not sufficient for us.

And if they are going to send us a Revit model then we have to make sure that everybody does it exactly the same way, because otherwise when we get new Revit model from, let's say, COWI send us one, and then Grontmij and Ramboll sent us one, if they are defined differently, how do I know what to write to take my quantities. I do not know what do they call "walls", do they call "walls" or they call them "væg" in Danish. Or the call walls A, B, C, D or whatever. So I do not know. I did not do the program; I did not name the objects. So I have to know precisely how many name types of objects there are and how to take quantities of it. And that is a problem if somebody else has done the Revit model, other than me.

So I would be really, really nervous. I might actually even just get my own design engineering to say: I want to take that model and I want you to rename every object and I want you them check and make sure there are no objects without the name that you have given to them. And then I sit down and try to get the quantities out. And that is a waste of time. And I just would not have a security.

Do you include in your price any contingencies?

Do you mean as a reserve or risk factor? We usually have a couple of percent we evaluated on a quality of the project material, we evaluated on complexity of project itself. There also might be a market risks: if the market is increasing, if Greece is going to go bankrupt, what is going to happen, are still prices going to go to the roof? Oil prices are going to go up or they are going to go down?

We have negative risks as well. You can say OK, we can get an up site here, and if we want to win the project we take the up site in right now, win the project and still make our money.

We always have an evaluation. We will usually do that in the end. During the process we try to, while we are doing the quantities and then we are having a dialog with sub trades.. we sort of make a brutal summary of all the risks we see, and then we try to cross them up. So we say: how do we handle this risk?

Can we do something here in our bid work to make sure that we do not have that risk? Is there a risk that we can minimise? How do we do that? What do we include in the bid, or how do we handle that? Is it something we have to do in contract negotiations? So then we try to analyse all the risks we find up, how do we reduce them, and then afterwards we end up with that sum. Then we say: what if I put so much money on each? But the chance of everything going wrong at once is pretty marginal. What would be realistic put aside as a reserve?

What problems do you see right now in bidding process, in bidding material content itself, and what would be your suggestions to improve it?

Right now the quality of bid material is terrible. Drawings are insufficient. If there are quantities there is a huge amount of mistakes in quantities. They are not in quality controls. But just a drawings and design level is very poor now. And if you are bidding on price that means we bid on what is drawn, and if it is not drawn - it is not included in the price. And what happens is expectations of building owners is... well they say: I do not have money for that, why do I have to pay for that, it suppose to be in the project. And the problem is that the design engineer he, the way it is legally Denmark, if it should have been in the project – it is not design engineers fault.

They are really quite quick, the design engineers in Denmark, because let's say that he designed foundations and it suppose to be 50 kg per cubic meter, what it says in bidding, or when you measure in the bid that is what you can see. So we calculate for 50 kg per cubic meter of reinforcement. We get a contract, we start working on it. He (design engineer) starts detailed design, finishing detailed design, and then it appears there is 75 kg per cubic meter of reinforcement. Then I am going to the building owner and say: excuse me, I need money for 25 more kg per cubic meters. And he will go to the design engineer and say: why did not you include that in bid? – Well we had not go in the design that far yet. –But that is a fault, because in the price I have not got it. Maybe I cannot afford to build this, and then I should never have started building it. How do I get out of this? – You cannot, you have to pay them. – You will have to cover my lost. – No. If it is necessary for the building process then you cannot regress towards us.

If we had poured foundations and had to tear them down, they need to go back and get design engineers' insurance to cover that. But otherwise it is not.

So a building owner is very much at the mercy of the quality of the bid material. And bid material defines the quality of the bid.

What information is required to provide reliable bidding price, which information do you expect to receive form designer to be sure the price you will offer is correct? How materials should be represented, what properties should be present, how location should be specified? Quantities: any special way of counting, calculation?

We start working in Dubai where we have 160 store buildings. Here you have a lot of different parameters you would have include in bid. But in normal Danish 5 storey buildings you have some vertical anchors which you just pour into the wall. They are included in the precast. It is just hallow steel pipe in it and you put reinforcement throughout there and then you pour it out, so you have sort of an anchor point. So that is not very advanced when we are talking about 5 storey buildings.

But when you get up to the higher you actually have start making connectors and different things. And you would have to include that because it is extra work and takes extra time.

We also do a time table. When we do calculations we look how many hours are included. When we know this many hours we need, we can ask how fast we can do it. If we have 3000 hours of work and if I put 100 men on this it mean that they will have to work 30 hours each and I am done in 4 days. Is it realistic for 100 to be on this? No, it is probably not. Then I assign 30 men and then I am done in 100 hours. And is that realistic; is there a room enough for 30 men? Do I need to work double shifts, if they can work 15 men – 15 men?

When I do estimation, I divide document into different production activities. I have Earth Works, sheet piles, piles. And then I have concrete works, in that sense all type of concrete done on the site. I will have precast elements erections here. And then I have sorts of different sub trades and suppliers for precast elements, maybe supplier of stairs, steel construction. And all the direction production cost. So this is

what it cost of all things that are built in, and what it cost to do that. Then I have to have a crane, and all what things which I have to include in bid.

Is it included in cubic meter of concrete, or is it just a physical act of pouring cubic meter of concrete including necessary crane, and scaffolding. So that is also what you have to decide how you define that.

Then I have to think insurance in guarantees, financing; do I need to be out of pocket for this project so do I have to find financing for the amount of work I do.

Then I have some different levels of here this is how many months of permanent employees I have on, engineers, foreman on the site, project managers and that sort of things. And then how much of risk I decide project must have.

So that is basic setup.

This is the information you provide in the bidding?

No. This is my estimation program.

If we look at concrete forks to be more specific, that is the layer of concrete you put underneath the foundation to separate it from the earth. So when you pour you reinforced foundation you do not have any earth mixed into that. So it is thin layer you put on the bottom in cubic meters, then the formwork in square meters, reinforcement in tons and the concrete in cubic meters. And actually in those 4 points I put all foundations. So I actually do not need much more information. Unless I need to make some sand blasting in the joints, or make waterproofing in there separately, do I need something like that.

And in that price I have enough room for holes for sewerage canals, so things like that would be included in that price. Not just like lots of them, but small things would be included.

If we look at elevator, we have that cleaning thin layer, I need to pour the bottom, I need the formwork just for the bottom, I need do reinforcement for the bottom, and then I pour the bottom.

So this is the information you provide for bidding?

Yes. But behind that I do all the calculations in more detail for equipment, labour force for instance.

How do you deal with complicated shapes of elements to work on?

The material cost is the same. I might have instead of 10 % spillage 15% spillage because you have these strange corners. Bus spillage would not be that much more. But the hours to do it per square meters would go up. So I might ho up and say: 30% more difficult to do, so that would increase the amount of hours.

In which way you want to see what shape of element you want to work with?

I want to be able when I look at the quantity list and as you are saying to know to each drawing it relates, and look at that drawing and analyse it maybe through details in it or I might be able to see just on normal drawing. But I want to be able to visualize the difficulty in it. So I know that I need to bid on particular level.

In America they often have this practise that contractors participate in design process and they can follow all the project development. So it is easier to predict the project price in early stages of the project. Do you have such experience in your practise?

We had some. Sometimes it is bided in early stage. Then you get in and you get close and you get involved in design phase. Then you work in design phase and at the end you say that price is so much. Now we have designed to this level and we can give fixed price at that.

It is not so common. But it does happen and even public bid include that where they call that Phase separated bidding process, where you have Phase 1 where you have sort of finish the design, materials and at the same time keep an eye on the pricing: does design is becoming more expensive, do we find financing or we stay at the same level. And then we end up at the point where Phase 1 is done and in Phase 2 we sign a contract. And we usually got soma payment for Phase 1.

So can you say that during this collaboration the bid price is more reliable?

Definitely.

Would be it possible to receive from you some information about the quantity list you would like to get in bidding material: structure of list, units of quantities?

If you look at floors I need to know if there is any sort of insulation. I do insulation by square meters because thickness will be given. Is it smooth surface concrete to be done? Any holes? What type of concrete?

There actually do not have to be a lot of information. The parameters do not have to be that many. Because if you ask how much square meter of floor cost? And if you tell me how much insulation there is, what surface quality is expected and how much reinforcement, the thickness of the concrete and the type of the concrete, I can actually give you a square meter floor price all inclusive. I just need to know what I need to include in that 1 square meter of floor.

The same is with foundation. I can give bid price for cubic meter of foundation; I just need to know the other parts.

Appendix D Interview with Torben Seemann (Pihl)

Date: 2011 09 27

Location: Pihl Headquarters

Interviewed person: Torben Seemann, Estimator/Engineer, E. Pihl & Son A/S

Interviewing person: Daniel Rogisnki, Master student in Civil Engineering, Technical University of Denmark

Can you describe the bidding process, how do you receive bidding material, what do you do with it and what do you deliver to owner?

It is a very good question, first of all. Because every time we receive documents it is a new way we are receiving it. It is also because it is in International Department I work in. So, whether we receive papers or design documents it is a different challenge. Sometimes it is very limited drawings, there is a lot of risk in it, we have to go in and calculate the risk.

It is a very hard question actually, but normally, my main responsibilities in design process, we put it out of the box to external consultant. It is a like harbour project or something like that. Then we need to know ground foundations. We get an external consultant paid to do the design. But if it is smaller jobs, small building or something like that, we can do it in our own department here.

How long usually estimation process lasts?

That depends on the project size. Usually it depends how big scale project is, because we work with projects from 15 million dollars to 300 million Euros/dollars. And depending on that the time is from 1 month to 6 months. But they always want it quick, so usually we get very busy when we are getting new to the point. But it is depending on the size of the project.

How often do you experience project price increase comparing with bid price?

It is a hard question to me because I have not been so involved in. But of course you hear about projects there, that many mistakes have been made in the tender process. For example they did not think about some of the design and then we lost money on it. But at the same time it can go both ways. Sometimes we have made very good profit because there was slightly error, so it rises above, I would say.

How do you evaluate the risks?

I know we usually got an excel sheet where we put all faults and then what we work on that. I know we are developing a new system where it is going to be evaluated through probability and statistics. But it is not implemented yet in the company.

What does bidding material you receive usually includes?

Normally they include set up drawings and requirements, work descriptions. And that is what we normally receive.

What about quantity takeoff?

Very basic quantities, so it is very limited what is in those quantities. So if it is a Harbour, it is maybe the length of the... It is very limited. It is more like how much earth it is.

What about the building elements like walls, windows? Do they give a list of that so you can give the price for each line in the list?

I work in the international department. I have mostly been on civil jobs. But when I worked in UK, we received an exact bill of the quantities with beams, windows – everything was in it. But that was the UK way of doing it. I do not know if it is that detailed here. It is more standardised in the UK, when you do not get standardised system in Denmark.

Do you have such experience that when you receive bidding material it has lack of information so you cannot give reliable price?

Always.

For example, when you count material you just miss some parts of building you could not see in drawings, or it is not clear what shape of some elements is, which actually could influence the price.

Ok. So of course you have to go in there to evaluate it. Because for example the formworks you have to build are very complicated and you have to put extra cost for that. But normally on the complicated project like that I would think there was more detailed bill of quantities or it would say in the document that it is your responsibility that the wall is built. So it would be very clear, I would think.

Can you specify names of items you use in your estimations? What units for quantities of those items/elements/objects do you use? What is the structure of the report?

In our company here it depends on the job. We do not have standard bill setup. Of course, we have got a standard bill setup of estimating software, but not for example for excavation, concrete works and all that. I know that in UK, when I was over there, everything was just after the book. And here in the company, because I work in the international department, we structure the bill following the document we receive. That is our best experience.

We are at the moment working on trying to standardise bid, because it is different all the time depending on which estimator is doing it.

But owner usually requires bid of certain structure, does not he?

Yes. They most of the time do the bid structure themselves, so we have to adjust our bill to that. That is why we cannot use standardized system, because internationally there are so many different countries we work with so we receive something new all the time. And we have to adjust our system to work with that all the time. So that standardization is very hard to do.

Are you satisfied with existing bidding process or you maybe see some areas which could be improved?

Yes. I definitely see areas where it can be improved. Especially with a new estimation software which are available on the market. The estimation software we are working here in Pihl is Pihl's own estimating software. It was made I think somewhere in '90s. And it specially was designed for the company. And it is getting a bit old now. So there are lot of new possibilities with new software out there.

I have been working with estimating program called "CANDY?" which incorporates all economic systems which you use in the company like this. Also it uses programs like time schedules and you can link that into the bill. And it just makes your work a lot easier.

How do you perform calculation for estimation, do you do it manually using excel sheets or you have automated system?

It is a program Pihl Calc.

Does it include database with prices?

No, we come with new prices every time. That is the policy. Of course we can use prices if they are 2 or 3 month old, but we do not use database.

So you look at each line at the quantity bill and give it a price?

Yes. We do it all over again all the time to make sure price is correct.

How do you measure quantities if you are getting only drawings and work descriptions?

We measure them straight of the drawings.

What format drawings do you receive?

Old school estimators, they have it in pdf or they get it printed and they measure straight of the drawings. But if I can get dwg drawings I use AutoCAD tool to measure it. And I also draw AutoCAD drawings which we are submitting for the tender.

How do you make sure that you have measured everything what is in the project? Is it possible that you miss something?

Well you have also a paper, you measure the element and then you highlight it in colour or somehow else. That is the standard method of doing this. So you do it one part on the paper drawing and part on the computer.

How do you think, what would be the best content of bidding material, what should it include? I mean, which building elements should be included, what level of detail should be there? What element properties should be provided? Is location of element important? What do you think about 3D model involvement in bidding?

3D model is very good. I have seen that in project as well that there has been a 3D model. And I think it should be included, because it makes everyone more aware of the whole building, it makes it easier what are they bidding on. From the clients point of view maybe they would not do it, because tender may be then too high. It actually could go both ways. I could make it easier and contractor would not calculate some other risk in the building or they maybe also will not see a problem and they will just make a smaller bid.

I would possibly like to have a mode and BIM as well. It is new and I have not worked with that so much. I worked a bit with Revit Architecture just to try it out to see how it works. I think it is brilliant. I talked to our drawing department on a recent job where we make a design and we make drawings and all that, and we were trying to pursue making model in that, but it was too late in the process. And what he also told me was that when they work with architecture they work with AutoCAD because they have more free thoughts when it comes to put it down to AutoCAD. But with Revit it gets too complicated. But maybe new school of architects will think is freer to work with Revit or BIM modelling.

What do you think about bidding process when you just receive BIM and you calculate all the quantities on your own?

I think it would be also good. But then you put all your trust into computer. I would rather put the trust in the computer, but I am sure that many of senior estimators, they would not agree on that. Because old school they are more old fashion and they have to make everything update.

How old are they?

That is from 40 to 55. But people are still old fashion in this industry.

Do you have experience working with BIM software?

Not in professional projects. But we have our own BIM department at the moment, where they build some bridges with all the reinforcement and other things. So they make whole 3D models and it have been very successful.

In America they have this practise where contractors are involved in design process. This way they can follow the project development and prepare more realistic bid price. Do you have experience of such collaboration? If so, how did it go?

Well it depends on what project do we receive. Some of them are design-build contracts, where we have to do design, so it is our responsibility that design is correct. That is where we get in to design phase. But I could not see it else, because normally when it is a big job the design is made by the architects and consultancy. And then it is put out for the tendering process, so five contractors will tender for it. And then you will not have so much influence on the design.

Do you prefer to receive bid material in special work breakdown structure?

I have not seen work breakdown structure here in Denmark from international projects. I have seen it only in UK where we were bidding Library. I also worked as a site manager on a project in Liverpool where they also had WBS. I think it is very nice structure, it is very easy to go through documents and find a way to it and I like it. But it is different from project to project.

Here I got document from VICO Software, where they explain how they do measurements of quantities of different building elements. They explain what each value represents. For example

wall volume, is it the value representing the volume of wall with window holes or volume of window holes are extracted. Do you use similar documents in bidding process?

We do not have it in international department, but I know in Denmark there is a system where it describes how material quantities are measured. But I did not use it.

Have you ever received claims for more quantities than you have measured? For example there were more walls than you stated in bid process.

You mean if the quantities are re-measured and then you get a claim? No, I did not receive any. But I was working in Liverpool where we had this project and of course depending on how the project is developed, maybe the quantities went up a bit, or lower a bit. For example I did some measurements for quantities of IS? (AS?), they (in UK) have this education – Quantities of AS, and I helped them in measurements in AutoCAD as well, where to measure areas on some external pavements. And because subcontractor had performed quantities and put it down saying "now we want this much". Then we went to AutoCAD and put all measure down and we found out that there were about 100 square meters fewer pavements than subcontractor stated. Then it went a little bit back and forth and we finally agreed on the certain amount between the parties. And that is how it works.

With this of course in a building you get a really good idea of how much the quantity is. But when you get down on the project there will always be more, because it changes all the time through the process. After you made the design and come out and build it there are always some small or big changes.

Do you add any contingencies to a bid price?

No. We say they are included in our profit.

What do you do when you see that bidding material, for example drawings or list of quantities, is missing information on quantities of building parts or elements which you know by logic will be in the project?

Then you would submit a technical query for what the problem could be and you wait for client to respond to that and then see how it goes.

In many cases when contractor receives bill of quantity for estimation in bidding process they are asked to give prices for each line from the list. But very often they give sum of particular element quantities used in whole building. This method does not give actually the good picture of circumstances in which element is built or installed. That actually could cause the price increase. What do you think about having list of quantities separated in groups which would represent particular zone of the building so you can check particular drawings and evaluate all circumstances like height of element installation, complicated shape elements like ceiling of room which is in shape of star for instance? To go further, each line could have a small drawing of an element or a reference to a drawing where element is presented.

And actually this is why experienced estimators do not put trust in computers to do everything automatically and do all the work. But I think it is brilliant what you said. And I can definitely see good possibilities with that.

If you have wall quantity in square meters and you have to paint it, but you also know that there will be suspending ceiling system, do you subtract the area which is above suspending ceiling?

I would say "yes, we do". You would just add up to 100 mm above suspending ceiling. I would do that. But of course that depends on estimator. I cannot say how they do it in the Danish department, if they got specific requirement for that. But I would say 100 mm above it.

Do you specify in the bid price what part of wall is going to be painted?

No. We do not do that. But it depends on the project. If it is a big prestige project you would probably do that and you would be very specific about how you do that. But here in the international department where I work it is a bit different when we bid on job in Haiti and Jamaica you do not go that much into details, there is no requirement for that.

How do you work with subcontractors in bidding process?

When I was estimating the Library project in the UK, it was for management contract, basically all the work was to be performed by subcontractors. We worked then with a program "Candy?". It was kind of starting update to see if it was a good program. In Candy you have got a whole bill of quantities. Then you go in and start defining each item for which subcontractor it belongs: is it for cladding subcontractor or roofing subcontractor and so on. When you finish defining each item it was quite easy, because you could take big pages at the time. You could go in and then say "export out to the bill", which you send to subcontractor. You take the WBS, the specific description out and send all that information to a subcontractor along with a standard contract. We ask them to send back the bill of quantities with sums put in. Then it was easy when we receive the bill, we just in the software program imported it and could compare prices from different subcontractors, to see in which lines prices are different. And this way you get quick overview. I think we had 130 subcontractors pricing different things of the project.

In case if you have two walls of same amount of square meters, but one of them is 5 meters in height, another is 10 meters in height; do you give different prises for them?

Yes. In this case you would have the walls up to 2,5 meters for one price, then walls from 2,5 to 5 meters for another price and so on. So we split the price.

Do you specify this in you bid papers?

If the client requires then yes, we would. But on projects I have been work on we did not have to specify that, we only use this internally. But if the client would require this structure then the bids from all contractors would be more comparable.

Do you perform clash detection in projects in bidding process?

It is not something we look at specifically. The first we look at is the contract document to see if there is everything what it should be before we even start bidding process. We do it to make sure we are not bidding on project with unreasonable demands.

Last comment: what would you like to improve in bidding process?

I would get is standardised more; get the bill of quantities which is more structured. And of course, when you propose this BIM modelling it is a very good solution, I think, and could be a good future solution. But it is up to the bosses what they think about it.

Appendix E Interview with Stefan Brandt Johansen (Pihl)

Date: 2011 10 05

Location: Pihl Headquarters

Interviewed person: Stefan Brandt Johansen, Research and Development Engineer - BIM Manager, E. Pihl & Son A/S

Interviewing person: Daniel Rogisnki, Master student in Civil Engineering, Technical University of Denmark

The aim of this interview is learn how bidding material content can be improved and what you expect from bidding material in order to provide reliable bid price of the project. But first of all could you describe current practice in tendering process?

It is quite complex today because Pihl is giving tender in building site and in civil structures. And tendering processes in two different areas are quite different. Further on Pihl is worldwide company today so we give a lot of tenders in Denmark but also in Africa, Jamaica, Panama, Greenland, US and so forth. And material we receive from client in Panama is not the same we receive it from client in Sweden. So to give exact answer to this question is not possible.

Could you then describe process in Denmark area, how do you do it here?

Normally it is also quite different. It depends on clients. Sometimes we receive full bill of quantity list where we need just to set the prices. Other clients forward material to us and we should find the quantities ourselves. So that is two different ways of giving tenders. If everybody gives the same bill of quantities list then you have to find other ways to win the project because everybody just can sit with a list of quantities and set the prices. But if you want to differentiate from other bidders to that project you have to find some places in the project material offer the client something else, something better, do some value engineering and so forth. So that could be a scope of work.

Further on it depends how early in the process are we involved. Sometimes we are involved in very early stage where we can develop project with client, architect and consultant. In other projects we receive a project what is finished by the consultant and we cannot do anything to improve the project.

So it differs from project to project and it is quite difficult for company like Pihl just to do tendering process in one way, because we are dealing with so many projects and size of the project and scope of the projects are so different and a material are always different.

What do you think about having some rules or requirements for bidding material content let we say for Denmark's market? Would it be helpful?

It would be helpful for clients. Because when they are going through tenders it is easier for them to compare tenders. If we should takeout quantities and so forth ourselves we have an opportunity to deliver some value engineering or offer the client some other material which we think is better and cheaper. It gives us an opportunity to win the project.

If all clients just say: we have to do tender like "this", then the price in Denmark will get even lower and competition even bigger than it is. And that is good for the client. And maybe it can be also good for us, because then we have to be very sharp. I just do not really think it gives the best tendering process because you are not sure as a client that you receive the best product, because all contractors will underbid each other to get the project and they will just try to earn their money somewhere else.

But then rules could include that for particular parts of the project you are welcome to suggest your solutions to make it cheaper or/and even better.

Yes. Actually in projects where we have an opportunity to get with our own ideas is often projects which are best for us to build it in real life, because we have an opportunity to optimise the design from the consultancy so it is easier and cheaper for us and in the last end for the client actually to build the project.

How often you experience that project price increases comparing to bid price?

It depends how project material is put together. In many projects today we receive "design", but it is not detailed design. And when we start making the project all the details designed appear in state "as built" and often that is not a good idea because we receive detailed design in the last minute sequence. That often gives us challenges, and today projects are often made this way. In that case sometimes we receive some design too late and we have to say to the client or to external consultant that we have for example to close the building for the winter, we cannot wait any longer for you to finish the design, we need more money if you want us to close the building exactly before winter.

In many projects it is not a case today that we get a higher price than we have given tender. Often what happens is that the client does not always know what he is asking for. So when process starts suddenly he realises that he forgot to add some components to the project, and suddenly in the middle of the process we should build the staircase instead of rooms, then of course the project is getting more expensive because we have to hurry up for doing design for particular part of the building, because all other parts are waiting for this part to be done. Then of course project is getting more expensive than we were expecting. And it is not our mistake. But we are very tight on schedule and if we are not on time than client can ask for money. So it is going back and forth.

How do you think how important is well prepared material quantity bill?

We use a lot of resources to optimise and make sure that the team doing the tender for particular project is totally knowledgeable about the project, they know very last piece of it, every room and every facade solution and so on. We use different tools for that, because in some stages is still made from 2D pdf drawings and then you have to look in to it and then look to the description material as well. That is one way of working with it.

In other projects today we receive sometimes quite detailed 3D BIM models. It is very helpful because large building projects or civil structures you can go months using 2D drawings and making your own image of project. But when we receive this model it is very fast to put all people together in the room and screen model using the projector and see all building parts, services. It is so much faster to get the team that is doing the tender to understand the project. That is huge benefit.

When you receive 2D drawings do you model your own model?

Yes, but not always. If we look just into simple building skilled person just can look at the drawings and understand completely the building. But in other projects we are doing 3D models ourselves to get the exact quantities.

In what format you receive BIM model when it happens? Is it IFC or native format of the software building was modelled in?

It depends. We have received IFC models but also we have received in some cases the native Tekla Structures model and Revit models as well.

Do you have any problems when you receive IFC format?

Sometimes it comes with some errors and often the problem with the models from consultant is that when you are extracting quantities it is not modelled the way contractor wants it to be modelled to make the right estimate. A good example is to extract a quantity for the painting the wall of the room, it is easy to do in Revit for example, but we paint room only to suspended ceiling level, we do not paint above it. So how do you control that? I could give a list of example where the model from the consultant is not optimised for the tender. But what we often do is we use it as a basis for a tender and then we do our own modelling as an overlay to finish it up so it actually fits our bidding process.

When you are doing the model you always have to be very sharp, you need to know what the purpose of it is, what quantities are there you want to extract.

When you receive quantities, how the list is usually structured? Is it a list containing one lines with particular elements with its quantity in whole building or quantities are grouped in the way that each group represents different zone of the building?

I have actually have seen both. It depends how the consultant has worked with the model and grouped the objects in the model. But I think it is better to receive bill of quantities arranged by zones, because

when you do the high-rise building for example it cost much more money to build column in top floors than in the bottom of the building. So it is important for us that when we are going to a tender to know that particular column is more expensive than other even though they are exactly the same geometry. And if consultant had some thoughts for us it is very powerful help for us.

What do you do when you receive drawings and bill of quantity which is structured in the way that each line represents one type of element which is used in whole building in different places and you have to give price for it? What price is given in this case?

Person sitting and doing the tender on particular beam always is trying to find it on 2D drawing and define how many same beams are in different zones which would have different price. Taking this into account average price is given in this case. Otherwise it is too risky to give a tender. But it takes a lot of time to do it in 2D when you have a lot of drawings. It is much faster to do it in the model.

I have heard such opinion from previous interview with project manager from MTHojgaard that in many cases it is important to know cubic meters of the wall not excluding holes for windows. It is because subcontractor does not care how many holes are in the prefabricated wall for example. The price which could be saved due to less material used for wall production because of window holes is transferred to extra amount of money needed to make those holes. How is it with those quantities of wall for example from your point of view?

It depends on your subcontractor. I know a lot of subcontractors who are interested in knowing how many holes are in the wall. But it is just important to know if we talk about quantities what those quantities represent. It is very important.

What information is required to provide reliable bid price? Which information do you expect to receive from Design Company?

We do not expect that much. We want to be flexible partner for the clients. If client wants us sometimes today to be a part of early design process and want to involve us to lower total price of the project and ask us to assist in doing tender with an external consultant and architect, we would like this building made, then we do not expect that much at all. Then we want to be a help to client making a project.

How client chooses contractor to be part of project in early stage of its development? Is this decision made through competition or client chooses contractor by particular preferences?

Sometimes it is competition sometimes client wants Pihl's opinion on a project client is thinking about doing. We were asked if we could try to estimate or come with sub proposals for the project then they would appreciate that.

Can it happen that you participate in design and later there would be another competition for choosing contractor?

Yes, that is an option. But that is not so common today but I think we will see more of that in the future. It is not that common but we see it today. It is difficult question to answer because it depends on the client. And if a client comes and says: we have no fully covering material for particular project, we do not say that we cannot help you. Of course we go to the dialog with a client trying to solve this issue and come with our proposals to optimize and do a good project for the client.

But in some cases we receive all the information we need. That is also the case in some projects. So again it totally depends when in the process we are involved.

So sometimes we are involved very early and sometimes we are involved too late I would say.

To do an offer with an exact price without any risk for us as contractor we need quite large set of data and information regarding the project.

What about the risk for the client? When do you think is the best for the client to start tendering for contractor?

I think the earlier the better. Then we can solve out issues where risks are for the contractor and therefore we can set better price for the total project. It is mine opinion.

If you look to foreign countries like US, Finland, Norway you see that a lot today. They do not see contractor as the last party to be involved in that process. Today they are involved very early in the process because in the long term it gives client a cheaper and a better project. I think that in couple of years we will see it more and more here in Denmark and other countries which are doing it in old fashion way. And that is how I see the development in this industry.

What software do you use to perform calculation of quantities, estimates?

It depends what kind of model are we receiving, how detailed is the model, are we doing the model ourselves. There are a lot of questions.

But most often we would normally use Revit or Tekla directly to extract the quantities and these are our main BIM tools today where we are doing a lot of modelling and also we receive models made in this software.

But we also use other tools like VICO. We are not familiar with that yet, but we see a huge potential in VICO Office. And we talk with VICO vendor about how we can optimize the process because there is a lot of interesting tools.

How do you think which method is more efficient: calculation material quantities from 2D drawings or using automated BIM tools, and which one is more reliable?

It depends. If you want to extract quantities from BIM model you really need to know how model is made. There is a difference between models made by external consultant and by Pihl. The scope of the consultant is not the same as scope of contractor.

As an example I can provide one issue we had with model provided by Design Company. It has been decided to have composite beams made of steel profile and concrete should be poured onsite. Design Company has represented this beam in their model only with metal part but assigned concrete material to the beam. When we tried to extract quantities from the model we could see, that we have very little tonnage of beam, as density of concrete is much lower than metal.

So I think that maybe client should be more familiar with the possibilities of BIM and say to the consultant that they should do the model which is easy and trustworthy for the contractor to use in tender stage. Because if consultant is doing BIM model which is not sufficient enough to use for contractor – contractor will make another one. And the total price of the project is getting higher again. And what is the benefit for the client? The one who is paying for that is the client.

So you are saying that when you receive the model you cannot do a lot with it? Is it only helpful for visualization?

Well, yes. And if I want to use it I have to go through it step by step and look for all materials, all surfaces… It is actually normally for the contractor because you get more familiar with the project. But it is not optimal enough. And those mistakes are often confusing.

And that is a problem, because consultants do not care because they not getting paid for doing exact models with all the information and clients in Denmark do not know that much about these technologies and its possibilities. So first they pay for consultant to do a work, afterwards the pay contractor for tender. But client just could pay the consultant a bit more for better work and then he would not have to pay more for contractor. Because now we are doing the same jobs two times.

So it is better to make your own model yourself instead of working with low quality model received from contractor?

Yes, exactly.

Which software do you use for estimation? Do you use only Sigma?

We are working on different software to do the estimation today. We have actually 3 or 4 different systems today, because the way of doing tenders in Denmark and other countries is different , also depending is it building site or civil site, we need different systems. And we know that Sigma cannot handle all of our projects.

We have tested Sigma and we think it is quite interesting and they have nice integration to IFC format. But as long as IFC model is not better than this we cannot use it that much. There is huge potential but we need good models to use that potential. So now we are looking to VICO as a whole package solution.

What is your prediction about bidding process in the future with perspective on BIM?

When I look at the countries around us especially at Norway and Finland I can see that tendering process on many large projects are much more controlled and clients up there are very familiar with technologies like BIM. And they know the huge potential to get cheaper price on the total project if they from the beginning said to the consultant: we want the model that contractor could use to extract quantities from. And I think that when clients in Denmark realize the potential here. Then in a couple of years we will see a lot of projects that would be bid out in tenders where we use models directly as a tool to extract quantities and understand the projects better.

And I hope and I also think that the government will set up some goals for this to say all projects done by state should be done in this way. That is what they have done in Finland and in Norway as well. That turned out to be a huge success because it influences the private market as well.

What do you think about bill of quantities which would include reference to the drawing near each element in the bill?

That could be brilliant.

We are doing actually right now detailed design on project on huge concrete block where is a lot of reinforcement and all this reinforcement we are doing in the model so if you select reinforcement in the model in which 2D drawing I can find it.

Appendix F DTU_328_2011_07_14 IFC FOR REVIT Error Report (2011.11.09 14:42:54)

Error message	Elements
Can't make cut-out.	Void Extrusion : id 157092 IfcOpeningElements : Opening 171907 : Opening 171907 : id 157119
Can't make cut-out.	Void Extrusion : id 157099 IfcOpeningElements : Opening 171907 : Opening 171907 : id 157119
Can't regenerate Family Opening 171907. Edit Family to modify it.	Opening 171907 : id 157088 Type : IfcOpeningElements : Opening 171907 : Opening 171907 : id 157117 Opening 171907 : id 157118 IfcOpeningElements : Opening 171907 : Opening 171907 : id 157119
One element is completely inside another.	Walls : Basic Wall : 3940*300 : id 153689 Columns : Ų80*2 : Ų80*2 : id 157900
One element is completely inside another.	Walls : Basic Wall : 3940*300 : id 153689 Columns : Ų80*2 : Ų80*2 : id 157901
One element is completely inside another.	Walls : Basic Wall : 3940*300 : id 153689 Columns : Ų80*2 : Ų80*2 : id 157902
One element is completely inside another.	Walls : Basic Wall : 3940*300 : id 153689 Columns : Ų80*2 : Ų80*2 : id 157903
One element is completely inside another.	Walls : Basic Wall : 3410*200 : id 154618 Columns : Ų80*2 : Ų80*2 : id 157926
One element is completely inside another.	Walls : Basic Wall : 3940*200 : id 154783 Columns : Ų80*2 : Ų80*2 : id 157920
One element is completely inside another.	Walls : Basic Wall : 3940*250 : id 154951 Columns : Ų80*2 : Ų80*2 : id 157904
One element is completely inside another.	Walls : Basic Wall : 3940*200 : id 156820 Columns : Ų80*2 : Ų80*2 : id 157921
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157203 Columns : Ų80*2 : Ų80*2 : id 157934
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157203 Columns : Ų80*2 : Ų80*2 : id 157935
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157240 Columns : Ų80*2 : Ų80*2 : id 157961
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157240 Columns : Ų80*2 : Ų80*2 : id 157962
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157240 Columns : Ų80*2 : Ų80*2 : id 157963
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157275 Columns : Ų80*2 : Ų80*2 : id 157831

One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157275 Columns : Q80*2 : Q80*2 : id 157950
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157275 Columns : Q80*2 : Q80*2 : id 157951
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157310 Columns : Q80*2 : Q80*2 : id 157824
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157310 Columns : Q80*2 : Q80*2 : id 157936
One element is completely inside another.	Walls : Basic Wall : 3410*400 : id 157310 Columns : Q80*2 : Q80*2 : id 157937
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157346 Columns : Q80*2 : Q80*2 : id 157928
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157346 Columns : Q80*2 : Q80*2 : id 157929
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157371 Columns : Q80*2 : Q80*2 : id 157952
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157371 Columns : Q80*2 : Q80*2 : id 157953
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157371 Columns : Q80*2 : Q80*2 : id 157954
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157404 Columns : Q80*2 : Q80*2 : id 157829
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157404 Columns : Q80*2 : Q80*2 : id 157944
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157404 Columns : Q80*2 : Q80*2 : id 157945
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157427 Columns : Q80*2 : Q80*2 : id 157826
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157427 Columns : Q80*2 : Q80*2 : id 157940
One element is completely inside another.	Walls : Basic Wall : 5060*400 : id 157427 Columns : Q80*2 : Q80*2 : id 157941
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157451 Columns : Q80*2 : Q80*2 : id 157930
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157451 Columns : Q80*2 : Q80*2 : id 157931
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157488 Columns : Q80*2 : Q80*2 : id 157955
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One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157488 Columns : Q80*2 : Q80*2 : id 157957

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One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157558 Columns : Ų80*2 : Ų80*2 : id 157827
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157558 Columns : Ų80*2 : Ų80*2 : id 157942
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One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157593 Columns : Ų80*2 : Ų80*2 : id 157932
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One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157630 Columns : Ų80*2 : Ų80*2 : id 157960
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157665 Columns : Ų80*2 : Ų80*2 : id 157830
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157665 Columns : Ų80*2 : Ų80*2 : id 157948
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157665 Columns : Ų80*2 : Ų80*2 : id 157949
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157700 Columns : Ų80*2 : Ų80*2 : id 157825
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157700 Columns : Ų80*2 : Ų80*2 : id 157938
One element is completely inside another.	Walls : Basic Wall : 3360*400 : id 157700 Columns : Ų80*2 : Ų80*2 : id 157939
One element is completely inside another.	Walls : Basic Wall : 3980*200 : id 157777 Columns : Ų80*2 : Ų80*2 : id 157888
One element is completely inside another.	Walls : Basic Wall : 3980*200 : id 157777 Columns : Ų80*2 : Ų80*2 : id 157889
One element is completely inside another.	Walls : Basic Wall : 3980*200 : id 157777 Columns : Ų80*2 : Ų80*2 : id 157890
Instance of in-place family is not cutting host.	Floors : Floor : 270*7994 : id 153738 IfcOpeningElements : Opening 43538 : Opening 43538 : id 153774
Instance of in-place family is not cutting host.	Floors : Floor : 270*1945 : id 154395

	IfcOpeningElements : Opening 112737 : Opening 112737 : id 154419
Instance of in-place family is not cutting host.	Floors : Floor : 270*1945 : id 154456 IfcOpeningElements : Opening 113017 : Opening 113017 : id 154480
Instance of in-place family is not cutting host.	Floors : Floor : 220*2234 : id 154484 IfcOpeningElements : Opening 113185 : Opening 113185 : id 154508
Instance of in-place family is not cutting host.	Walls : Basic Wall : 5060*400 : id 157371 IfcOpeningElements : Opening 175403 : Opening 175403 : id 157403
Instance of in-place family is not cutting host.	Walls : Basic Wall : 5060*400 : id 157404 IfcOpeningElements : Opening 175659 : Opening 175659 : id 157426
Instance of in-place family is not cutting host.	Walls : Basic Wall : 5060*400 : id 157427 IfcOpeningElements : Opening 175913 : Opening 175913 : id 157449

The following problems were encountered in the IFC file: Error 20050: Instance #170824, attribute 1: The aggregation shall contain at least 3 elements but it contains 2!

The following problems were encountered in the IFC file: Error 20050: Instance #170862, attribute 1: The aggregation shall contain at least 3 elements but it contains 2!

The following problems were encountered in the IFC file: Error 20050: Instance #170884, attribute 1: The aggregation shall contain at least 3 elements but it contains 2!

The following problems were encountered in the IFC file: Error 20050: Instance #170906, attribute 1: The aggregation shall contain at least 3 elements but it contains 2!

The following problems were encountered in the IFC file: Error 20056: Error opening the temporary swapfile!

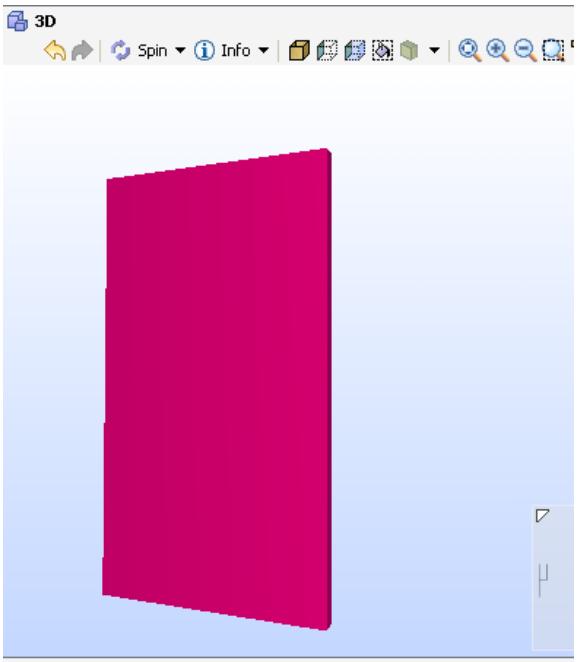
The following problems were encountered in the IFC file: IFC: Only 2 points in polyloop #170824, expected >= 3.

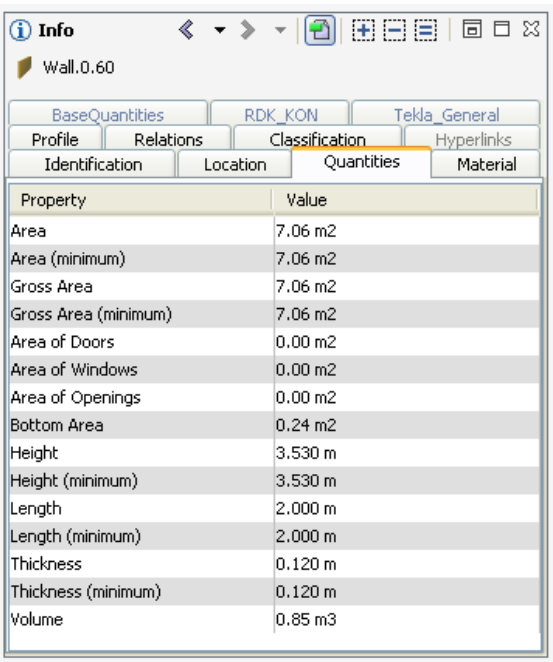
The following problems were encountered in the IFC file: IFC: Only 2 points in polyloop #170862, expected >= 3.

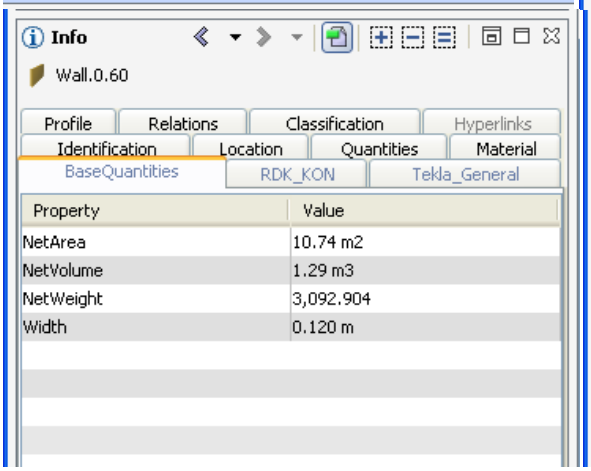
The following problems were encountered in the IFC file: IFC: Only 2 points in polyloop #170884, expected >= 3.

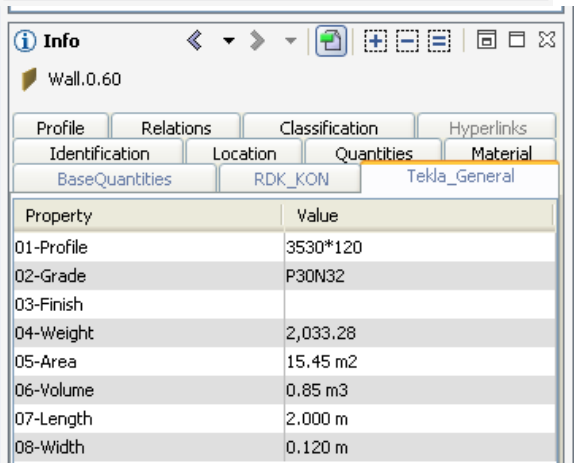
The following problems were encountered in the IFC file: IFC: Only 2 points in polyloop #170906, expected >= 3.

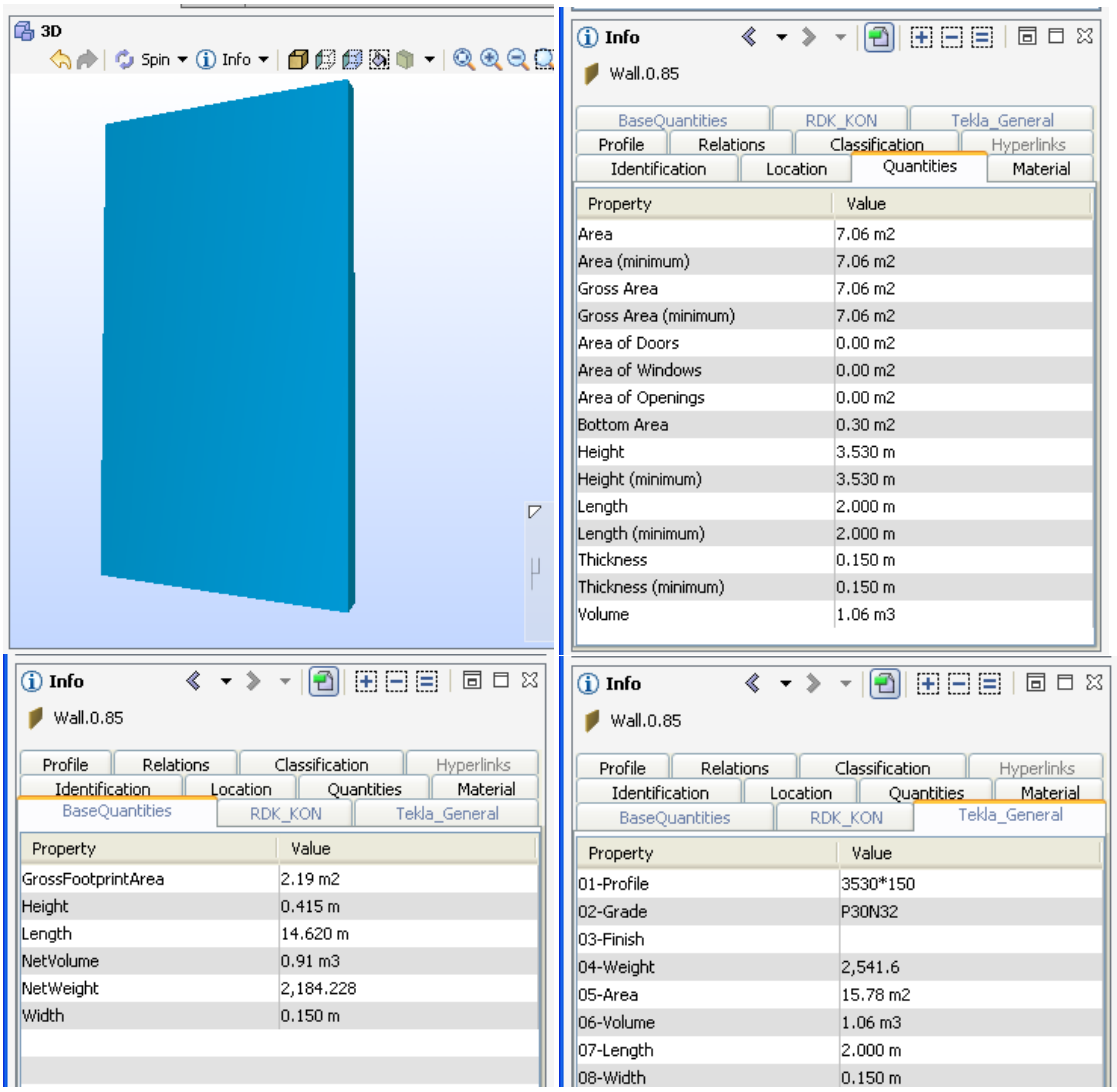
Appendix G Comparison of available geometrical parameters of two walls in Solibri Model Checker v7










3D
Spin
Info
Info
Wall.0.85
BaseQuantities
RDK_KON
Tekla_General
Profile
Relations
Classification
Hyperlinks
Identification
Location
Quantities
Material
Property
Value
Area 7.06 m2
Area (minimum) 7.06 m2
Gross Area 7.06 m2
Gross Area (minimum) 7.06 m2
Area of Doors 0.00 m2
Area of Windows 0.00 m2
Area of Openings 0.00 m2
Bottom Area 0.30 m2
Height 3.530 m
Height (minimum) 3.530 m
Length 2.000 m
Length (minimum) 2.000 m
Thickness 0.150 m
Thickness (minimum) 0.150 m
Volume 1.06 m3
Info
Wall.0.85
Profile
Relations
Classification
Hyperlinks
Identification
Location
Quantities
Material
BaseQuantities
RDK_KON
Tekla_General
Property
Value
GrossFootprintArea 2.19 m2
Height 0.415 m
Length 14.620 m
NetVolume 0.91 m3
NetWeight 2,184.228
Width 0.150 m
Info
Wall.0.85
Profile
Relations
Classification
Hyperlinks
Identification
Location
Quantities
Material
BaseQuantities
RDK_KON
Tekla_General
Property
Value
01-Profile 3530*150
02-Grade P30N32
03-Finish
04-Weight 2,541.6
05-Area 15.78 m2
06-Volume 1.06 m3
07-Length 2.000 m
08-Width 0.150 m