Kasper Lyngsfeldt

Analysis of the handover of digital data and models from engineer to contractor

In preparation for HVAC contracts

MSc Thesis, Fall 2012 - Spring 2013

DTU Civil Engineering
Department of Civil Engineering

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Supervisors:
Jan Karlshøj, Associate Professor, DTU Civil Engineering
Morten Alsdorf, Civil Engineer, Rambøll - Buildings, Structural Engineering Dept.
Niels Treldal, Civil Engineer, Rambøll - Buildings, Health and Pharma Dept.

DTU - Technical University of Denmark, Kgs. Lyngby - 2013

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This report was prepared by:
Kasper Lyngsfeldt
Student-ID: s071956
kaly@ramboll.dk

Advisors:
Jan Karlshøj, Associate Professor, DTU Civil Engineering
Morten Alsdorf, Civil Engineer, Rambøll - Buildings, Structural Engineering Dept.
Niels Treldal, Civil Engineer, Rambøll - Buildings, Health and Pharma Dept.

DTU Civil Engineering
Technical University of Denmark
Brovej, Building 118
2800 Kgs. Lyngby
Denmark
Tel: +45 4525 1700

info@byg.dtu.dk

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Abstract

This thesis deals with the digital handover of models and data from designer to contractor. The basis of the thesis is the digital tender, which stated as a requirement in the executive order for the use of Information and Communication Technology (ICT) [BEK no. 1381 (2010)]. The main argument for the introduction of the digital tender was to ensure that contractors was tendered a standardized and equal tender with quantities. This initiative suppose to save contractors time on the discharge of the tender, but this potential is according to a report from the Danish Construction far from settled [Flemming Grangaard (2012)].

For this reason, the goal was to analyse the problems that may be related to the execution of digital tender for HVAC contracts comprising liability regarding quantities, level of detail, the structure of the tender list with quantities, measurement rules and process regarding extraction from BIM models. In addition, the aim was also to propose solutions to the identified problems. As an extra thing the American concept of Integrated Project Delivery (IPD) were analysed in relation to the use of BIM and implementation. In this context, the emphasis was placed on such quantities and other digital tender documents.

In connection with the thesis there were performed QTO and structuring of tender list with quantities for HVAC contracts for a specific project: Mærsk Bygningen. This gave the opportunity to test the process and to be subjected the rules for a digital tender. In addition, this case study was also supplemented by two other cases and a series of interviews with both designers and contractors.

At the beginning, a process was set up for QTO on four different pieces of software and then gathered into a tender list with quantities. Then followed a definiton of which objects and parameters that were relevant to extract from each specific software. The challenge was in that context to ensure that everything relevant was measured while some components were not to be measured in more than one piece of software. For this purpose, a schedule was established, which was the starting point for how the components should be measured from and what exactly should be measured. Then a code was set for each software which made the QTO to a standardized process from Excel to Sigma, from which the tender list was generated from.

The thesis concludes that, based on the available methods, there is no basis for making standardized tender lists of with quantities at the moment. In that connection it is proposed to contribute to Cunecos work with information levels and building components. In addition, recommended that the tender list with quantities of structured and priced per system and a change of ABR 89 and AB 92, which can handle responsibility in relation to the designer makes measurement mistakes in a digital tender.

In relation to IPD, it is concluded that this collaboration can help to utilise the postulated BIM potential. There is also positive on the concepts that relate to the management of costs (predictable costs) and the use of detailed quantities for calculation of the design phase.

Resumé (Dansk)

I dette speciale behandles den digitale overdragelse af modeller og data fra rådgiver til entreprenør i forbindelse med HVAC entrepriser. Udgangspunktet for specialet er det digitale udbud, som er et punkt i IKT bekendtgørelsen om krav til anvendelse af Informations- og Kommunikationsteknologi (IKT) i byggeriet [BEK no. 1381 (2010)]. Hovedargumentet for indførelsen af det digitale udbud, var at sikre at entreprenørerne bød på et standardiseret og entydigt udbudsmateriale med mængder. Derved skulle entreprenørerne spare tid på afgivning af tilbud, men dette potentiale er jvf. en rapport fra Dansk Byggeri langt fra indfriet [Flemming Grangaard (2012)].

Af den årsag var målet at analysere, hvilke problemer der måtte være i forhold til at udføre det digitale udbud for HVAC entrepriser, herunder juridiske forhold omkring mængder, detaljeringsniveau, struktur af tilbudsliste med mængder, opmålingsregler samt processen omkring det mængdeudtræk fra BIM modeller der ligger til grund for mængderne. Derudover var målet også at foreslå løsninger til de identificerede problemer. Som en ekstra ting blev det amerikanske koncept Integrated Project Delivery (IPD) analyseret i forhold til udnyttelsen af BIM og implementering. I den sammenhæng blev der især lagt vægt på mængdernes og det øvrige digitale udbudsmateriales betydning.

I forbindelse med specialet blev der udført mængdeudtræk og strukturering af tilbudslister med mængder for HVAC entrepriserne på et konkret projekt: Mærsk Bygningen. Dette gav mulighed for at teste processen samt være underlagt de gældende regler for et digitalt udbud. Derudover blev dette case study også suppleret af to andre cases samt en række interviews med både rådgivere og entreprenører.

Til at starte med blev en process blev stillet op for hvordan mængdeudtrækket skulle udføres på fire forskellige stykker software og herefter samles til en tilbudsliste med mængder. Herefter fulgte en definiton af, hvilke objekter og parametre der var relevante at få med fra hver specifik software. Udfordringen var i denne sammenhæng at sørge for at alt kom med samtidig med at nogle komponenter ikke blev talt fra flere forskellige softwares. Til dette formål blev der etableret et skema, som var udgangspunktet for hvor, hvilke komponenter skulle tælles fra og hvad der egentlig skulle tælles. Der blev herefter sat en kode op for hver enkelt software, som gjorde mængdeudtrækket til en standardiseret process fra Excel til Sigma, hvor tilbudslisten blev genereret fra.

Specialet konkluderer, at der ud fra de tilgængelige metoder, ikke er basis for at lave standardiserede tilbudlister med mængder på nuværende tidspunkt. I den forbindelse foreslås, at der jvf. Cunecos arbejde med informationsniveauer, bliver etableret definitioner af informationsniveauer pr. bygningskomponent indbefattet information om hvilken mængde, opmålingsregel, visuel representation og beskrivelse der skal knyttes til et givent informationsniveau. Herudover anbefales der at tilbudslisten med mængder struktureres og prissættes pr. system samt en ændring af ABR 89 og AB 92, der kan håndtere ansvar i forhold til at rådgiveren laver opmåling af mængder i et digitalt udbud.

I forhold til IPD konkluderes at denne samarbejdsform kan være med at udnytte det postulerede BIM potentiale. Der ses endvidere positivt på de koncepter, der relaterer sig til håndtering af omkostninger (predictable costs) samt brugen af detaljerede mængder til kalkulation i projekteringsfasen.

Preface

This master thesis is a partial fulfillment of the education Master of Science in Civil Engineering. The work load of the project comprises 30 ECTS points and the studies and reporting has been carried out mainly at Rambøll Head Office in Ørestad. The report covers the studies conducted during the 2012 and 2013. The purpose was to get a better understanding of the digital tender and the execution of QTO for the HVAC trade contracts.

The thesis describes both the theoretical background and the practical point of view. It was carried out as a collaboration between the Department of Civil Engineering at DTU and Rambøll Denmark. In this respect I would like to thank Associate Professor Jan Karlshøj for supervision during this thesis.

I would also like to thank the Mærsk Bygningen project group of Rambøll. In particular, Niels Treldal and Morten Alsdorf for spending time helping and contributing to this master thesis. Furthermore, also a thank to the interviewee's.

Ørestad, March 5th 2013

Acronyms

AEC Architect, Engineer, Contractor

AIA American Institute of Architects

BIM Building Information Modeling

Bips Building, Information, Productivity, Collaboration (byggeri, information, produktivitet, samarbejde)

CAD Computer Aided Design

DANSKE ARK Danish Companies of Architects (Danske Arkitektvirksomheder)

DB Design-Build

DBB Design-Bid-Build

DBK Danish Building Classification (Dansk Bygge Klassifikation)

FRI Association of Consulting Engineers (Foreningen for Rådgivende Ingeniører)

HVAC Heating, Ventilation, and Air Conditioning

ICT Information and Communication Technology

IFC Industry Foundation Classes

IPD Integrated Project Delivery

MEP Mechanical, Electrical, Plumbing

SfB Samarvetskomitén för Byggnadsfrågor

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Chapter 1

Introduction, scope and motivation

1.1 Digital development in the construction industry

The construction industry has been wellknown as an industry controlled by old habits and a traditional mindset. But over the last decades the digital development has challenged the traditional way to manage the workflow and the processes in the industry.

The digitisation has developed through several of years in Denmark in the construction industry, but first after the national enterprise Digital Construction[1] (DC) was introduced in 2003 things took off in Denmark. The Digital Construction requires the public clients to put demand in relation to Information - and Communicationstechnology (ICT), tender quantities and also introduces the term of information levels among others [Digital Construction (2012)].

Today the majority of all complex construction design in Denmark are performed digitally in models with intelligent objects. Either on 2D digital flow charts or in 3D digital building models [FRI & DANSKE ARK (2012)]. According to Morten Alsdorf, from the Danish consulting engineering company Rambøll, the intelligent building models has changed from not only being a service delivered to public owners on basis of DC, but also a service delivered for other (private) owners. Thus the demand of digital building models with intelligent objects are increasing at the designing companies. This fundamental change in designing buildings can be characterized as a paradigm shift, as the digital technologies provides a new way of designing construction projects by going from document based to model based methods [BIMlab (2013)].

The theory of digital modelling prescribes that it is possible to optimize and quality assure almost all parts in the construction process from programming over design and construction to commissioning with the application of new digital technologies like Building Information Modeling (BIM) [Digital Construction (2013)]. All over these technologies should have the perspective of adding value to the construction industry, but still there are some issues connected to this development, which will be outlined in the following sections.

[1] Det digitale byggeri

1.2 Building Information Modeling

Building Information Modeling (BIM) has become one of the most popular terms in modern construction history and according to one of its leading proponents *Chuck Eastman*, it is a promising development in the architecture, engineering and construction (AEC) industries [Chuck Eastman (2011)].

The precursor for BIM was early 3D modeling in the 1960s and the concept of computer modeling for buildings, which originally was developed by Shawcross in 1975, Eastman in 1975 and Yaski in 1981. In addition, object based parametric modeling was also developed for manufacturing in the 1980s. In 1987 the BIM concept came to the AEC industries in a program called 'Virtual Building' developed by Graphisoft [Chuck Eastman (2011)].

The term 'BIM' was first mentioned by Phil Bernstein, but it was Jerry Laiserin who helped standardizing and branding the term as the new technology of modeling, communication and collaboration in the construction industry [Wikipedia (2013)]. BIM has gradually becomed a widespread and acknowledged method with a potential of making the construction process more efficient. According to *Chuck Eastman* it is important to state that BIM is both a technology and a process change, but there are still many who do not know the methods and possibilities of it [Chuck Eastman (2011)]. The above history of BIM tells that the mindset and technology of BIM are not new. The actual concept was developed many years ago, but the tools and especially the branding has been a long time coming.

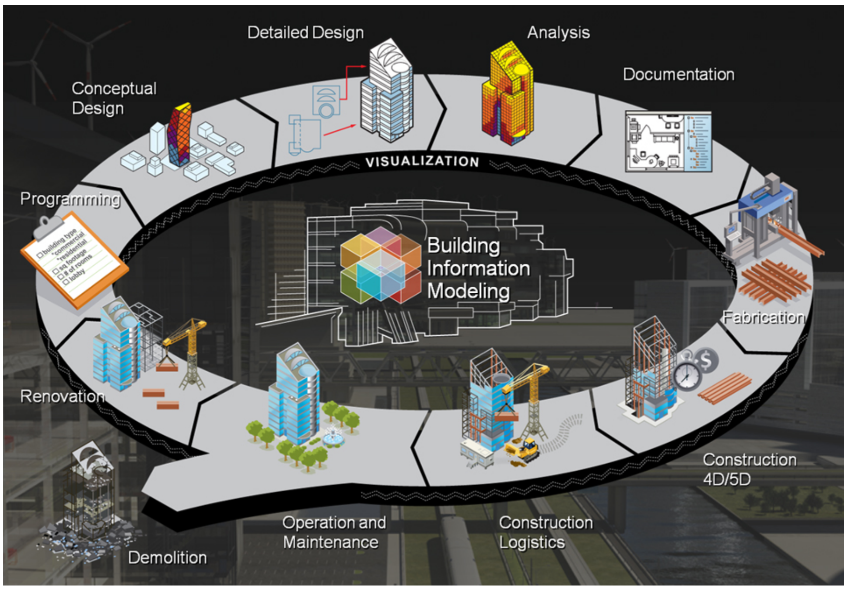


Figure 1.1: BIM illustration [buildipedia.com (2013)]

According to DC there will be a huge profit, if the construction industry can utilize BIM and thereby make sure that information and data, which once has been created in a specific project, gets handed over and used again in all following processes up to and including commissioning. The BIM technology is predicted to have the potential to fulfil this ambition, although there can be challenges regarding implementation and technical knowledge etc [Digital Construction (2013)].

There are many different opinions about BIM and its potential. But the consensus is that it represents a fundamental change in the way a building project design is prepared and implemented [Sieminski (2007)].

1.3 Problem area

The construction industry is based on a project-based production with many different collaborations, distribution of roles and division of responsibilities among owners, designers, contractors etc. Unlike a factory production, the production of constructions are never identical, hence it is harder to standardize the different processes. Instead, most of these construction projects are controlled by 'common practices' [FRI & DANSKE ARK (2012)].

One of the problems is the information handover from designer to contractor(s) in a tender based on the main project. The point of a tender is competetive bidding, which enables all interested contractors to make a bid on the project (or a part of the project) on the basis of the tender documents. The bid presuppose that the contractor understand the project, implied that it is known, what kind of work that needs to be done. More sources points out that this is not always the case and Digital Konvergens (DiKon), a cooperation between six large companies in the danish construction industry (Cowi, Grontmij, MTHøjgaard, NCC, Pihl and Rambøll), states that this information transaction causes a lot of challenges and value loss for the construction projects [Digital Konvergens (2012)]. Furthermore, if the project exceeds a certain threshold value and the owner is public (or public contribution of at least 50% from the state) the project is covered by the executive order regarding *public owner demands for the application of ICT in the construction industry* called BEK1381[2] [BEK no. 1381 (2010)]. This implies among others that a *Digital Tender* should be executed instead of a normal tender. The special aspect about the digital tender is that the owner should demand for 3D digital building models, classification, measurement rules and tender quantities in the tender documents from designer to contractor in order to achieve aforementioned digital potential. In particular the fact that the designer has to measure quantities instead of the contractor is a new implementation, which should give the contractors an equal basis of making a bid.

In that connection The Danish Construction Association published a report called *The Contractor Potential, Challenges and Demand for Digital Tender* in June 2012 [Flemming Grangaard (2012)]. One of the main conclusions in this report is that the tender documents, which is prepared by the designer on behalf of the public owner, does not meet the demands of the majority of the contractors. In other words, in relation to the digital tender there is gap between what the contractor demands of bidding information basis to the information that the designer delivers. This is illustrated in Fig 1.2.

[2]Bekendtgørelse 1381 af 13. december 2010

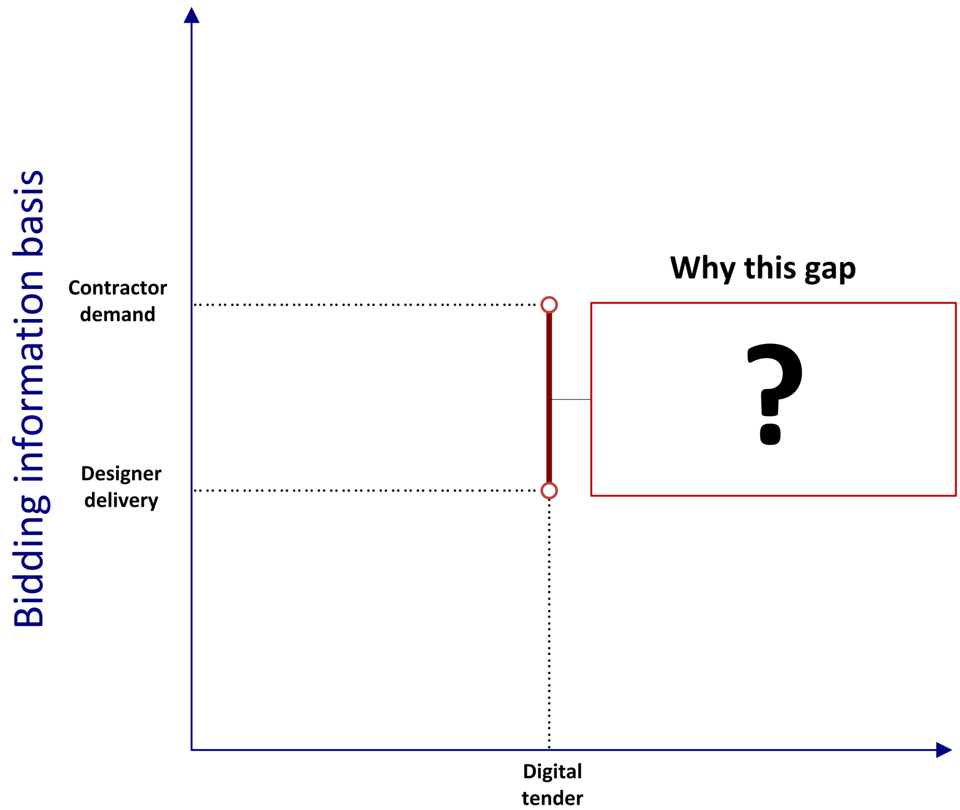


Figure 1.2: Insufficient bidding information basis for the contractor

In proportion to this the report suggest that it would be desirable if the contractors recieved standardised tender documents, which was based on editable data and contained BIM models and tender quantities on a appropiate level of detail. According to DiKon the tender documents in a digital tender leads to several problems on both the designer and contractor side, which is illustrated on Fig 1.3.

Based on those problems this thesis will investigate the tender documents for HVAC contracts, whom in particular are embraced by the challenges represented in Fig 1.3. The focus will be on the tender quantities (with reference to other tender document parts) as those by many are characterised as the focal point in the digital tender documents.

1.4 Thesis

The overall purpose of this thesis is to analyse if the handover of digital models and the exchange of tender quantities from engineer to contractor can be optimized. Hence the approach will be to investigate why the information gap in relation to the tender list with quantities exist. This implies a further investigation of the topics mentioned by DiKon in Fig 1.3. In addition, the emphasis will also be on making visible the potential of early involvement of contractor. To elucidate the thesis the following problems will form the basis of this report:

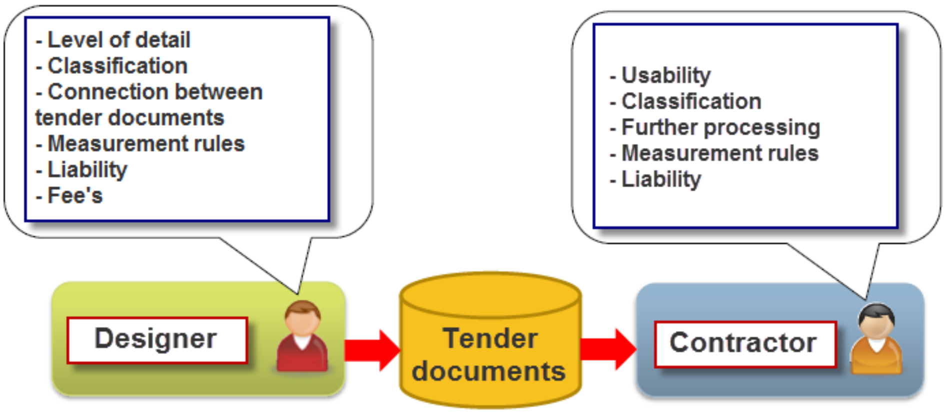


Figure 1.3: Challenges for both designer and contractor in a digital tender [Digital Konvergens (2012)]

- Which problems underlies for the digital tender documents for both designer and contractor in relation to HVAC contracts?
- How can the speficic problems identified be solved? In addition, is it possible to solve all problems due to current framework conditions of the construction industry?
- Is it possible to optimize the handover process from design to construction by rethinking the way of tendering?

On the basis of those questions the intention is to identify problems, to solve them within current conditions and to reconsider the mindset of designing a building.

1.5 Objectives

The aim of this project is to inspire the construction industry in generel including the AEC companies, The Danish Construction Association, Danish Building and Property Agency[3], Danish Business Authority[4] and other relevant authorities to implement necessary initiatives or standards, which will lead to transparency and make the industry able to acquire the huge economical potential, which is postulated in connection to digital design and digital tenders. In addition, the intention is to stimulate the initiation of a number of initiatives to standardize and thus streamline the digital tenders.

[3] Bygningsstyrelsen
[4] Erhvervsstyrelsen

1.6 Delimitation

This master thesis is preferential pointed at the danish constuction industry, hence the reference will be danish legislation, norms and standards. However the theory applied can originate from other countries. In the danish construction industry it is mainly the relationship between designer and contractor, which is being handled with a special intention on the informations shared between them in a tender or in another kind of collaboration. The focus is on the digital tender documents and in particular the tender quantities.

Since the digital tender can be executed in various kinds of contracts and project organisations, it is important to outline which kinds of contracts, that are being analysed in this thesis. The thesis investigates the digital tender for the common contract forms in Denmark, which are based on the main project:

- Individual trade contract[5]
- Prime contract[6]
- General contract[7]

As a simplification the three contracts will be treated as equal, because they from a designer to contractor tender perspective are quite similar. Moreover these three contracts are also mentioned together in the digital tender section of the executive order for demands in application ICT in construction projects [BEK no. 1381 (2010)]. The turnkey contract[8] is ignored in the perspective of analysis due to significant difference, but it will be handled seperatly and used for a discussion about early tenders. Besides these common contracts the project also seek to investigate how to perform a tender in collaborative forms of project deliveries. This is done through a theoretical investigation and discussion of the american concept Integrated Project Delivery (IPD).

In generel this project applies to the BIM way of working and for the public projects covered of the ICT executive order, thus the application of BIM models is a requisite for the use of this report.

1.7 Structure and reading guidelines

The report is divided into nine chapters, which are described in this section.

Chapter 1 - Introduction, scope and motivation: This chapter introduces the AEC industry, the relevant technology and the problem area. The relevant problems are summarized in a thesis (problem statement) with subsequent objectives and delimitation of the master thesis.

[5] Fagentreprise
[6] Storentreprise
[7] Hovedentreprise
[8] Hovedentreprise

Chapter 2 - Methodology: The pre-understanding and the overall indexation of the problems is desbribed in chapter. The methods used are a literature review, case study and interviews, hence this chapter is reporting why they are chosen and how they are applied together in the problem solving.

Chapter 3 - Framework conditions of the construction industry: This chapter outlines the current conditions in the Danish construction industry, comprising contractual forms and ICT

Chapter 4 - Theory: This chapter will on theoretical basis investigate BIM and related topics like IPD and IDM in relation to the digital

Chapter 5 - Cases: This chapter outlines the main case Mærsk Bygningen and the two other cases, which are used as empirical for the analysis

Chapter 6 - Tender documents in a digital tender for HVAC contracts: This chapter will analyse the tender documents of the three cases and outline problems

Chapter 7 - Discussion: This chapter discuss the problems on basis of the analysis and comes up with suggested solutions

Chapter 8 - Conclusion: This chapter sum up the relevant findings of this thesis

Chapter 2
Methodology

In a thesis like this it is necessary to consider different approaches in order to solve the problem statement. This chapter outlines pre-understanding of the different terms used, how the different topics are handled and gives an overall indexation of the suggested solutions. Moreover it clarifies for the three methods used; literature review, interviews and case study.

2.1 Pre-understanding

This section deals with perception of the different terms related to contracts, tenders and BIM including what is implied when using the different terms. This is important as the terms are used indiscriminately during the thesis. Moreover a short description of the different construction industry organisations are provided.

2.1.1 Digital tender

The term 'tender' is also used as the term 'procurement' since both covers the idea of providing material for the bidding contractors. Moreover the term 'digital tender' refers in this thesis to the definition presented in the executive order for public owners [BEK no. 1381 (2010)]. Furthermore, when using the term it is implied that tender quantities is included in such tender. In addition, when using the term 'tender list with quantities' it is implied that it consist of a tender list and a quantity list as supplement.

The difference of making a digital tender with quantities and a traditional tender, is among others that the designer measure the quantites. Previous this was done by the bidding contractors, who measured the quantities each in their own way. This change means that the designers gets more responsibility and simultaneously the bidding contractors do not have to do the quantity measurement. This implies that there is the same conditions for all the bidding parts.

This is meant to add value to the owner, who is getting a more exact and transparent price, as the designer has most knowledge at that stage for making quantity measurement. It means that there is a correlation between the designed quantities and those who gets tendered to the contractors.

2.1.2 Contracts

As presented in the previous chapter this thesis only deals with the common danish contract forms and the american concept IPD. The thesis will in general be distinguishing between the two kinds of contract forms:

- Late tenders (Design-Bid-Build): General contracts, Prime/Individual contracts
- Early tenders (Design-Build): Turnkey contracts, Integrated project deliveries (IPD)

Where the main difference is that DB contracts are tendered on an earlier basis and emphasises the early involvement of contractors and simultaneous there is no actual tender from designer to contractor. The terms *late tender* (DBB contracts) and *early tender* (DB contracts) are specified in the framework conditions chapter of the construction industry.

In relation to the analysis of HVAC tender documents including digital handover, the DBB contracts are interesting because they have an actual tender from designer to contractor. As there exist an endless list of different contract forms with combinations of each other, the perception of a DBB contract in this project is illustrated in Fig 2.1. Thus the point of treating the DBB contracts equally is that the information from designer to contractor often will end up at a specific contractor in a similar way as shown in Fig 2.1.

The DB contract includes the wellknown tradtional turnkey contract and all the new collaborations and organisation forms that supports the early involvement of the contractor. In this thesis the american concept IPD will be used as discussion basis in the last chapter. The perception of both the turnkey contract and the IPD are illustrated in Fig 2.2. In relation to BIM the IPD is interesting as the BIM Handbook [Chuck Eastman (2011)], postulates that early integration and collaboration are the keys to effective use of the BIM technology.

2.1.3 Digital building models

There is many perceptions of the idea of a digital building model, hence three different terms will be used; *3D model*, *Object based model* and *BIM model* based on the BIM handbook [Chuck Eastman (2011)]. The perception of each is illustrated in Fig 2.3. For that matter it is implied that in relation to a digital tender regarding digital quantity measurement either an *Object based model* or a *BIM model* are needed to accomplish this task. In proportion to the understanding a *BIM model* is also an *Object based model*, but an *Object based model* is not necessarily a *BIM model*.

2.1.4 Relevant organisations in construction industry

In this thesis many different organisations from Denmark and other countries is mentioned. Below is a list of all these with a short description.

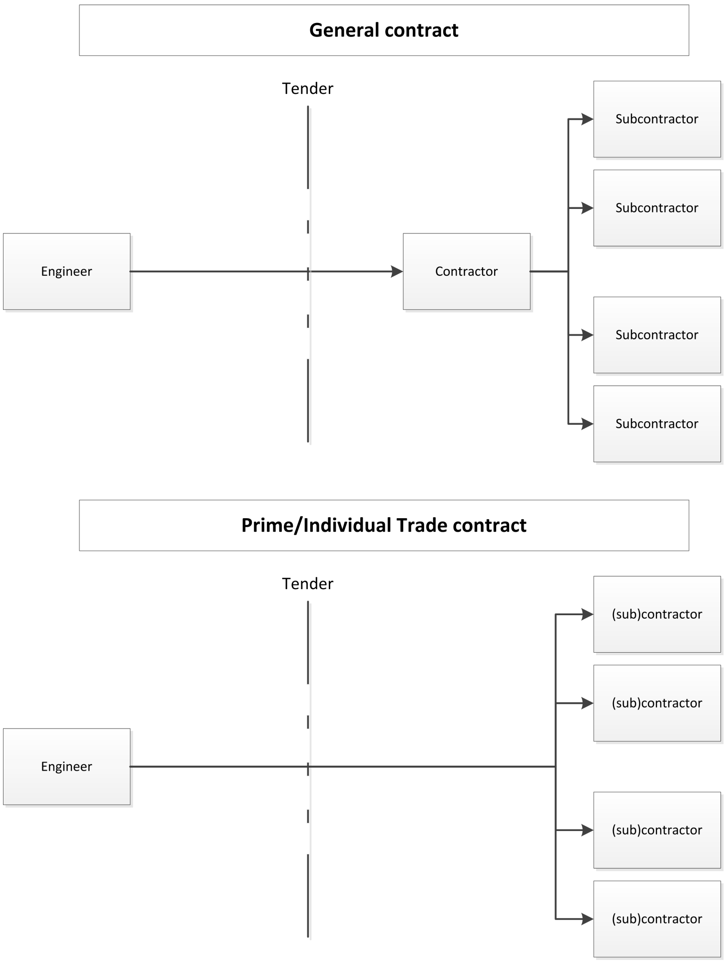


Figure 2.1: Illustrations of the DBB contracts

The Danish Construction Association An employers' organisation for approximately 6.000 companies, comprising about 70.000 workers from contracting and manufacturing companies within the Danish building and construction sector.

The Danish Association of Consulting Engineers (FRI) A trade association of Danish consulting firms providing consulting services, planning and project management on a technical-scientific basis.

BuildingSMART The "trademark" for the international collaboration about open standards for BIM (earlier known as the International Alliance for Interoperability). With support from more than 25 countries the organisation is working on developing and spread open standards for the exchange of object based model data.

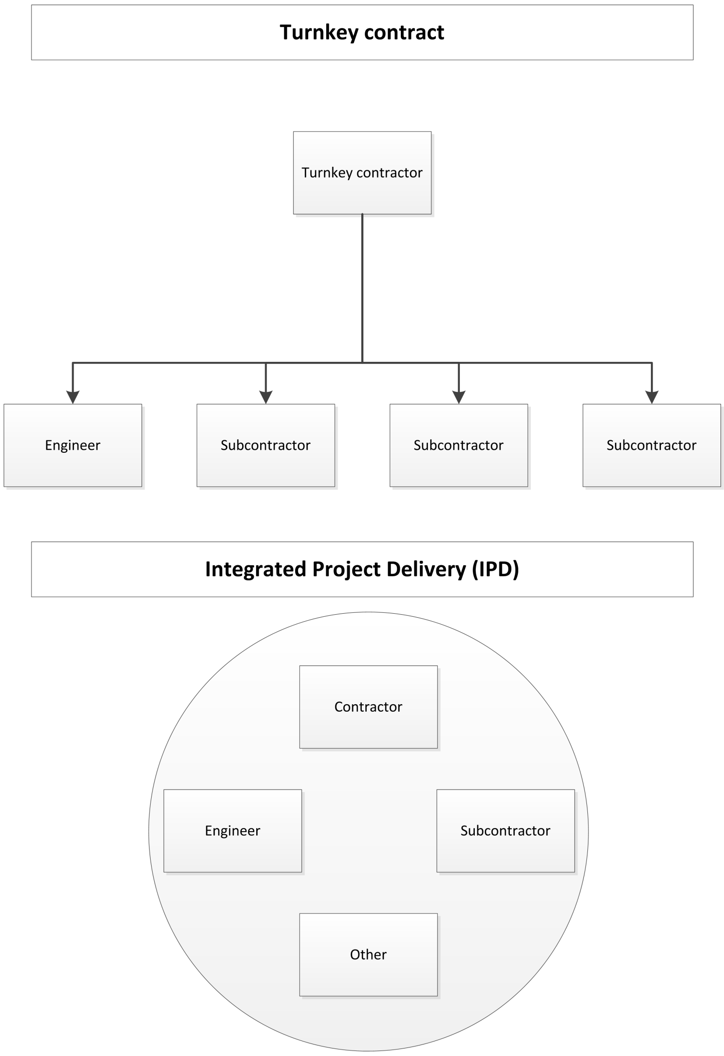


Figure 2.2: Illustrations of the DB contracts

Bips A Danish memberdriven non profit association for the construction industry companies. BIPS is an abbreviation of Byggeri (Building), Informationsteknologi (Information technology), Produktivitet (Productivity) and Samarbejde (Cooperation). It is a common digital development- and tools forum for the building and construction industry.

Digital Construction A Danish government initiative meaning that governmental owners should make a number of demands related to Information and Communication Technology (ICT) [BEK no. 1381 (2010)]. These demands aim to ensure increased and improved knowledge-sharing between the parties of the construction sector. Moreover DC is also behind a couple of other initiatives.

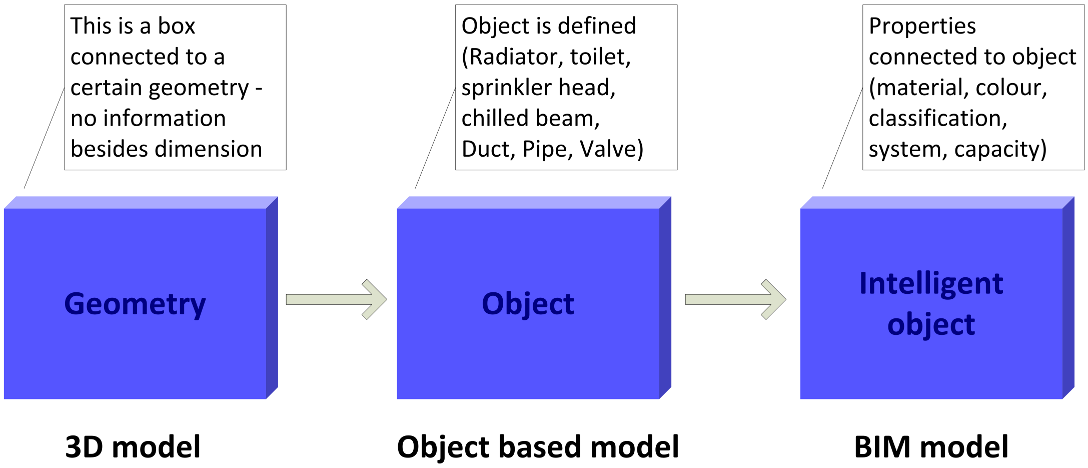


Figure 2.3: Illustrations of the the different digital building models

The American Institute of Architects An American leading professional membership association for licensed architects, emerging professionals, and allied partners.

Cunego A Danish development project going to 2014. Cunego develop, test and implements common standards for improved exchange of data through all construction phases. Cunego is driven by BIPS in a partnership with many other construction organisations.

2.2 Overall approach

The overall approach is first to analyse the HVAC tender documents from both a designer- and a contractor perspective. This analysis is mainly supported by the case study of 'Mærsk Bygningen' and two other cases, which all are carried out as digital tenders of individual trade contracts. The analysis of 'Mærsk Bygningen' relies on the tender documents for the HVAC trades, but as the tender documents for HVAC first will be put out for tender in March 2013 (same time as handing in this master thesis), it has also been a task to produce this material. Thus the understanding of the produced tender documents of 'Mærsk Bygningen' and the process of producing this digital tender with quantities will contribute to a great extent for this analysis. On basis of the analysis a discussion is made with the view of providing suggestions or solutions to the specific problems identified.

The last discussion point will be to investigate the opportunity of implementing IPD contracts in Denmark. This analysis is based on the experience from America, where the AIA has published literature for the use of IPD [AIA (2012)]. It will be investigated how IPD or parts of the IPD concept is carried out and how it will change the framework conditions of the Danish construction industry if implemented.

2.3 Indexation of suggested solutions

When analysing the above mentioned areas, it is possible that some suggestions are simple, whereas some requires fundemental changes. For instance it can be a specific software problem or the specific contract form, which is conflicting in order to fulfill the ambition of delivering the right informations for the contractor. To avoid these completely different problems and suggestions to be mixed up, the problems and related suggestions will be indexed in a top-down pyramide as shown in Fig 2.4. One of the points is that when going down in the pyramide the implementation is harder [Liebich (2012)].

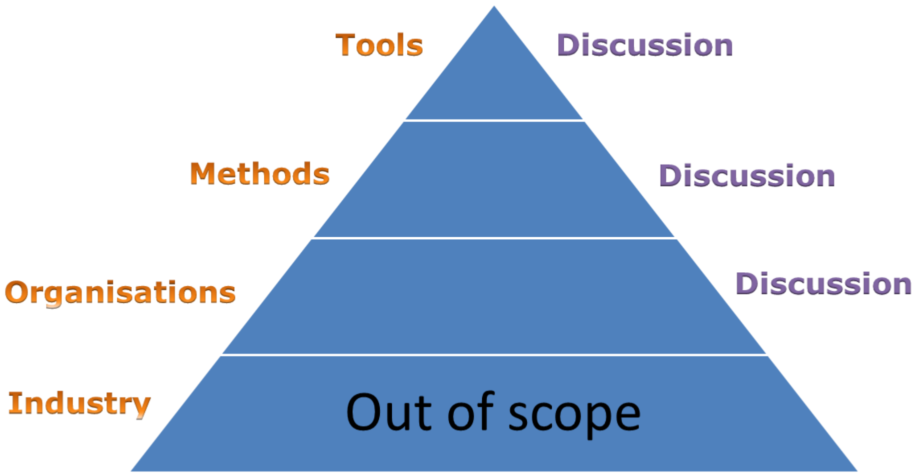


Figure 2.4: Change management pyramid [Liebich (2012)]

In other words, the different kind of problems identified requires a sort of action on either the tool-, method-, organisation or the industry level. As illustrated this thesis will only operate on the first three levels. This indexation is intended to give a more clear structure in the discussion chapter. Examples of actions on each level are mentioned below.

Tools: Change softwares

Methods: Create standards/Information Delivery Manuals

Organisation: Change contract forms

Industry: Amendments

2.4 Empirical evidence

As a basis of solving the thesis three empirical evidence methods has been used; literature review, interviews and case study. All three are clarified in the following sections.

2.4.1 Literature review

The literature used in this thesis can be divided into two parts. One part adressing the framework of the construction industry in Denmark and another part adressing theories related to BIM and IPD. The framework of the construction industry in Denmark is naturally based on Danish studies, whilst BIM and IPD are primary based on American studies.

The danish construction industry is outlined from various of books, articles and websites. Worth mentioning sources is the organisations Bips, PAR & FRI, DC, The Danish Construction Association and DiKon. Furthermore, the publications from [Anlaegsforeningen (2011)], [Naldal (2011)] and [vaerdibyg.dk (2010)] has been contributing to this section.

The BIM theories is mainly from the BIM Handbook [Chuck Eastman (2011)] and other American studies. This is done due to the fact that America is seen as an innovator on the field of BIM and IDP. In addition the IPD study is based on publications from The American Institute of Architects [AIA (2012)], who was the inventor of that concept.

2.4.2 Case Study

In general the case study can be defined as an intensive analysis of an individual unit (as a person or community) stressing developmental factors in relation to environment [Flyvbjerg (2006)]. In this context it is a way of investigating the real world situation in a specific construction project. As this thesis is time constrained it has only been possible to follow a narrow selection of the project. This selection has been in the late design phase up to tender as it fits well into the problem area.

The choosen case is Mærsk Bygningen (formerly known as 'The extension of the Panum complexes') in Copenhagen, which is being designed by C.F. Møller, Rambøll and SLA. The basis of this case study is Rambøll, where the tender list with quantities for the HVAC contracts are being produced as a part of this thesis. Mærsk Bygningen is a 42.000 m^2 construction project with an estimated construction cost of approximately 1.3 billion DKK. This case has been choosen for several reasons:

- Prestigious and complex project in Denmark
- Project covered by ICT executive order for public owners, whick implies 'digital tender'
- Designer intends to use BIM models for QTO
- EU tender directive involvment

As seen above there is many interessting things in relation to the scope of the project. The method of data collection will be done in relation to the production of the digital tender with quantities for the HVAC trade contracts. Furthermore, participation on meetings within the HVAC trade group and through conversations with BIM related project members has contributed to this emperical data collection.

2.4.3 Interviews

In the project it is also choosen to collect data through qualitative interviews, as it is very time consuming to set up and to process objective quantitative data from a questionnaire. In addition, the use of interview also makes the investigation realistic because this method gives a data basis of opinions of those interviewed.

The interviews can be characterised as partly structured, which means that for the interviews questions are expressed as open and prepare the ground for dialog [Andersen (1998)]. This gives a certain flexibility while maintaining the structure in the interview. The structure ensures that it will be possible to compare the different opinions and statements from respondents even though it is qualitive data. The interviews used is related to either the main case Mærsk Bygningen, the two sub cases or the generel perspective of digital tender documents. The main case study is providing a small segment of real-world conditions, which can be difficult for generalization. Hence the interviews should embrace a more broad perspective which combined with the case study should form a solid argumentation.

Interviewees

The interviewees are showed in Table 2.1 and should represent three participants from both sides in relation to designers and contractors. Thereby the thesis achieves kind of equilibrium regarding different opinions among the participants.

Table 2.1: Overview of interviewees

Interviewee	Position	Company/organisation	Perspective
Niels Treldal	Project manager HVAC	Rambøll	Designer
Morten Alsdorf	Project manager Structures	Rambøll	Designer
Martin Nielsen	Project manager HVAC	Moe & Brødsgaard	Designer
Freddi Lading	Bid actuary HVAC	Brøndum	Contractor
Carsten Kramer	Bid actuary HVAC	Henriksen & Jørgensen VVS	Contractor
Flemming Grangaard	Chief consultant	Danish Construction Association	Contractor

Chapter 3

Framework conditions of the construction industry

This chapter is based on existing literature focused on the framework conditions in the construction industry and the ICT in Denmark. Although the main subject is digital handover of model and data in proportion to the digital tender documents, it is important to introduce other related terms and subjects to describe it. Therefore, this chapter will outline the liability topic including phases of construction, organization, tender forms and other generel contract conditions. In other words this chapter outlines the rule of the game in the industry.

3.1 Construction phases

Construction projects can be complex to concieve, build and operate. Many participants needs to cooperate to create one single product, which has to fulfil expectations from the owner, the user, authorities etc. The process of a construction, from the owners first idea to the daily use, can be described through a number of phases, which all major construction projects goes through. The content of each phase is not always the same as it vary from project to project. The content depends among others on which project contract that is used in the specific project [Naldal (2011)].

Figure 3.1: The traditional phase subdivision of a construction project [Naldal (2011)]

The traditional construction life cycle process can in generel be divided into four phases (or more in a fine-grade subdivision) as seen in Figure 3.1. This common perception of a phase model in Denmark is build on the Description of Services [FRI & DANSKE ARK (2012)]. The construction process is initiated by the owner and it can be carried out in several ways depended on the project contract chosen.

The process in between the different phases is called the phase change. This change is relevant for this project as it coincide with the handover of digital model and data. The phase change is by many called the 'weak point', and many thinks that a lot of knowlegde and value is lost during this process. The main cause is that the project reshape and changes hands. This is where the project participants meet and hands over the project from one competency to another. The challenge is how to keep the owners and the users value through the whole construction process. To do so it is important to focus on cooperation, communication, contractual basis, matching of expectations, organization and decisions [vaerdibyg.dk (2010)].

3.2 Contractual form

The contract form is also pivotal for how the business partners form part of the building process organization. The owners choice of project contract is often depended on the owners experience and the extent of the construction project. Traditionally there is two main contract types, which distinguish on time where the owner chooses his partners; 'early tender' and 'late tender' [Anlaegsforeningen (2011)]. These terms can be connected to Design-Build (DB) and Design-Bid-Build (DBB), which corresponds to the American terminology [Chuck Eastman (2011)].

3.2.1 Late tender (DBB contracts)

The late tender or DBB contracts are covering the traditional tenders where the main project is the tender basis. Overall the late tender emphasize the owners opportunity to impact on the functional, aesthetic or other areas in details.

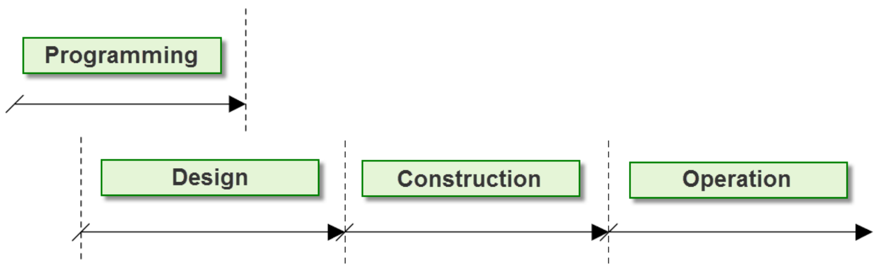


Figure 3.2: Illustration of the DBB contract form [Anlaegsforeningen (2011)]

DBB contracts can be divided into three different types of contracts; individual trade contract[1], prime contract[2] and general contract[3]. The DBB form consists of two tendering stages. The first stage is before the design phase where the design will be tendered to architects and engineers. Second stage involves obtaining bids from contractors, which is placed later on in the process than the early tender.

Individual trade contract

The individual trade contract fits the traditional trade division of a construction and gives the owner the opportunity of doing business with specialised companies. Moreover the owner also has the direct contact to the single trade contractor. As there exist a considerable number of contractors within each trade, the competition is increased, which all things being equal, will lead to lower prices. The individual trade contract involves many internal stakeholders, which is why it demands a careful planning and management of the building process. The owner risk is compensation claim, if the timewise requisites do not last for delayed contractors [bygningsstyrelsen.dk (2012)].

Prime contract

The owner can achieve a simplification of the building management tasks by choosing a prime contract instead of an individual trade contract. This happens by gathering associated trade contract into bigger socalled prime trades. This will affect that there will be less trade contracts to manage and coordinate. By adding up small individual contracts the owner might also avoid that delays of those small contracts leads to compensation claims. The fact is that it can be hard to demand payment from the contractor that caused the delay [bygningsstyrelsen.dk (2012)].

General contract

The next level is a general contract where the owner only contract with one contractor. The management and coordination of the individual trades passes from the owner to the general contractor, whom usually lets many individual trades get subcontracted. Thus the general contractor includes a general contractor fee in his bid. The owner has no contractual terms with the subcontractors, but only relate to the general contractor. Furthermore, the owner should aware in the selection of contractors during competitive bidding, that the selected general contractor should have the qualifications to manage the building process and the economical capacity. Since not every contractor are able to undertake the role as general contractor, the competition is often smaller than in an individual trade contract, which might influence the price of bids [bygningsstyrelsen.dk (2012)].

3.2.2 Early tender (DB contracts)

When using early tender or DB the tendering process happens after the programming and that type of contract is in Denmark refered as the traditional turnkey contract. In this process, the owner contracts

[1] Fagentreprise
[2] Storentreprise
[3] Hovedentreprise

directly with the DB team which, according to Chuck Eastman, normally will be a contractor with a design capability or working with a designer [Chuck Eastman (2011)]. The DB contractor then defines a schematic design that meets the clients and after this an estimation of time and cost is carried out.

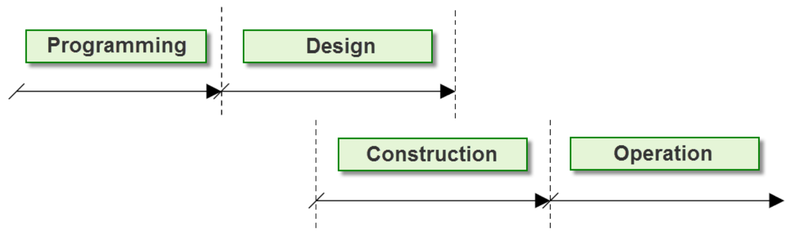


Figure 3.3: Illustration of the DB contract [Anlaegsforeningen (2011)]

Turnkey contract

The turnkey contract covers all services among designing and all the represented trade contracts. In practice the turnkey contractor will on basis of a dialog with the owner, suggest designers and subcontractors. Moreover, the turnkey contractor manage all planning and management tasks. The advantage is that the owner only have to contract with one company. Moreover by choosing a turnkey contract it is noticeably faster to start the project than other contracts, since the EU tender law is avoided. On the other hand the owner has less feeling with the project and the quality [bygningsstyrelsen.dk (2012)].

Integrated project delivery

IPD is a relative new American concept of a contract organisational form, which also prepares the ground for rethinking the traditional phase model in Fig 3.1. It is a multiparty collaboration agreement, where all disciplines works as they are only one company. The goal of IPD is to reduce project time, reduce costs, have no trials and a more smooth process for the whole project team [AIA (2006)]. The American Institute of Achitechts (AIA) is one of the main developers of the concept and they define IPD as:

> *IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication and construction.*

The AIA California Council (2006)

The IPD concept resemble partnering on many areas, but it differ on some areas as it also includes elements from LEAN and BIM. The IPD will be described further in the next chapter of theories related to BIM and discussed in the last chapter.

3.3 Contractual basis

Besides the overall contractual- and organisation form in Denmark there is the contractual basis. The contractual basis consists of several documents and additional agreements. The most important are:

- Description of Services 2012 [FRI & DANSKE ARK (2012)]
- ICT-specifications [Bips (2011)] and Information Delivery Manuals [buildingSMART (2012)]
- Normal Conditions for Technical Consultancy and Support[4] [ABR 89 (1989)]
- Normal Conditions for Worker and Deliveries in Building- and Construction companies [5] [AB 92 (1992)]
- Normal Conditions for Turnkey Contracts[6] [ABT 93 (1993)]

Description of Services serves as a basis for providing consultancy in connection with building and planning, whereas ICT specifications is more an additional agreement based on digital design [FRI & DANSKE ARK (2012)].

Furthermore there is some standard contracts for designers and contractors. When the building owner has to enter into an agreement with designers or contractors, the owner is by default exempted from the common frame of Contracts Act[7] with regard to the layout of the contract. As there is many conditions and participants, it has been chosen to develop specific standard documents for the building sector. There is three significant documents regarding the role of the owner, the designer and the contractor, which mostly are connected as seperate agreements for a standard contract: ABR 89, AB 92 and ABT 93. Overall these documents describes the consultant's and contractor's services, responsibility and remuneration in relation to the owner.

It is important to state that these three documents are not Danish law but a contractual basis and therefore as basis it needs to be agreed by the parties to become valid. The essential parts of only the two documents ABR 89 and AB 92 are sketched below as ABT 93 is more like a special case of turnkey contracts. The paragraphs of relevans in connection to this project is described in the following subsections.

[4] Almindelige Bestemmelser for teknisk Rådgivning og bistand
[5] Almindelige Betingelser for arbejder og leverancer i bygge- og anlægsvirksomhed
[6] Almindelige Betingelser for Totalentreprise
[7] Aftaleloven

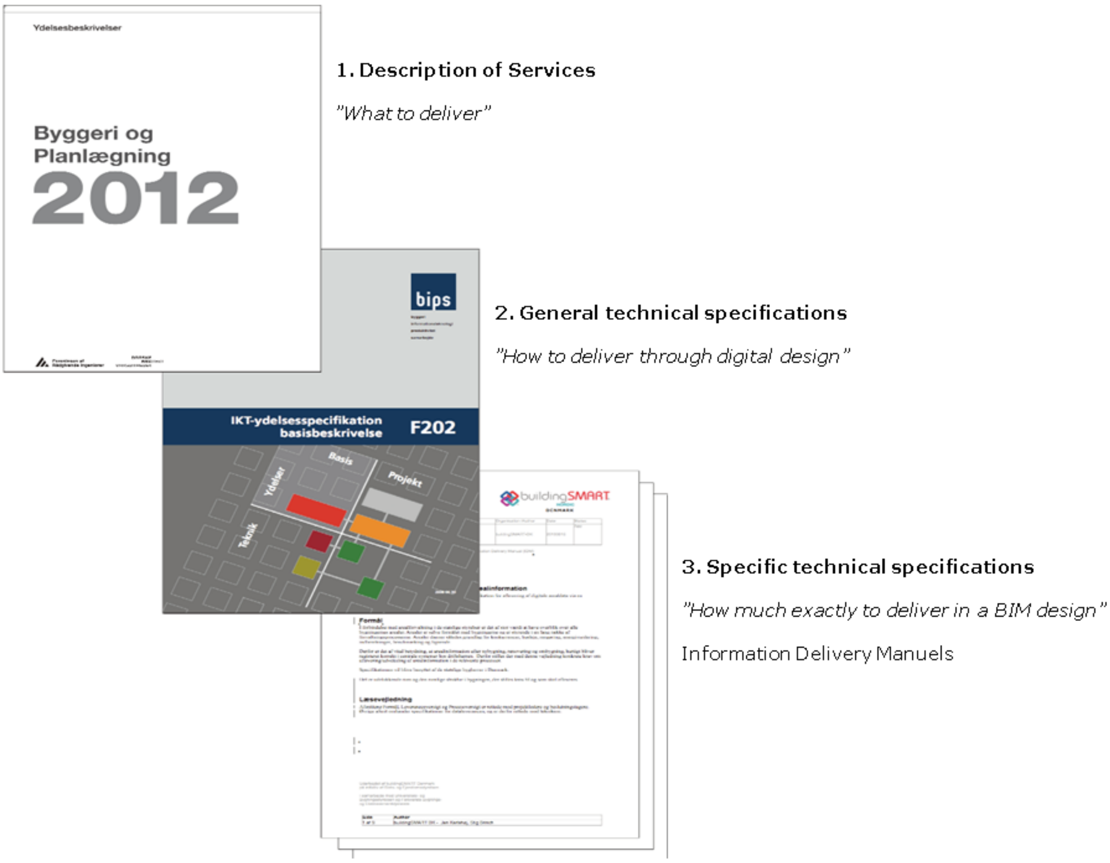


Figure 3.4: Digital agreements [FRI & DANSKE ARK (2012)]

3.3.1 ABR 89

This basis document forms the agreement between the owner and the consultants (engineers and architects). The client in this case can be refered as the owner, another cosultant in relation to sub-consultancy or a turnkey contractor.

1.2.1 *The client shall be responsible for the contractual study of drafts prepared by the consultant for tender documents, acceptances, contracts etc.*

4.1 *The client, to the extent agreed or assumed in the agreement, shall be entitled to use the material, which has been worked out for carrying out the assignment. The consultant retains all rights to his ideas and the material prepared by him.*

6.2.1 *The consultant shall be liable under the provisions of Danish law concerning compensation for errors and negligences in the performance of the assignment*

3.3.2 AB 92

This basis document forms the agreement between the client and the contractor. The client in this case can be refered as the owner or another contractor dealing with a subcontractor.

§2.2 *The bids are made on the basis of the informations contained in the tender documents. This material must be precise and designed in a way that it is transparent in relation to service extent and content*

§11 *The client is able to decide, through the tender documents, that the contractor must participate in a project review. Furthermore, conditions about the extent of tests that the contractor needs to submit, can be specified. These specifications can form part of a tendering control plan. Participation in the project review, the provision of the documentation and the tests are a part of the contractor deliveries*

3.4 Information and Communication Technology (ICT)

The use of ICT in the construction industry has been discussed over the last couple of years, but a common perception is that when doing a digital design then there will be a need for technical agreements - which informations is exchanged when, how and between who. The challenge is to configure the agreements in a way, that they will not become too technical in relation to processes, formats and tools in a too early stage. The workaround is in general to adjust the ICT-specification during the process [FRI & DANSKE ARK (2012)]. The Description of Services 2012 recommends a division of agreements for digital design in three levels as shown in Figure 3.4.

1. Determination of the overall design service according to Description of Services 2012. This agreement is devised by owner/'client design advisor' in relation to programming and is signed between owner and designer in the designer contract.

2. Determination of technical guidelines for collaboration, processes and digital services are written in the ICT-specification. The ICT specification can be devised in connection to the programming and attached to the designer contract. Alternatively it can be devised by the ICT manager as a part of the design management and later on made valid for everyone in the project.

3. Determination of specific digital processes and services can be agreed on basis of an Information Delivery Manual (IDM)

3.4.1 ICT specification

The ICT specification is a collaborative agreement, where the different parties in a construction project specifies, how they agrees to use ICT in a specific construction project. It is an additional agreement, which supplement the usual service- and delivery contracts in a building project. The ICT agreement is signed between the owner and the respective parts, which is involved in the project. The main agreement document is the *ICT service specification*, which consist of a project oriented part and a basis description.

The project oriented part the ICT agreement describes all points of services in the specific building project in relation to digital communication, building models/CAD, tendering and delivery. Whereas the basis description of services forms the common frame of references. Hence the project oriented only needs to be specific on areas where the project differs from the usual frame of references in the basis description. Besides the service specification there is also an *ICT technical specification*. It provides the details for how the agreed ICT applications can be realized from a technical point of view. This specification focus on technical solutions. In practice a responsible from the different parts is choosen to maintane the ICT specifications and ensure that the agreed ICT applications is used by the participating parts through the whole project period [Digital Construction (2008)].

Public client demands for ICT

As mentioned the DC was an initiative from the Danish Ministry of Economic and Business Affairs. The initiative is based on the governments ambition to optimize the Danish building sector through national requirements. The point is that the public building politic will make the public owner a more attractive customer. High and homogeneous owner demands from the public owners influence the corporate building industry and thereby contribute to more productivity and quality. Therefore the state needs to lead the way in digitisation the Danish building sector.

Based on that there has been developed a basis and standard for the public owners ICT-requirements to the construction industry. This effort results today in the ICT client demands BEK1381, which apply to almost all public clients (expanded to municipal and regional clients in 2012) [BEK no. 1381 (2010)]. According to BEK1381, the public clients included in these rules must according to the legislation place the participants demands on:

- Classification
- Projectweb
- Digital building models
- **Digital tender**
- Digital delivery

Moreover BEK1381 is only becoming effective if the estimated project cost exceeds 5 million DKK. Since the Digital tender is essential for the scope of this thesis, the extent will be described in the following section.

Digital tender

Demand for digital tender with quantities in individual trade contracts and general contracts.

This requirement is divided into 5 parts. The point is that the public owner needs to ensure that the digital tender documents meet the following requirements:

1. There has to be a structure according to Danish Building Classification (DBK) if the building project exceeds present threshold values in EU's procurement rules
2. There has to be descriptions, which are devised on the principles in BIPS description tool B1.000 'Description instruction - structure'
3. There has to be digital building models in 3D for visualisation and information take-off on building elements. The digital building models has to be delivered in the file format IFC
4. There has to be tender quantities in the tender list and a link between the tender list and the building element specification
5. There has to be rules of measurement, in which it clarifies which services all the tender quantities includes and how the tender quantities are determined

The aim of this demand is to replace the paper based tendering- and bidding process for contracts with an electronical process. The demand has to be implemented by the owner in the tender process towards the contractor, and simultaneously the contractors has to submit their bid electronicly. Overall the vision is that the designer produce the tender documents digital in a way, that the contractor to a great extent can reuse the material in the bidding process as well as the execution. The purpose of executing the digital tender with quantities is primary to utilize the opportunities, which are present from the object based building models in 3D. Thereby the bidder is released from this traditional and resource demanding measurement work. Furthermore, the digital tender with quantities favours the wish of homogeneity and thus comparability of the incoming bids. A condition, which according to DC will optimize the process of estimating the bids [Ministry of Housing, Urban and Rural Affairs (2012)].

3.5 Tender laws

In relation to tenders and procurement there are some established rules for how to manage it. In general the Contracts Act[8] is valid, which defines a tender as:

> *Tendering is a request to put forward a bid and every bid (oral or written) is binding*
>
> Contracts Act [LBK no. 781 (1996)]

After removal of the competitive bidding law in 2001 there is no longer a demand for private building projects to be regulated by special tender rules. On the other hand when the owner is public, the application of tender law forms are determined from the kind of work and the kind of economy the project represents. Depended on the contract sum the tender is subjected to either the Danish Tender Law[9] or the EU tender directive[10]. Hence the following section will describe the rules within both laws.

[8] Aftaleloven
[9] Tilbudsloven
[10] EU's udbudsdirektiv

3.5.1 Danish Tender Law

The Danish Tender Law [LBK no. 1410 (2007)] concers the public and public supported project's tenders. Retrieval of bids on design or construction, which is included in the Danish Tender Law, has to be by public competitive bidding, limited competitive bidding or secret bidding. Moreover the provider of the tender has to create sufficient competition by outlining non-discrimination criterias and be objective with the selection of bidder and also ensure equal treatment. The following threshold values exists (all amounts are in DKK and exclusive of VAT):

Table 3.1: Danish and EU tender coefficients [Udbudsportalen (2012)]

0	-	300.000	No demand of competitive bidding or secret bidding
300.000	-	500.000	Minimum two secret biddings
500.000	-	3.000.000	Minimum three (four) secret biddings
3.000.000	-	37.200.000	public or limited competitive bidding
37.200.000	<		EU tender directive

Secret bidding is tenders, which is not gathered by competitive bidding or on basis of a framework agreement. Besides secret bidding, public procurement or limited competitive bidding there is also a couple of other forms of tenders. Those are not introduced in this project. The relevant information from Table 3.1 in relation to 3D modeling and tender list with quantities, is that in public building projects with a budget exceeding 3 mio. DKK, it is demanded that a competitive bidding process is conducted. This means that from a practical point of view some things needs to be taken into account. Among others it is not allowed to mention product names in the tender documents directly, but the expression 'or similar' has to be used. This can cause problems in relation to the 3D model as some softwares are built on product specific components.

3.5.2 EU tender directive

As the Danish Tender Law, the EU tender directive also has the purpose of limiting discrimination and differential treatment in tender cases. A project must be put out in EU tender if the total contract sum is estimated to exceed a given threshold value (current 37.2m DKK) [Udbudsportalen (2012)]. The directive supports the tender documents function to provide sufficient and complete description of the tendered task. This is done by giving technical specifications cf. Art. 23(8) of the EU tender directives:

> *Technical specifications shall not refer to a specific make or source, or a particular process, or to trademarks, patents, types or aspecific origin or production with the effect of favouring or eliminating certain undertakings or certain products*

The above is a tightening of the application of reference products and means that the expression 'or similar' cannot be used in a EU tender. This is a radical change as there has been a widespread practice of refering to trademarks [Bech-Bruun (2010)].

Chapter 4
Theory

The objective of this chapter is to present the technology of Building Information Modeling (BIM) in a theoretical perspective. The main aspect is to provide an understanding of BIM including the potential and opportunities of using BIM. The perception of BIM in this chapter follows in general the *BIM Handbook - A Guide to Building Information Modeling* [Chuck Eastman (2011)].

4.1 Building Information Modeling

Chuck Eastman claims that BIM has the potential of adding value to all construction processes and also all stakeholders involved in a building project [Chuck Eastman (2011)]. This section will not go through all of these, but only a general definition and the themes who adresses focus on the design, digital handover and tender process.

4.1.1 Definition and vision

Many sourches agrees on one thing - BIM is not just simply a 3D model or a type of software [Chuck Eastman (2011)]. But except from that fact there exists a lot of different defintions for BIM. In many ways BIM shares the same vision as the Digital Construction, which among others are greater productivity, efficiency, and quality in all business processes throughout the life cycle of a building facility. The main difference between a regular 3D model and a BIM model, is that every building elements are modelled as geometric objects containing informations (specifications, classifications etc.) and attributes (length, size etc.) as shown earlier in Fig 2.3. Moreover a 'true' BIM model is parametric, which makes it possible to change dimensions on elements by which the rest of the elements adapt according to this change [Chuck Eastman (2011)].

On that basis the BIM technology has been a driver in relation to the development of BIM tools. These tools gives the opportunity for cost estimation, time scheduling, energy analysis, operation and maintenance data, bill of materials and much more. Thus in relation to tender documents it is possible to generate different kind of useful data, e.g. drawings or a tender list with quantities. Furthermore, BIM models can be exported crosswise different softwares, which is useful in order to perform different

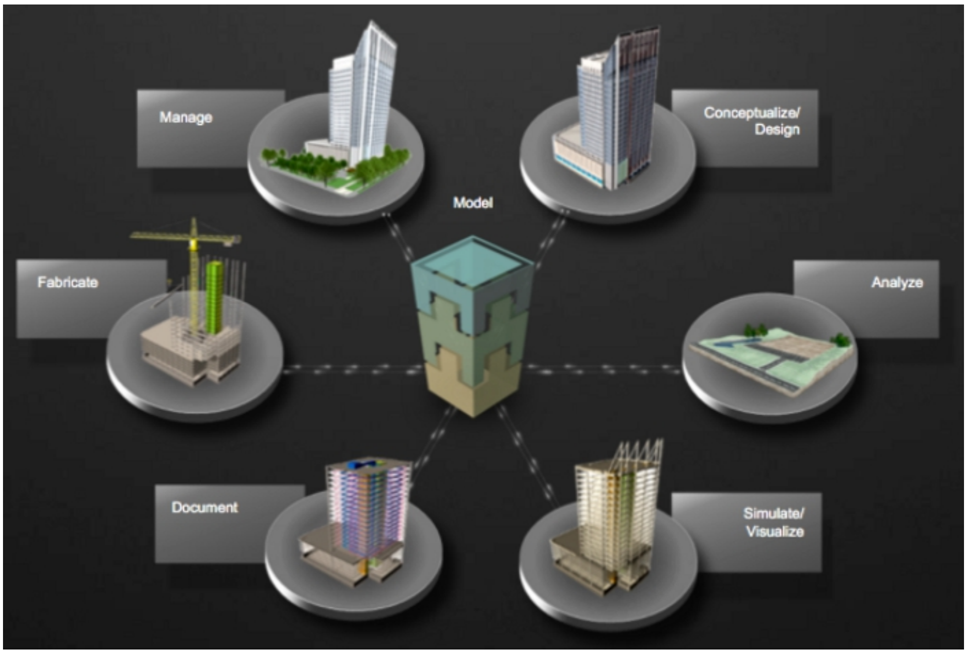


Figure 4.1: BIM overview [Autodesk (2010)]

analysis to the model. The data format is called Industry Foundation Classes (IFC).

According to Chuck Eastman it is important to state that BIM is not just a technology change, but also a process change. In continuation hereof BIM not only changes how building drawings and visualizations are created, but also alters all of the key processes involved in designing a building. Thus there is lot of different definitions focusing on either technology, process or an intelligent building model. In addition, there is an opinion that the building industry has to change processes to avoid reducing BIM to a simple 3D tool [Dana K. Smith, Michael Tardif (2009)]. In that connection Chuck Eastman states that there are visions in the near future of taking BIM to a higher level and impact the construction contracting due to closer collaborations among designers and contractors [Chuck Eastman (2011)]. This comes from the statement that BIM provides considerably more advantages in the context of design-build and integrated project delivery type procurement arrangements. The idea is that as design and construction companies gain experience with BIM, they will recognize the added value that can be achieved. The assumption is that it will push them to move building procurement from DBB to IPD arrangements.

4.1.2 Information levels

When dealing with BIM models, the Digital Construction defined the term of 'Information level' to describe the degree of detailing a BIM model. An information level is an indicator of the specification of the building objects in the specific trade model. Hence the trade model contains specific building elements in shape of building objects with a certain level of detail and properties. In this concept the basis is seven different information level with an increasing clarification [Bips (2006)]. One 'demand-model' (no geometry) and six other different level of details of the BIM model.:

0. Demand-model (owner programming, demands, terrain, building site etc)
1. Visualisation of suggested solution (volume and space models)
2. Decision-model (functional properties, constructability)
3. Scheme design
4. Tender project (basis of tender, calculation and plan of prodcution)
5. Construction project (basis of production)
6. As-built model (as-built documentation for operator)

Those seven level are sketched in Fig 4.2 to illustrate the concept of increasing clarification. Depended of the tender form, the project organisation and the wishes of the owner, the different parts can decide whether to use the information level or other milestones. However it is a prerequisite for the model based working process, that there is an agreement about which informations can be reached at a certain information level [Digital Construction (2010)].

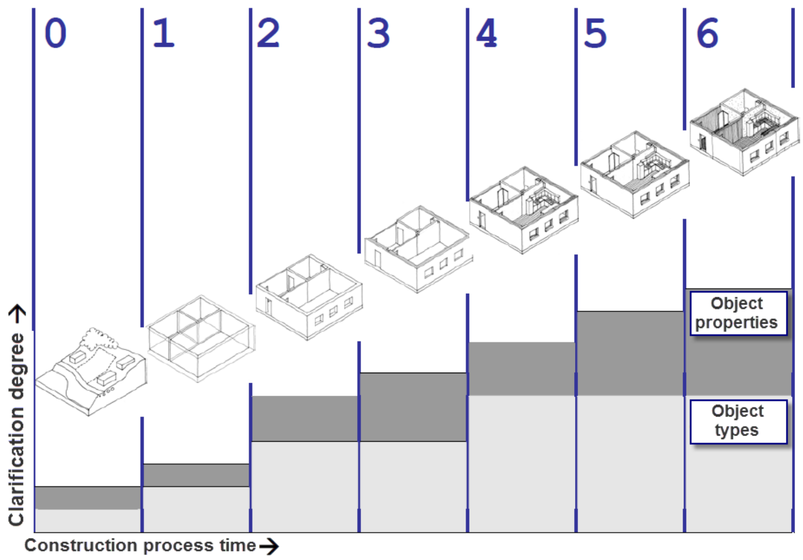


Figure 4.2: Information levels illustration [Bips (2006)]

In relation to the further study the information level 4 since it is used in proportion to the main project and thereby creates a basis for tender. In connection to tender this information level demands a model, which is able to extract quantities for calculation. Thus the building objects shall be connected to a quantity list and specifications. Besides this, all information about geometry, which affects the planning of prodution, should be visualised on this model [Bips (2008a)].

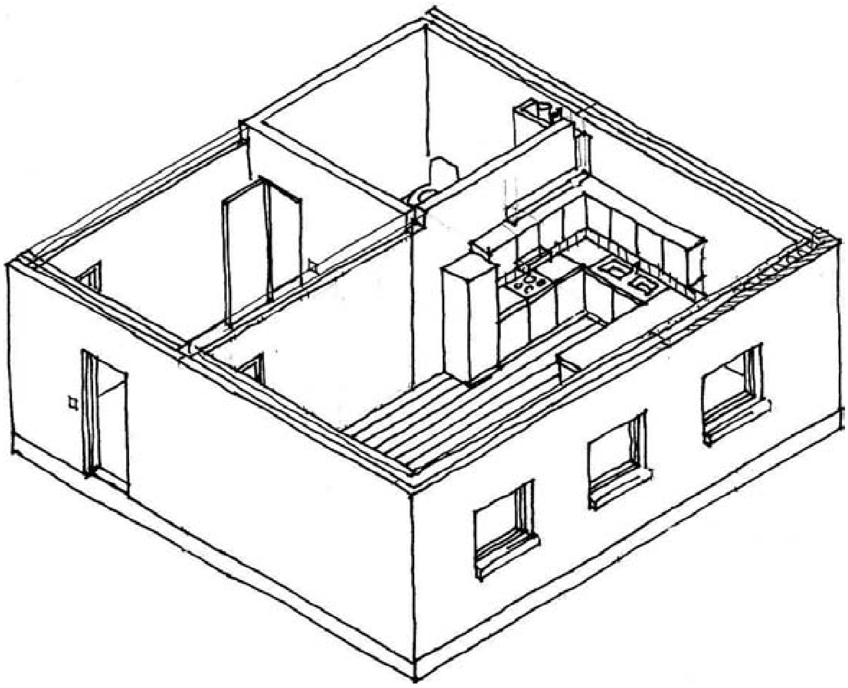


Figure 4.3: Illustration of information level 4 [Bips (2008a)]

4.1.3 Modelbased quantity takeoff

The quantity take-off (QTO) discipline is one the main reasons of having intelligent building objects with informations and attributes. In relation to digital tender with quantities in Denmark this has a great focus on the designer side since the quantity measurement task has been transfered from contractor to designer. The different kind of estimators (designers or contractors) uses a variety of options to utilize BIM for QTO. Chuck Eastman states that no BIM tool provides the full capabilities of a spreadsheet or estimating package, which means that estimators must identify a method that works best for their specific QTO and estimating process [Chuck Eastman (2011)]. The BIM Handbook shows three primary options:

- Export building object quantities
- Link the BIM tool directly
- Use a BIM quantity take-off tool

Export building object quantities

Most BIM tools offered by software vendors include features for extracting and quantifying BIM component properties. These features also include tools to export quantity data to a spreadsheet or an external database. Surveys has shown that Microsoft Excel is the most commonly used tool to export to when using this method. The method is very manuel as the estimator often will get the raw data into Excel and then has to organize and structure the data as it fits to the overall structure in the tender list.

Link the BIM tool directly

This method uses a BIM tool that is capable of linking directly to an estimating tool through a plug-in. This has become more used as many of the larger estimating packages now offers these plug-ins in the specific bim tools. The estimating tool providers and softwares are: Sage Timberline via Innovaya (Innovaya 2010); U.S. Cost (Success Design Exchange 2010, Success Estimator 2010); Nomitech (CostOS v3.6 BIM estimating 2010); and Vico Estimator (Vico 2010).

These estimating tools can associate the objects in the BIM model with assemblies and recipes. Furthermore, it is possible to connect the objects with predefined prices from the estimating tool or a generel price database as 'V.S. Prisdata' in Denmark. The assemblies and recipes defines the steps and the resources needed for the specific construction component operation (either on site, for the erection or installation of prefabricated components). Assemblies and recipes also often include activites needed for construction. These functionalities gives the designer a good basis of creating an accurate and complete tender list for the contractors.

Allthough it seems very easy this method can not be defined as a completely automatic. The designer has to assign each object (or group of objects) to specific assemblies or recipies, which can be time consuming. But when that process is done it is rather easy to make QTO and to make a quality assurance afterwards.

Use a BIM quantity take-off tool

This third option is to use a specialized QTO tool that imports data from various BIM tools. This QTO tool gives the designers the oppurtunity of using af take off tool specifically designed for their needs without having to learn all of the features contained within a given BIM tool, e.g. Tekla for structures or MagiCad for installations. Some examples of QTO tool providers and softwares are: Autodesk QTO (QTO 2010); Exactal CostX Version 3.01 (Exactal 2009); Innovaya (Innovaya 2010); and Vico Takeoff Manager (Vico 2010).

These QTO tools has features that links directly to items and assemblies, and create visual take off diagrams. Moreover the tools offers different kind of options in relation to automated extraction and manual take off features. Designers and estimators will have to use a combination of both manual tools and automatic features in order to support the wide range of quantities.

Some of the tools is also able to manage changes to the BIM model. For instance the Innovaya system provides a visual model of all the objects that have been improted from the BIM model and then highlight in colors those object that has been changed since last time. For quality assurance it also highlights the objects who has not been included in the quantity list yet.

4.1.4 Design process changes

The majority part of all information are generated in the design phase, which make this phase particularly interesting in relation to BIM. Chuck Eastman divides the whole process into: Pre-design, Schematic design, Design development, Construction documentation, Procurement, Construction administration and Operation [Chuck Eastman (2011)]. The point outlined by Chuck Eastman is that in the traditional design phase the primary effort occurs in the construction documentation part. Whereas the BIM way of working prefers to make a higher effort earlier in the process. The displacement of effort/effect is shown in Figure 4.4.

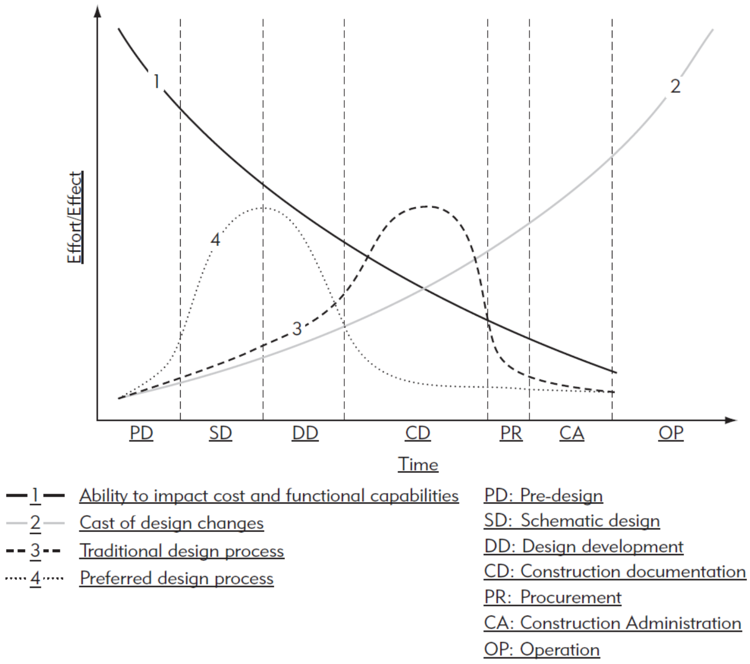


Figure 4.4: Distribution of design services [Chuck Eastman (2011)]

The displacement in Figure 4.4 is theoretical, but based on the assumption that BIM significantly reduces the amount of time required for producing construction documents by doing an extra effort earlier. The change in distribution of effort prepare the ground for changing to new collaborative forms of project delivery.

4.1.5 Collaborative forms of Project Delivery: IPD

When it comes to collaborative forms of project delivery in relation to BIM, Chuck Eastman has a clear statement:

Early integration and collaboration are the keys to effective use of BIM technology

Chuck Eastman (2011)

In particular IPD is mentioned as a relatively new procurement process that is gaining popularity as the use of BIM expands. At the moment the industry in the US experiments with this approach, hence there is multiple approaches to IPD.

IPD is quite different than DBB and has similarities to DB. Unlike the DB contracts, which constitutes the contractor in a leading role on a building project, the IPD represents a concept where the entire team including the owner, architect, general contractor, building engineers, fabricators, and subcontractors work collaboratively throughout the construction process [Randy Tuminello (2011)]. Based on that concept the American Institute of Architects has defined five key elements that are essential for a fully integrated process:

- Early involvement of key participants: Including key participants in a SPE (Single Purpose Entity) company.
- Jointly developed and validated project goals: The use of a 'target cost' and a 'target schedule' established on basis of the competitive bidding (bidding basis will often be conceptual design). Those target costs becomes focal points in the whole process and will be used as benchmarks to measure the successful outcome of the projecy
- Shared risk/reward among key participants: Based on the target costs plan of distribution is made to clarify how the risk/reward is shared among the project members. This gives the designers incentives of making improvements of the construction.
- Collaborative decision making by owner, architect and contractor: The project is governed by the project team rather than just the owner. The owner, architect and contractor each have a project representative on the management team and discusses and collaboratively makes all project decisions. In those rare instances when the management team cannot reach an unanimous decision, either the owner makes the final decision, which may result in a change order, or the matter goes through a formal dispute resolution process.
- Reduced liability exposure among key participants: Creation of legal documents called 'liability waiver' where the key participants sign to acknowledge the risks involved their participation.

After the invention of IPD a couple of years ago, there has not been many so-called "pure" IPD arrangements, thus the application of IPD has been divided into two areas; IPD as Philosophy and IPD as Delivery Method [NASFA, COAA, APPA, AGC, AIA (2010)]. For instance the 'multiparty agreement' in relation *Jointly developed and validated project goals* and the 'liability waivers' in connection to *Reduced liability exposure among key participants* are often not fulfilled when performing IPD arrangements since the participants found that the liability waivers often have no legal standing. The above five points also leads to five motivation categories for the different parts to participate in an IPD arrangement.

- Market Advantage: The cases of IPD in America has been focussed on the healthcare sector and the trend shows that IPD may may become an expected standard delivery method. Hence the participation of an IPD collaboration can give valuable experience in relation to future IPD projects.
- Cost Predictability: This motivation is focussed on the owner. The cost predictability is present due to the extensive use of detailed BIM models and running QTO's during the design phase.
- Schedule Predictability: Similar to the cost predictability.
- Risk Management: The management of risk can be connected with cost and schedule, but may also include transactional risk inherrent to project type, site or other conditions.
- Technical Complexity: A high degree of complexity will often demand integration of expertise and require a level of coordination that is achieveable in an IPD environment.

It is important that above motivations are not new in relation to building projects. However the idea is that IPD may offer strong motivation among the key participants in several categories, hence the IPD may offer an advantage compared to the tradtional project delivery. In addition collaboration and integration can occur in any project delivery method, but IPD sets up structures that gives incentives among participants, thus it makes it more likely to occur [AIA (2012)].

4.2 Information Delivery Manual (IDM)

In order to standardise processes in the construction industry, BuildingSMART has developed the Information Delivery Manual (IDM), which also is known as the 'buildingSMART standard for processes'. The IDM describes the processes, roles and the demands for information deliveries. The justification of an IDM is the fact that in a construction project there is a lot of information, which is exchanged frequently. Hence there is a need in relation to deliver information a in standardised way, thus the all parts know what to deliver and recieve at a given time [Bips (2012)].

The development of IDM's is handled on different levels such as international, national, trade specific and organisational. However it is only buildingSMART International that can approve a 'true' IDM based on a couple of requirements. In Denmark DiKon has been active on a national level by doing the initial work for IDM's and then passed the work for buildingSMART International. Basically an IDM consist of two parts:

- Process part: Role specification, process specification, data object specification
- Data part: Technical specfication (MVD)

The purpose in Denmark is to connect the IDM's to the ICT specifications made with the owner as illustrated in Fig 3.4. Thereby the IDM will ensure that a connection is made from the selection of services from the owner and the actual work delivered [Hejnfelt (2011)]. The connection is illustrated in Fig 4.5.

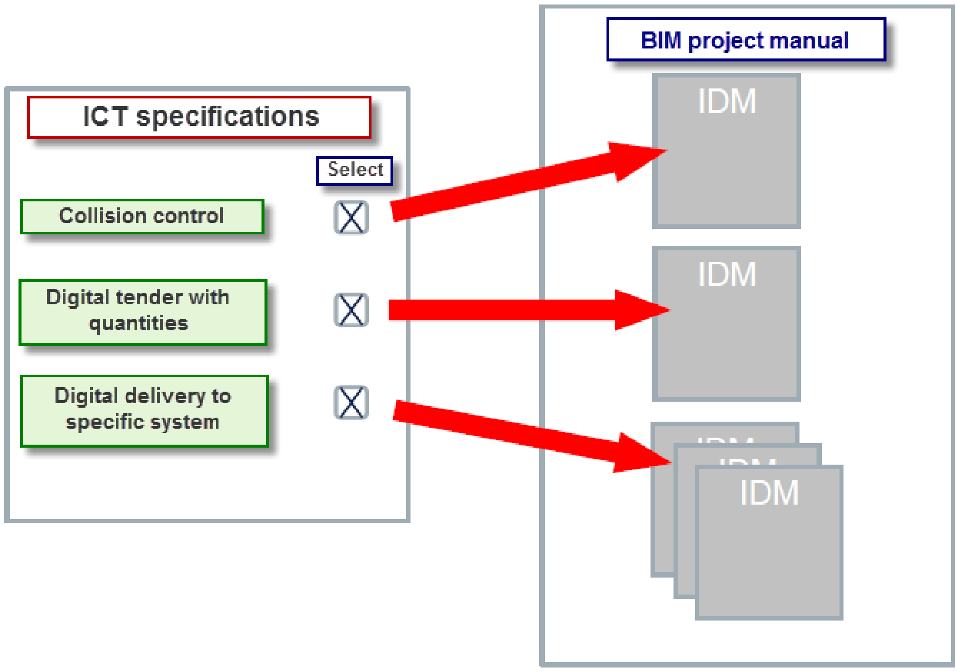


Figure 4.5: ICT specification in relation to IDM [Hejnfelt (2011)]

This implies that the IDM functions as an additional contractual basis. The IDM's can be different as some a process oriented and others are focussed on the technical implementation. The basis in this thesis is usability in relation to the digital tender with quantities.

Chapter 5
Cases

The cases studied in this thesis is the main emperical part among other emperical parts such as interviews, articles etc. It deals with one main case, which is one of the most complex and prestigious building projects at the moment in Denmark called *Mærsk Bygningen* (MB). The project information from this case is mainly gathered from the engineer company Rambøll, who is designing the building in cooperation with the architect C.F. Møller. Furthermore two more cases are being investigated;

- DTU Building 328 (DTU328) designed by Rambøll
- New Technical Faculty for University of Southern Denmark (TechFac) designed by Moe & Brødsgaard

It is important to state that this chapter only describe the essential parts (in relation to the scope) to understand the projects. The deeper investigation is presented in the following analysis chapter.

5.1 Mærsk Bygningen

This case study desbribes an university extension being built in Copenhagen, that will extend the existing Panum Institution, which is a part of University of Copenhagen (UC).

The project is an extension of the current Panum institution and will be taking place on Blegdamsvej in the centre of Copenhagen. The owner of the building project is Danish Building and Property Agency (BYGST), which is an experienced public owner on the Danish market. BYGST owns the main part of UC's buildings and will as standard become the owner of new buildings of UC. Futhermore BYGST is a proponent of public buildings to be effective and to lead the way in the digital development of the Danish construction industry.

The project was in the programming phase put out to tender for lead consultancy services in a project competition on the basis of competition program, which was developed by consultants and the future users. The competition was in this project performed with a prequalification in the spring 2010, where the different full-service consultants consortiums sent information regarding their competences, references and capacity to solve this building project. In the end the winning full-service consultant consortium was the architecht company C.F. Møller, the consultant engineering company Rambøll and a couple of sub-consultants.

The project Mærsk Bygningen was originally called *The Extension of the Panum Complexes*, but the name was changed during the design phase of the project. This name change probably happened as the owner are sponsored by the A. P. Møller foundation, who's former chairman Mærsk Mckinney Møller died the 16th of April in 2012.

Table 5.1: MB Project overview

Location	Blegdamsvej, Copenhagen
Type	Health, medical science research and studies
Contract	Design-bid-build
Project period	2009-2015
Owner	Danish Building and Property Agency (BYGST)
Renter	University of Copenhagen (UC)
User	Faculty of Health and Medical Science (SUND)
Architect	C.F. Møller
Landscape architect	SLA
Engineer	Rambøll
HVAC contractor	Unknown (competitive bidding starts in April 2013)
Building Area	42.000 m^2 Approx.
Building budget	1.3 Billion DKK
Building height	75 m
Storeys	18, 3 of it in the basement
Rooms	1700 Approx.
Workspaces	900 Approx.

5.1.1 Project description and vision

MB is created to offer ideel frames for modern science and educational environment. It is a 42.000 sqare foot 18-story project with a budget of 1.3 billion DKK. In addition, it has a building height of 75m, 1700 rooms and workspaces for approximately 900 scientist.

The building is divided into two main parts; the starformed base (from basement to 1st floor) and the tower (from 2nd to 15th floor). It is intended that 85% of the total square meter is allocated to laboratory- and science facilities, while the last 15% is intended canteen, teaching, and auditorium facilities. The

Figure 5.1: A computer-generated image of the new university extension and its campus setting

building is visualised in Fig 5.1.

The vision from the owner is a state of the art facilities for world class for research in humane disease. A worth seeing architecture and outstanding engineering, attracting influential researchers from all over the world. Furhtermore, a flexible, sustainable, intelligent and long living icon.

5.1.2 Digital aspects

The project of MB differ from other Rambøll projects by having public owner ICT-requirements, since BYGST is a public owner. Therefore the use of BIM was choosen in order to meet the requirements stated in the ICT executive order [BEK no. 1381 (2010)]. Among other the owner has to make demands for a *Digital tender*, which i.a. contains the following demands in relation to the tender list:

- Classification of all komponents
- Digital models in 3D for visualisation delivered in IFC-format
- Quantities in the tender list
- Correlation between quantities and specifications

- Clarification of measurement rules

The implementation of BIM was already done early in the design phase as the architecht/engineer made a 3D model. The different trade contract groups (including HVAC) started making the different trade contract models when doing the main project. Fig 5.2 shows how the different trade models are linked into a common model in the MB project.

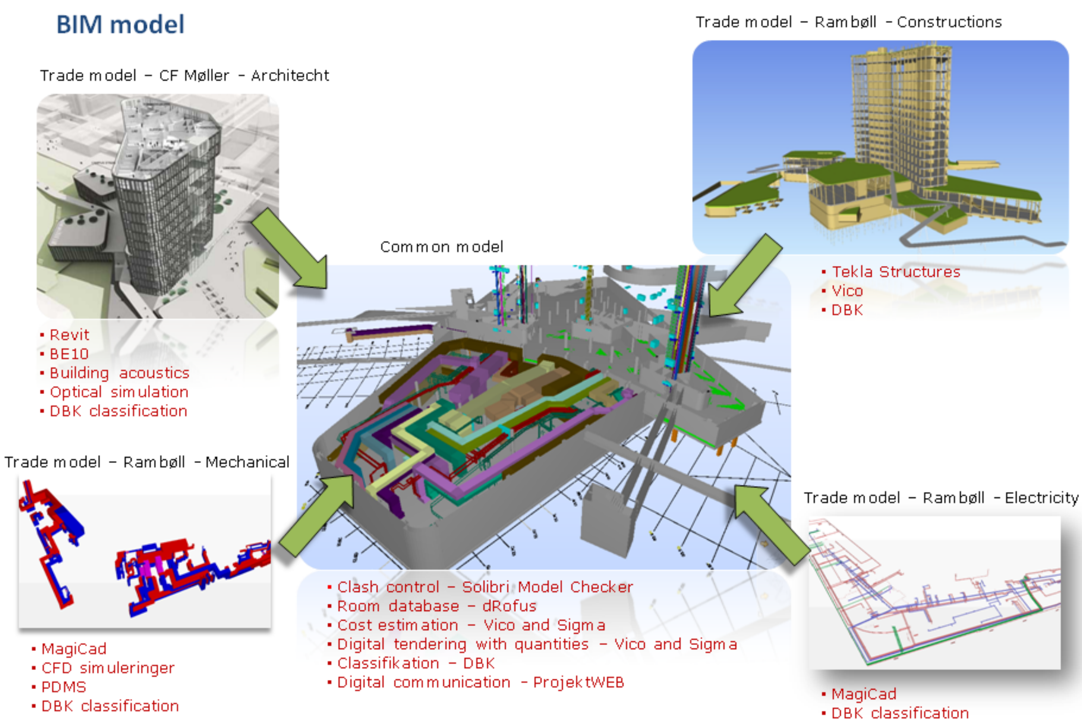


Figure 5.2: Illustration of BIM in the MB project

5.1.3 Tender strategy

The overall strategy for tendering of contracts is concerning individual trade and prime contracts. Hence it is given that these individual trade contracts can be outlined exact among themselves on basis of the main project.

The intention is that this tender form gives the owner the option to make contracts with specialised firms and have the direct contact, which corresponds to the theory of contractual forms (presented in Chapter 3.2). Moreover this can make plenny of constractors bidding on each trade, which under normal circumstances gives competitive prices. However this tendering form also gives many internal stakeholders on the project and it is therefore demanded a careful planning and management of the owner/construction leader. The owner also risk to pay for compensation claim if the timewise conditions in the tendering documents are wrong due to delays from trade contractors.

The MB project is being divided into 18 different individual trade contracts. Two of these contracts concerning HVAC is being investigated in relation to digital tender with quantities; *Plumbing* and *ventilation*. These two trade contracts are investigated further.

5.2 DTU Building 328

This case study describes an university extension built in Kgs. Lyngby, that extended the existing building 327, which is a part of the Technical University of Denmark (DTU). The project was an extension of the DTU Space institute and was taking place on Elektrovej in the norhern part of Kgs. Lyngby. The building owner was DTU Campus Service, whom consider themself as being on the forefront in relation to ICT specifications.

Table 5.2: DTU328 project overview

Location	Elektrovej, Kgs. Lyngby
Type	Electro lab science research and studies
Contract	Design-bid-build
Project period	2010-2013
Owner	DTU Campus Service
Architect	Erik Møller Arkitekter
Landscape architect	Kragh & Berglund
Engineer	Rambøll
HVAC contractor	Unknown
Building Area	3.200 m^2 Approx.
Building budget	80 million DKK

5.2.1 Project description and vision

The vision for the building is to offer an ideal frame for teaching and science plus creating an economical and environmental sustainable building. The building has four storeys inclusive basement and it contains both workshops, production labs and offices.

Furthermore the focus of DTU328 was flexibility, hence transverse walls can be moved and reconfigurated so the room sizes can be changed. Moreover a flexible 'zone disposition' with new types of rooms, which are matching the shifting demands and collaboration forms in a modern and dynamic teaching - and scientist environment. The building has in spite of the function a low energy consumption, which among others is due to an effective heat recovery and highly insulated vacuum insulation in the facades.

5.2.2 Digital aspects

The project was embraced of the same public owner ICT-requirements as the MB project. In addition, the focus in project was the application of DBK as the general classification system in the tender documents. Moreover the project was used as a pilot project for Rambøll in relation to quantity take-off and general measurement of quantities to the tender list.

Figure 5.3: A picture of the facade of DTU Building 328

5.2.3 Tender strategy

The owner divided the building project in 6 contracts, hereof one prime contract, two technical contracts and contracts for terrain, equipment and gases. Moreover they choose their project web system to be a digital tender portal.

5.3 New Technical Faculty for University of Southern Denmark

This case study desribes a new university faculty being built in Odense. The technical faculty will be a part of the University of Southern Denmark and will be located in the south-eastern part of the university campus in Odense.

The new technical faculty will accommodate three institutes placed in each corner of the world. Bridges to the 'Furniture' in the Faculty center connects the institutes and invites to communities and knowledge sharing. The 'Furniture' is illustrated on Fig 5.4.

Table 5.3: TechFac project overview

Location	Niels Bohrs Allé, Odense
Type	Health, medical science research and studies
Contract	Design-bid-build
Project period	2011-2015
Owner	BYGST
Architect	C.F. Møller
Landscape architect	Schønherr Landskab A/S
Engineer	Moe & Brødsgaard
HVAC contractor	Brøndum
Building Area	19.000 m^2 Approx.
Building budget	Unknown

5.3.1 Project description and vision

The new building is going to be a significant architecture, which interacts with the existing campus. The frames of the building is going to appeal and inspire for collaboration and innovation. More the building should be designed with focus on energy, indoor climate and sustainability.

The new faculty comprises of total 19.000 m^2 divided between three storeys and is going to contain labs, workshops, group study rooms and administration. This cocktail suppose to reflect interaction between research, scientific work and teaching.

5.3.2 Digital aspects

The project was embraced of the same public owner ICT-requirements as the MB and the DTU328. Those digital deliveries was new to the engineering company Moe & Brødsgaard. Therefore this project was also considered as a pilot project for them on this area.

5.3.3 Tender strategy

The project is in general tendered as a range of individual - and prime contracts. The HVAC contracts was specifically tendered as individual contracts for ventilation and plumbing.

Figure 5.4: A computer-generated image of the 'Furniture' of the TechFac project

Chapter **6**

Tender documents in a digital tender for HVAC contracts

This chapter will provide an analysis with overview on how the digital tender with quantities can be carried out for HVAC trade contracts. Furthermore, it will account for those challenges experienced by the designing teams and the bid actuaries on three parts of the tender documents including the classification: *Tender list with quantities*, *3D model* and *Bidding- and delimitation basis*. The analysis is based on current conditions that exist in DBB projects (late tender) and the main basis is empirical data from the MB project, but it also refers to the two other projects; DTU Building 328 (DTU328) and New Technical Faculty for University of Southern Denmark (TechFac).

Both of these projects was also carried out as digital tenders. Moreover the analysis is also based on interviews with the different participants. In addition to the analysis each of the three parts (including the classification) are being discussed with a perspective of both the designer and the contractor to outline the specific problems in the end of each section. The problems will be followed up in the next chapter.

6.1 General

The underlying basis for a digital tender is that quantities are extracted from object based- or BIM models and then shown in a tender list. Besides the quantity of building elements, the *specifications* (functional requirements, capacity, material, type, quality and similar) needs to be stated for each building element. Hence the public owner ICT-requirements requires relations between the following tender document parts:

- Tender list with quantities
- Bidding- and settlement basis
- 3D model
- Drawings

- Specifications

The above shown tender documents parts are on a basis of the MB project. As seen in Table 6.1, the three projects tender documents are not identical since some designers omit the *3D model* and the *Bidding- and settlement basis* to be a part of the tender documents.

Table 6.1: Parts included in the tender documents of a digital tender

	MB	TechFac	DTU328
Tender list with quantities	x	x	x
Bidding- and settlement basis	x		
3D model	x		x
Drawings	x	x	x
Specifications	x	x	x

The *Bidding- and settlement basis* document includes measurement rules and in general account for the things included on each quantity. It is a document, according to Flemming Grangaard from The Danish Construction Association, which is widely used on construction projects, but not on building projects. In Rambøll it was still used on the MB project as a pilot project in order to spell out what to include on the different building component quantities. If not including the *Bidding- and delimitation basis* in the tender documents, the alternative is to place the content of this item under the *specifications* as it was on DTU328 and the TechFac project - it is just a matter of structuring the tender documents.

The connections between the different parts are maintained by the specific classification, which is illustrated in Fig 6.1. At the moment the Danish Building Classification (DBK) is the valid classification cf. the current ICT executive order for public owners [BEK no. 1381 (2010)]. Though it should be mentioned that the DBK is being revised and is going to be named Cuneco Classification System (CCS) in the future.

Fig 6.1 can also be seen as a further development of Bips' figure presented in 'Examples of extracting quantities of 2008' [Bips (2008d)], which is shown in Fig 6.2. The difference shows that present Bips publications are not up to date on this area, since the demand is now connections between all parts through a classification code.

This thesis mainly deals with *Tender list with quantities*, *Bidding - and delimitation basis* and *3D model*. Hence the classificaton and those three will be analysed and discussed further in the next sections.

6.2 Classification (DBK)

The classification is important as it is the link between all the parts in the tender document. In relation to digital tenders where quantities are in the tender list, it has been mentioned as a problem, that the DBK is not precise in the code structure. For instance if considering HVAC systems -300.01.07 refers to a valve in a water system and -320.01-03 can refer to the same kind of valve in a heating system as shown in Fig 6.3. Because the building element *valve* is not consistent, it will some places get the component

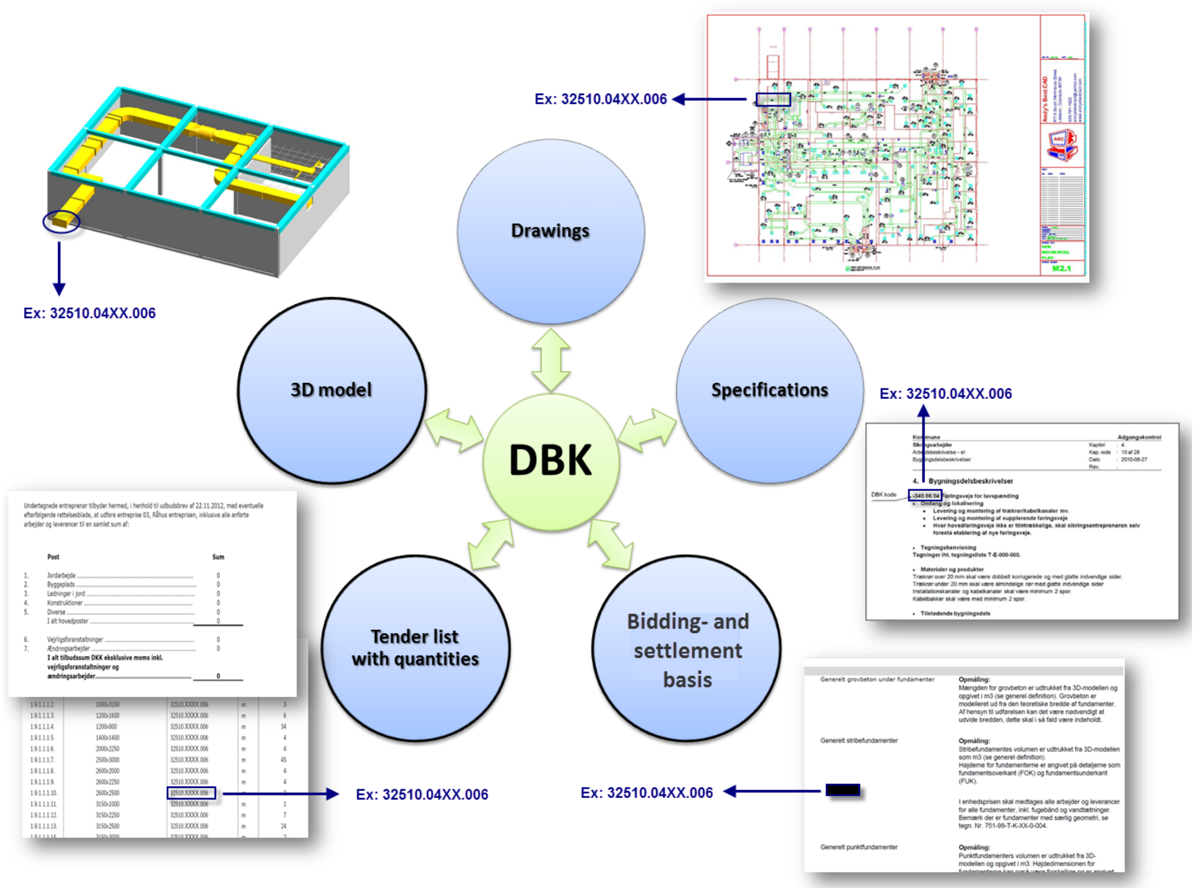


Figure 6.1: The connections between the documents for a digital tender

code .07 and other places .03. [Karved (2009)]

For that reason the MB project used a modified version of the DBK classification[1]. Even though the DTU328 and the TechFac project also used the DBK classification, there is a significant difference when comparing those three as shown in Table 6.2. In the table a rectangular duct is compared on the basis of the three projects way of classifying DBK. Besides the classification itself seems inconsistent, it is also affected by the structure of the tender list, which will be elaborated in the next section.

Designer perspective The specific classification is required by the owner due to the ICT executive order for public owners, thus the designers has to deal with this part. It provides another aspect when dealing with when modeling, because the designer has to consider at each element, which main- and sub system the element belongs to and also know the classification component code for the specific

[1] The component level is in this case inspired by CCS as it is a three digit code describing a component. In true CCS letters are used instead of digits for describing, but the concept is the same

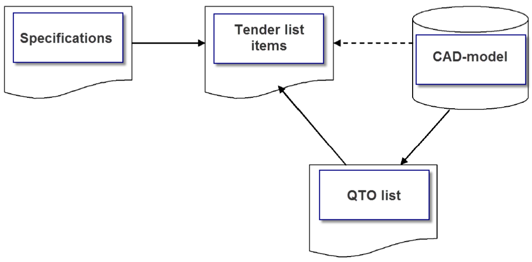


Figure 6.2: The connections between the tender documents according to [Bips (2008b)]

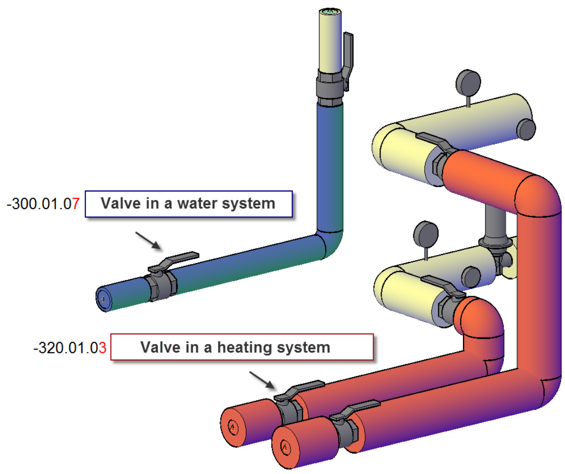


Figure 6.3: Comparison of valve in different systems [Karved (2009)]

Table 6.2: DBK Classification example

	A rectangular duct in ventilation system 1
MB	32501.XXXX.006
TechFac	325.07.01.01
DTU328	325XX.0401.0602

element. From the experience of the MB project this is not an easy task and according to Niels Treldal from Rambøll this gives rise to problems when handling digital tenders as the designer now has to relate to which main- and sub system the components belongs to and learn the specific component codes. Moreover it is not all modelling software, which is able to manage classifications in a proper way. A specific example in the MB project was the management of classificaion in AutoCad P&ID, which was causing problems in relation to extraction of components.

In the TechFac project it was necessary to combine the DBK classification with the princip of an old classification system Sfb according to Martin Nielsen from Moe & Brødsgaard:

> *We (TechFac designing team, red) were assigned to use DBK classification as a demand from the owner. For that purpose we used the Rambøll DBK-converter as inspiration, but still named differently some places. The DBK prepare the ground for so-called 'building element papers', but we did not do that on the HVAC systems. We have done it as you normally would do according to the old SfB codes..*
>
> *..the DBK has some weaknesses. Such things as building site - How do you implement that to a DBK code*
>
> Martin Nielsen, Project manager at Moe & Brødsgaard

Hence the classification leads to several of problems on the designer side and the application of the DBK classification seems to be project specific.

Contractor perspective Since the classification is known as the link for the tender documents, it is a challenge for the contractors to retrieve information when the classification is inconsistent. But according to the bid actuaries Carsten Kramer from Henriksen & Jørgensen VVS and Freddi Lading from Brøndum, the classification codes (Both DBK classification and others) are barely used in relation to estimate a price for the contract. This is due to the fact that the classification often confuses more than it helps due to different numbering within each project. They point out that they primarily uses the quantity names and the drawings to estimate. Still both Carsten Kramer and Freddi Lading could see the perspective of a stringent connection between the parts in the tender documents as these are becoming more comprehensive than they used to be.

Flemming Grangaard general thinks that classification is important, but the current DBK classification is not sufficient and he refers to a problem for indoor walls:

> *The level of detail that the DBK classification prepare the ground for is not sufficient. The level is so rough that when considering constructions for instance gypsum walls, it is not possible to see if we are talking two or more layers of gypsum. The same DBK code regardless how many layers there is*
>
> Flemming Grangaard, Consultant at The Danish Construction Association

Flemming Grangaard also disputes the precision and consistency of the classification and suggest that this also affect the fact that contractors are not using it more in relation of getting an overview of the tender documents.

Problem: Insufficient classification It seems like the current classification in Denmark (DBK) is not adding enough value to the digital tender, though it is the important link that connects the whole tender document. The designer claims that the quantities in the shape of different components are changing code according to the system they are placed in [Karved (2009)]. Moreover the DBK classification are modified and expounded in several different ways as shown in the Table 6.2. This implies that the contractors rarely uses the classification, thus information gets lost in the transaction from designer to contractor. Since the quantities sometimes are presented in a shape where implicit quantities needs to be included (pipes/ducts including fittings, supports etc.), the need of a consistent classification is even more important as the tender documents are getting more comprehensive, thus the classification is used as reference for look-up from the *tender list with quantities* to the *specifications*, *bidding delimitation basis* and the *3D model*.

Furthermore, the current ICT executive order indicates that DBK besides the classification also should structure the tender list [BEK no. 1381 (2010)]. This was rejected from all designers participated in this thesis, hence DBK is only a classification and not made for structuring a tender list. Though it should be mentioned that this point must likely will be excluded in the renewed ICT-requirements, which will become effective in April 2013.

As a consequence of the heavily criticism of the DBK classification, the building industry are already working on a solution as the DBK classication are being revised to a new system called CCS (Cuneco Classification System). CCS will also be a national classification and can be applied for both classification and identification (not information strucuturing of tender list as DBK) of building components, rooms and the relations between them. Basically the CCS will differ from DBK in the aspects of how to handle an object. In DBK aspects the different classes was defined for each object, whereas CCS aspects tells the correlation between the objects of same class and a way to adress them. Moreover CCS in general focus on the component and therefore more easy to handle in relation to a tender list.

6.3 Tender list with quantities

The tender list in a digital tender is special in relation to a traditional tender as the quantities has to be included. Moreover the quantities has to be associated with the single building elements since the ICT-requirements demands a certain extent of digital extracted quantities. Hence it is important early in the process to consider, which kind of structure, level of detail and the process for making the tender list.

The quantities in a project can be stated in many different ways depending on who the reciever is and when they are delivered. This section is based on the delivery after the main project from designer to contractor in relation to HVAC contracts. Besides the digital quantities there is also other kinds of general quantities and these should also be included as all price-bearing entries needs to be included. Thus the princip is that the sum of all price-bearing entries are equal to the contract price.

According to Bips, the quantities in the tender list are stated in net values and any spillage, leakage, and additional amounts arising from execution method are calculated by the bidding contractor and must be included in the bid [Bips (2008d)].

6.3.1 Structure of tender list

The structure of a tender list with quantities is significant in relation to the contractors perception of the quantities of a project. According to FRI, the tender list structure and level of detail is not determined whether it is a traditional- or a digital tender. In both cases the owner (in possible consulting with designer) decides tender form, structure and level of detail [FRI (2009)].

A tender list can among others be divided per storey, per element or per system. Another aspect, which also influence the contractor, is how the quantities are priced, which also can be per element (unit prices), per system (system prices) etc.

In the MB project the HVAC tender lists with quantities was divided after each main system. Therefore the overall level in the tree structure of ventilation could be: **325**01 Supply, **325**02 Laboratories, **325**03 Offices and so on (in Appendix A the tender lists of Mærsk Bygningen are shown). This was done in order to create an overview for all parties and to give the contractor improved requisites to tender for subcontractors per system. Simultaneous it is easier for the designer to assess if the measurements are exact as each main system is isolated in the list. This makes sense in a complex project like MB, where there is many systems in general and special requirements in relation to laboratorys, whichs leads to a lot of different HVAC systems.

On the other hand the DTU328 project tender list with quantities was divided after each component. The advantage of dividing per component is that the contractor directly can see the amount of a specific component. For instance from Fig 6.4 the contractor will know that there is 130m of 'ø250mm - Runde spiro kanaler' in total of the building as it goes accross systems. From Fig 6.5 the contractor will know

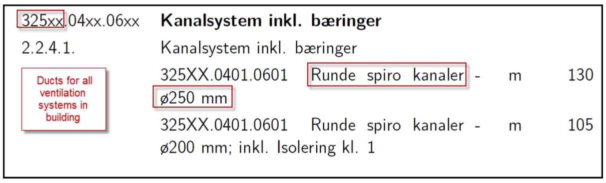


Figure 6.4: Tender list divided per component (DTU Building 328)

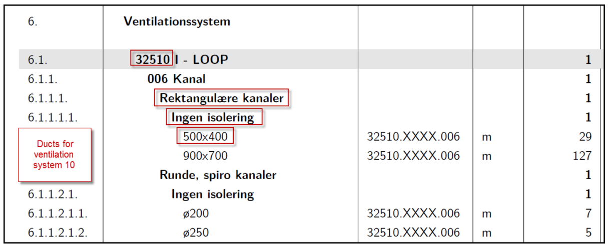


Figure 6.5: Tender list divided per system (Mærsk Bygningen)

that there is 29m of '500x400 - Rektangulære kanaler' in that main system (ventilation system 10) and therefore not the total of '500x400 - Rektangulære kanaler' of the building. Though it can be more difficult when dividing per component to outsource parts to subcontractors. For instance if a contractor wins the ventilation contract and only wants to do the normal office ventilation, but wants to outsource the laboratory ventilation to a subcontractor. Then he has all information within those specific laboratory systems in stead of having the total amount of each component. Furthermore, it is simple to cope with changes within the project as it can be delimited to each main system.

By comparison the Techfac and DTU328 project was divided respectively per system and per component as shown in Table 6.3. According to Niels Treldal it seemed like the right way to divide per component on the DTU328 as it was a smaller project with fewer main systems to handle. Thus it was easier to have a the aforementioned overview and assessing the measurements exactness.

Table 6.3: Structure of tender list and pricing comparison

	Divided per component	Divided per main system	Priced per component	Priced per main system
MB		x		x
TechFac		x	x	
DTU328	x		x	

Regarding the pricing it was choosen differently on the three projects. On the MB project it was choosen to price per main system (system price) in stead of pricing per component (unit price). This means that each main system is a sum, which the contractors are bidding on in stead of providing unit prices on 800-1000 different components. Niels Treldal points out that when providing a system price it is ensured that the contractor's bid covers the whole system. Moreover, it makes it easier to estimate what are and not are included and interface problems between joints are avoided. For instance it is a problem to manage a connecting piece between stainless steel and a PEX pipe. The disadvantage of tendering each main system compared to pricing per component is that extra adjustment items needs to be included, which is not neccesary when pricing per component as the contractor in that case allready has stated how much that will be charged for a certain quantity if there is any additional quantities.

Designer perspective Although the structure of tender list is decided by the owner, the three projects showed that the owners did not specify any structures but only approved a structure that the designer made. This gives the designer the opportunity of making tender list structure of own choice:

> *The owner did not require a specific structure on the tender list. We made a introduction to our proposal, and they commented and approved. Thus it was a free choice from our side to decide a structure of the tender list*
>
> Martin Nielsen, Project manager at Moe & Brødsgaard

According to Morten Alsdorf from Rambøll it was the same story on the MB project. Martin Nielsen elaborates that since there is no routine, standard or requirement on this point, the tender list structure is more or less controlled by what the easiest thing is to do on the specific project. Hence the tender list structure is different from project to project. Regarding the pricing on either the components or the main systems, it is a dilemma as the adjustment items are handled by charging on unit prices and the bid comparison is easier handled if only comparing the bids on the main systems.

Contractor perspective Given that the structure of tender lists often are different, it is difficult for the contractor to establish a routine to manage digital tenders. In that connection The Danish Construction Association states the following:

> *It demands relative much manual work to organise the calculations. This process is different from tender to tender as there are no standards for the tender list structure and configuration*
>
> *.. afterwards it is often a challenge to outsource the tender list to subcontractors, given that the tender list rarely is structured in a way that relevant data without further processing/division can be passed on to subcontractors*
>
> The Danish Construction Association

Furthermore, it is suggested from a contractor perspective that a future standard can be linked to supported software for calculations. This postulate is also published in Bips regarding the tender list XML-structure:

> *For the tenderers (bidding contractors) there will be a huge profit if the tender list automaticly is loaded in a calculation software as this task often is heavy in relation to time consumption. The owner (and designer) advantage will be that submitted bids will be loaded into another system, where the bids can be compared so the most beneficial bid can be identified*
>
> The tenderlist XML-structure F111b, Bips

In relation to which kind of tender list structure and pricing of quantities the contractors prefer, both Freddi Lading and Carsten Kramer agrees that it will be easier to do both per main system:

> *I think that the tender list should be structured per main system and only those systems should be priced. In addition there should be a bill of quantities, which shows what the different systems contain. It is often a mess if the quantities is directly on the tender list and very time consuming if each quantity should be priced. Furthermore, the tender list gets too long and confusing*
>
> Carsten Kramer, Bid actuary at Henriksen & Jørgensen VVS

In addition Freddi Lading states that in the TechFac project (Brøndum was selected as contractor on the ventilation contract on the TechFac project), which was priced per component. In that case there was 800-1000 entries in which unit prices should be submitted by Brøndum. Moreover that specific tender list was not even detailed with fittings, which could have made it to more than 2000 entries on the tender list. The funny fact, according to Freddi Lading, is that the contractor often are pricing the main system first and then divide this price out on the different units so it fits the total sum.

Problem: Different information structure and pricing of quantities The design phase generates a lot of data regarding quantities, which has to be structured into an information representing the quantities. The structure of the tender list with quantities in relation to HVAC contracts are different from project to project based on the Table 6.3. The contractors reports that many different tender list structures such as per element, per storey or per main system are experienced. The point is that the same data can be structured into several kind of different informations. Roughly speaking, the same data can therefore be understood in several ways depending on the chosen structure. Thus there is a need for a common information structure of the tender list, as this would prevent misunderstandings between designer and contractor. Hence, all things being equal, the contractor would be able to understand the building project earlier and thereby reduce the bidding phase time.

In relation to this problem, Cunego is currently working on a project that should develop a standardised tender list structure and a standardised digital format, which can be exchanged through IT systems. The purpose corresponds to the statement of [Bips (2008c)] in order to reduce difficulty for the bidding contractor and to meet the owner's need of assessing the submitted bids. This would also affect the pricing issue, if imagining an IT system which was able to manage both the unit prices and on basis of those create prices for the main systems without the need of entering more than 1000 unit prices first.

6.3.2 Level of detail

Likewise the tender list structure, the level of detail is also decided by the owner. In relation to a digital tender after main project it is common practice to deliver the quantities as building components with associated services. Therefore the level of detail deals with the problematics of how much to detail a quantity and how many of these building components to include in the tender list.

Under the overall tender list structure there are some levels of details, which function as price determination parameters. For HVAC-systems, the pipes and ducts have another number of price determination parameters than the rest of the components. Hence a distinguishing between 'ducts/pipes' (measured in running metre) and 'other components' (measured in pieces) are intuitive as these often are not broken down in the same amount of levels. An example of 'other components' can be valves or radiators (basically everything else than ducts/pipes).

During the MB project a tree structure of informations for both ducts/pipes and the other components was developed in order to standardise the price determination parameters. Below is just an example of how that task can be fulfilled:

Ducts/pipes

1 System code + System name

- **1.1** Component code + Component name
  - **1.1.1** Material
    - **1.1.1.1** Insulation
      - **1.1.1.1.1** Dimension

Other components

1 System code + System name

- **1.1** Component code + Component name
  - **1.1.1** Type
    - **1.1.1.1** Dimension

The above tree structure is one way of structuring the price determination parameters. A comparacy of the three projects regarding level of detail and informations are made in Table 6.4. As seen in the table the DTU328 project was missing the parameter of 'insulation', while the TechFac project missed both the 'insulation' and 'material' parameters. In those two projects the contractor needed to include those parameters in the price.

Table 6.4: Level of detail for ducts/pipes

	System name	Component name	Material	Insulation	Dimension
MB	x	x	x	x	x
TechFac	x	x			x
DTU328	x	x	x		x

Regarding the question of how many building components to include in the tender list as *explicit* quantities, the crucial point of HVAC systems is whether fittings and supports should be included as *explicit* or *implicit* quantities. The difference is that the explicit quantities is measured and can be read directly as an entry on the tender list, whereas implicit quantities are not measured but included in an explicit quantity. Therefore the higher level of detail, there will be fewer implicit quantities. For example a common practice when tendering after main project is to have ducts/pipes as explicit quantities with fittings and supports included as implicit quantities as shown in Fig 6.6. This methodology can provide some 'diffuse' quantities since an entry for a duct on the tender list is saying *1000 running metre of ø900*, but this quantity is not only the ø900 but also the fittings and supports needed for that distance. The question remains, how is this quantified and does it makes sense to deal with one unit price for a 'package' that includes more units. The issue regarding explicit- and implicit quanitities also relates to the measurement rules, hence it will also be brought up in that context.

In the MB project it was choosen to neglect all fittings (hence implicit quantities), thus the tender list

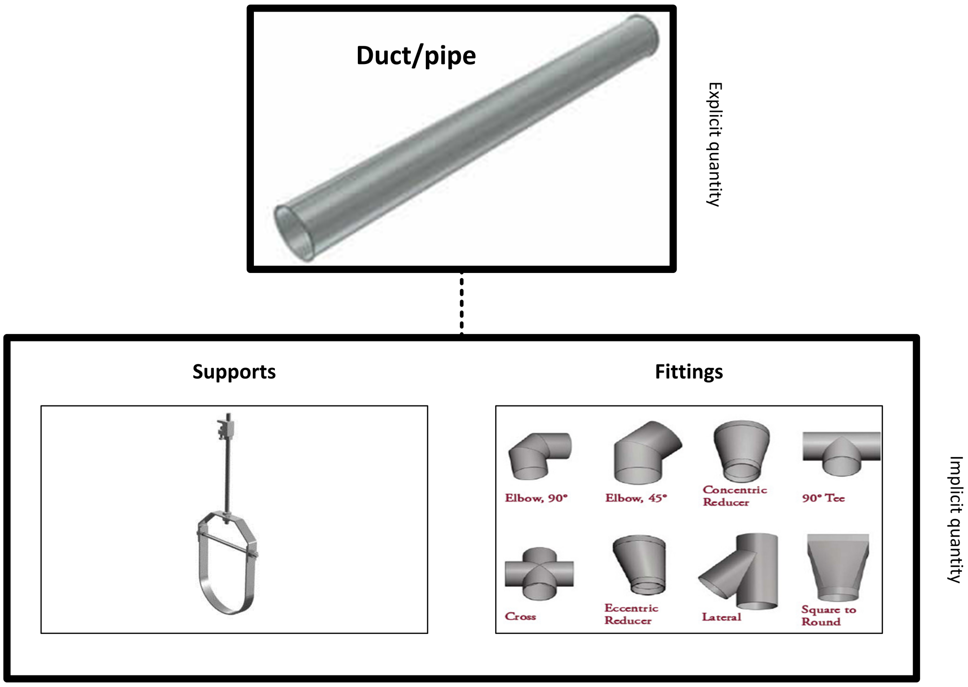


Figure 6.6: Example of explicit and implicit quantities

regarding pipes/ducts only contain straight pipes and ducts. This was done in order to keep an equal level of detail without deviation through the project as it was not possible to measure all fittings anyway according to NTR. The argument is that it nevertheless is not possible to have all fittings included due to the fact, that some fittings depends on the contractors way of executing. As the executing contractor is not known when designing, it is not possible to know which pipe/duct element lengths or air handling unit that will be used later in the construction phase. Furthermore, the designer cannot choose product specific elements or units as basis if the project is covered by tender laws (EU tender). That means that fittings like couplers, nipples, spacers, dampers etc. cannot be determined in the design phase as they are depended on the contractor.

Also in the TechFac project all fittings was omitted, while a lot of these was included in the DTU328 project. In the DTU328 project, the designer just delivered detailed known parts of fittings like tee's, elbows etc. as shown in Table6.5. The problem in that case was that the selected contractor assumed the other fittings (couplers, nipples, spacers, etc.) should not be priced as they were not present in the tender list. Therefore this contractor did not include them in his bid, thus this increased the probability of being the cheapest bidder. Afterwards, the contractor claimed for extra invoices on these fittings, which was not included in the bid. On this basis it may not be the cheapest contractor after all, that wins the contract. This example shows that it is important to find an appropriate information level and not deviate from that as it can lead to communicative misunderstandings.

Table 6.5: Fittings contained in the tender list

	Elbows	Angles	Tees	Reductions	Spacers	Couplers	Nipples	Supports
MB								
TechFac				x				
DTU328	x	x	x	x				

Designer perspective The designers are aware that increasing the level of detail, will increase the time consumption both when creating tender lists and the 3D model. According to Martin Nielsen the time spending will be more than doubled, if deciding to detail an object based model to information level 4:

> *There is a massive workload behind if you do a full detailed model and want to include the quantities like fittings in the tender list. Estimated it is 3-5 times the time that normally will be spent on such a type of building project. If you as a designer actually get something out of it I do not know*
>
> Martin Nielsen, Project manager at Moe & Brødsgaard

The above statement connected to the designer position thinking they are providing extra services (in relation to quantity measurement) for the same fee as in traditional tenders, means that the designers are not interested in detailing more without getting more fee. According to Niels Treldal it is not just a matter of getting higher fee's. He stats that the MB project with unlimited resources (and higher fee's) was not able to detail more due to the current framework conditions for projects of public owners. In particular tender laws and contractor depended units impacts and sets the bar of how much it is possible to detail on those kinds of projects. The aspect of contractor depended units is connected to the fact that the contractor will make changes to the project anyway. In practice the selected contractor fits his own solution (with product specific choices of components) into the project. For instance will changes in some of the duct- and pipe work due to pressure loss or other circumstances occur. This implies that the level of detail to a certain degree is unnecessary as the quantities anyway will change. This also raise the issue about who to verify the as-built quantities. The perception is if the new quantities are increased then the contractor will claim for invoices of the extra material used, but if the quantities are decreased then the money is not returned.

Furthermore, the tender laws is a vital barrier for those projects covered by them. These tender laws does to a great extent contributes to a lower level of detail on the components. If it was possible to specify products, it would be a lot easier to specify what the single quantities as radiators and sanitary wares should include. In addition the tender laws increase the time consumption of specification of components as 'description of the functions'. This process is inert as the designer now shall include all the functions and dimensions of a component and make sure that there are at least of couple of components meeting these demands, instead of just typing the product name.

Another aspect is pointed out by Morten Alsdorf:

> *There is no economic incentive for the designer to detail even more and generally do an extra effort. It is very important that we (designers, red) get these extra deliveries in the contracts with the owner. Otherwise we end up with the normal 12% and still has to deliver even more extra services...*
>
> *... in a future perspective in relation to the designers economic incentive I suggest that Integrated Project Deliveries collaborations are made out of the Danish partnering perception with pools of money and reward sharing between the different parties on a building project*
>
> Morten Alsdorf, Project manager at Rambøll

In general Morten Alsdorf points out that there is no motivation for the designer to do an extra effort when the money is not there. This fact does also contribute to a lower level of detail as higher level of detail demands more time in the design phase. Thus the amount of 'effort/effect' in Fig 4.4 also has reached its upper limit since the fee's are static for designers.

Contractor perspective In general the contractors are not satisfied with the level of detail delivered by the designer. Flemming Grangaard states that the level of detail of the tender lists are simply not high enough as being a bidding basis for the contractors:

> *Basically it is all about reuse of data that can be used after the bidding stage to production (and in the end also for operation and maintenance). But the level of details are not high enough for the contractors due to bidding and execution*
>
> Flemming Grangaard, Consultant at The Danish Construction Association

In addition Flemming Grangaard made a pyramide to illustrate how the contractors prices a contract, which can be seen in Fig 6.7. This pyramide is based on the explicit quantities shown in the tender list. According to Flemming Grangaard the two upper levels (yellows) are for estimate use, thus not a basis to make a bid on after the main project. The lowest level (blue/gray) is the contractors own concern and these boxes should be only competitive parameters when making a bid.

The two areas in the middle (orange/green) are interesting as those are covering the quantities delivered after main project. According to Flemming Grangaard the majority of delivered quantities is placed in the 'building elements' (orange), which corresponds to building components as ducts/pipes, fittings, valves etc, which is consistent to the three projects investigated. Flemming Grangaard propose the quantities to be represented in a higher level of detail in the shape of 'activities/unit prices' (green), which can be described as cutting/drilling (for holes) and assembling as this detail level gives a more precise bidding basis. In addition Freddi Lading underlines that the quantities for HVAC systems only covers a part of the building elements as fittings for instance is excluded since they are represented as implicit quantities. Those missing explicit quantities in the building elements level causes that Freddi Lading are actually measuring similar to a traditional tender. To make it work with the digital tender, the explicit quantities needs to be other things than the straight running metres of ducts/pipes. Things

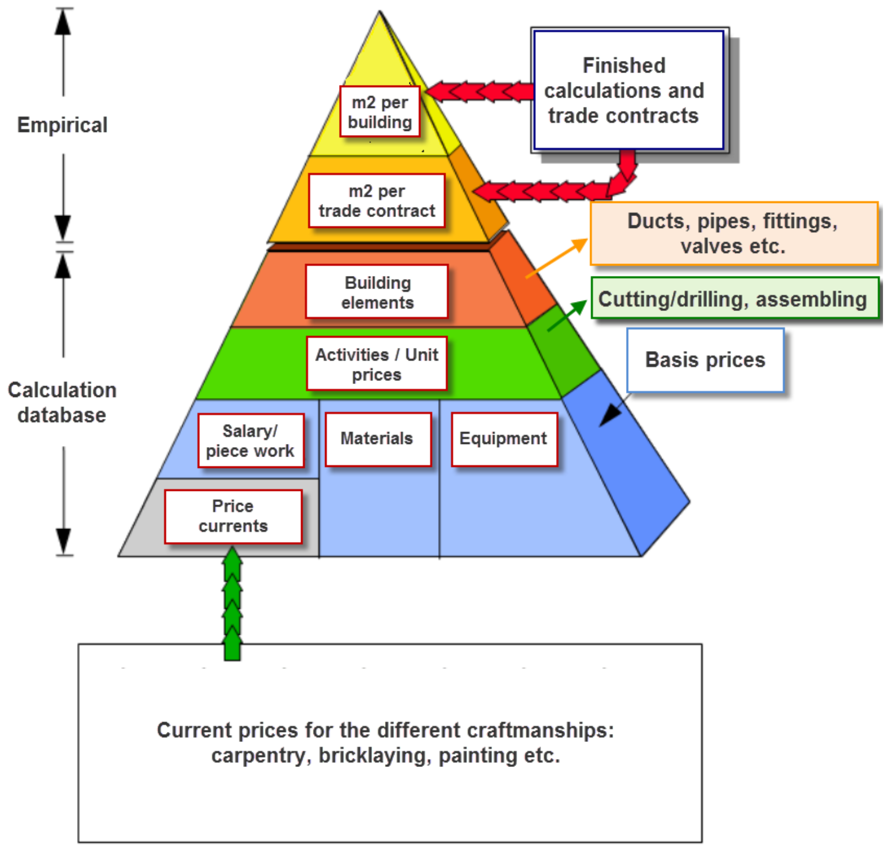


Figure 6.7: Price determination pyramid [Flemming Grangaard (2012)]

like fittings and silencers are also important, particularly beacuse those are very decisive in relation to the price of a contract, which is shown in Fig 6.8.

Freddi Lading made a rough estimation on basis of the TechFac project, which was showing that the fittings represented respectively 33% and 50% for circular and rectangular of the total duct system price. Freddi Lading underlined that this is project specific, but was sure that the fittings at least represented around 30% of the price in all cases. His pointe was that such a price decisive item should not be included as an implicit quantity.

Another aspect is the declaration. It should be indicated clearly in the tender documents, which detail level the measured quantities are delivered on. For this purpose the *Bidding- and settlement basis* can be an effective document and all the contractors involved in this thesis were sympathetic for that idea. They all mentioned that the *Specifications* could be too long if it also included clarification of measurement

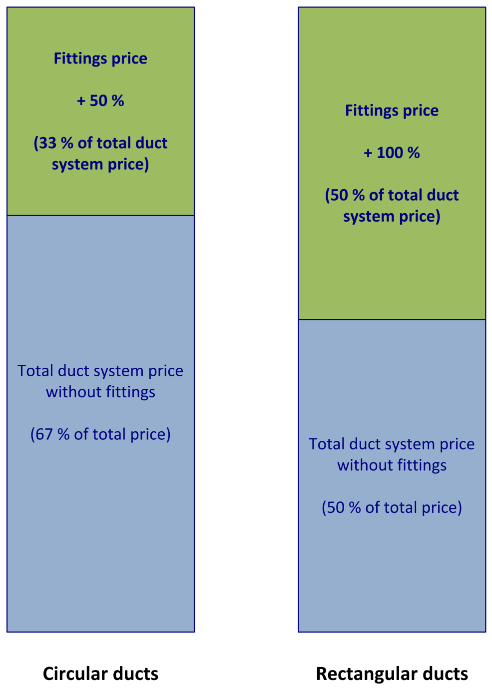


Figure 6.8: Price impact of fittings for ventilation on the TechFac project [Freddi Lading (Brøndum)]

rules and so on.

Regarding the tender laws, Carsten Kramer thinks that it is both a problem for the designer and the contractor that the communication needs to be blurred, especially in relation to EU tenders:

> *Specifications and descriptions of components becomes inscrutable. The designer is writing some blurred and we as contractors is trying to interpret what the designer means. We use four times more on this than when a product specification is presented. It would be easier if the owner could just specify what they really want*
>
> Carsten Kramer, Bid actuary at Henriksen & Jørgensen VVS

Hence both the designer and contractor agrees on this point, though the purpose of these tender laws is to create equal competition condition for both contractors and suppliers as the indication of product names implies a de facto favouritism of the specific supplier.

Problem: Limited level of detail and loss of information The HVAC contractors disputes the level of detail of the quantities in the tender list. The problem is that the designers are bounded in relation to present tender laws (in late tenders) and in general the HVAC quantities are very depended on the HVAC contractor, which is unknown at the certain time of designing. For instance the air handling unit has a major impact on the specific ventilation system as it specifices, which amount volume of air that can be supplied. Since the air handling unit can not be specified due to tender laws, it does not make sense to detail the whole ventilation system with fittings, silencers etc. Even if it was possible to specify certain products the designers claims that the contractor would make changes to the design for optimization in relation to function and price. This implies that the quantities has to be on an overall building element level in stead of activities/unit price level, which was shown in Fig 6.7. At the moment the building element level is not only consisting of explicit quantities as the fittings included under the pipe/duct entries as implicit quantities. This does not mean that the BIM models do not contain fittings, which is shown in Fig 6.9.

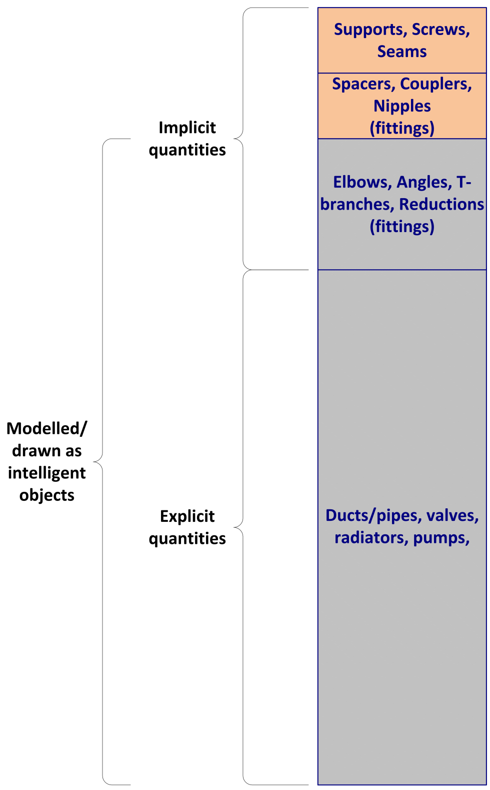


Figure 6.9: Modelled objects in relation to explicit/implicit quantities from Mærsk Bygningen

Fig 6.9 shows that objects like elbows, angles, nipples etc. are being modelled but not measured (implicit quantities are not measured). Thus there is a significant loss of information as some of the fittings are removed on the tender list. According to Niels Treldal this removal happens due to the purpose of not confusing the bidding contractors. By removing all fittings the princip of an equal level of detail is kept in stead of providing some fittings as explicit quantities and let the rest be implicit quantities. Niels Treldal estimates that it is only possible to model about 70% of all fittings, which means that the last 30% should be implicit quantities.

On that basis it is important to have a common perception that match the expectations of what a quantity includes and which quantities should be stated as implicit quantities. Hence there is a need of a definition saying which quantities should be respectively explicit and implicit. This definition for each building component should be linked to the different phases and say exactly which kind information that is needed for the specific component. Regarding this matter Cuneco has allready started a project to find all the relevant data for HVAC components.

6.3.3 Process

As in all deliveries it is important to have an established process to create the specified end product. This process of a tender list with quantities was not desbribed in the three investigated projects, hence it has been an experimental kind of work done by the designers, which is highlighted by Morten Alsdorf:

> *The thing we did on the DTU328 project was to experiment and test what we were capable of doing in relation to digital tender with quantities. Now we are trying to establish documents of methods and processes, which describe how we are handling digital tender in Rambøll*
>
> Morten Alsdorf, Project Manager at Rambøll

In relation to the preparation of the tender list with quantities it is important to consider, which elements are being measured and how to measure them. An HVAC designer knows all the components contained within the specific trade, but it is necessary schematize these components somehow because all HVAC trades includes many components. If the specific trade is only modelled in one piece of software (the electrical trade in the MB project was only modelled in MagiCad), the components should be schematized in 'software measured' and 'manual measured' and even in this simple case it can be rather complicated to control, which components are measured how. The MB project used four different pieces of software and a manual measurement for the components, hence it was necessary to do a schematization in that specific project to ensure that all components was included and a software was linked as shown in Fig 6.10.

Besides the component and software name, the table in Fig 6.10 is also containing information like 'properties needed' etc. Specific properties is needed for each component as the price determinated parameters often are different. For instance to price determine a pipe, properties like material, insulation and dimension will be relevant.

The specific process of QTO was already in 2008 brought up by Bips, when a document for the purpose of describing the QTO process was published [Bips (2008b)]. This process is shown in Fig 6.11.

The figure Fig 6.11 includes both *tenderlist with quantities* and *specifications*, thus it can be seen a bit confusing. Moreover there is no clearly defined steps, which makes it difficult to understand where to start and how to proceed as there is many parallel processes. On the basis of Fig 6.11, it can be determined that the designer is dealing with a building element overview and three kinds of quantities:

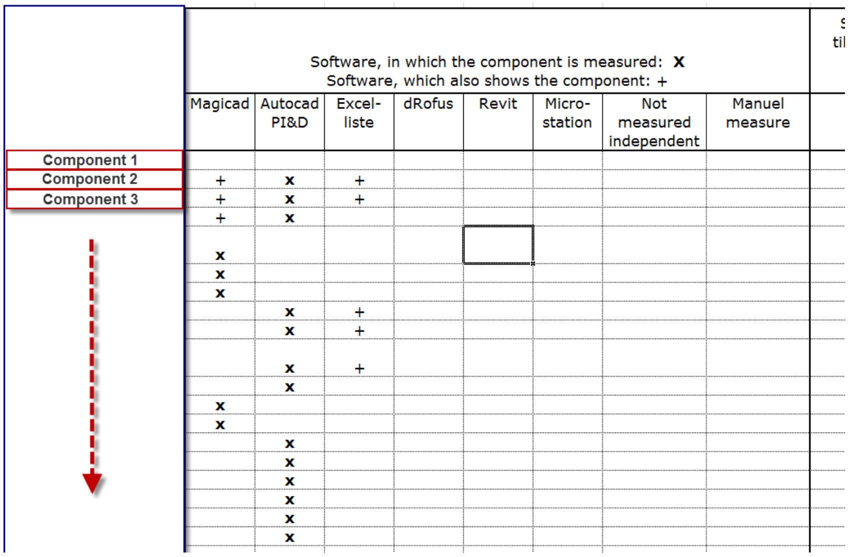


Figure 6.10: Example of schematization of where to measure the components

- Analog quantities (manual measurement)
- Digital quantities (semi-automatic measurement)
- General quantities (manual measurement)

The analog and digital quantities are interesting as they can be modelled, whereas the general quantities are the general non-modelbased services connected like construction site (scaffolding cost etc). When a quantity is analog it is often a manual measurement from a drawing or a schema. For all three projects the digital quantities was measured in a semi-automatic way from the BIM models. Semi-automatic in that sense that it was not just clicking a button to create the tender list with quantities, but a process with the involvement of Microsoft Excel. Overall there was an extraction from a BIM model(s), which was exported to Excel and then organised to a tender list.

During the MB project and in relation to this thesis a detailed process description of digital quantity measurement with documentations was developed. That process description is presented in Appendix D, but due to trade secret this is only available for the examiners and people authorized by Rambøll.

The overall process for creating a tender list from a BIM model is shown in Fig 6.12. This methodology supports the idea that all information comes from the models, thus there is no manual written tasks for the digital quantities. The five steps are:

(1) This step is concerning the export of data from a building model. The wanted data might need to be specified and then exported to a data file format (.txt, .csv etc.)

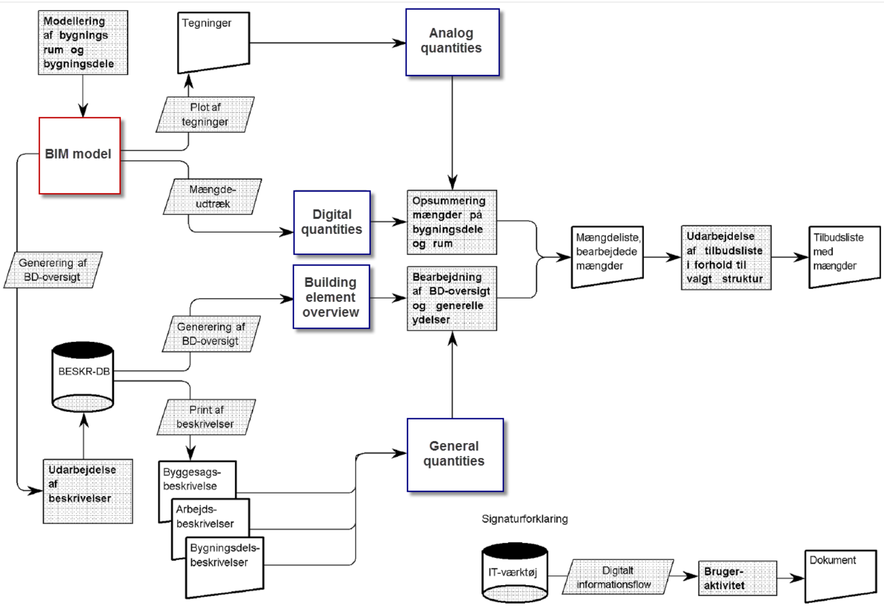


Figure 6.11: Extracting quantites - digital and analog process (Bips F110a, 2008)

(2) Excel can be used to sort and rephrase. Sorting is important as these softwares often gives more information than needed and rephrasing can be necessary to translate to Danish

(3) The structure of data gives an overview of all quantities and can be done in Excel in a Pivot Table.

(4) Export from Excel to a software to set up tender lists (the calculation software Sigma can be used for this task). The tender list can also be set up directly in Excel.

(5) The different tender lists are gathered into a tender list per trade contract

The above flow demands a technical implementation consisting of code in Excel or another spreadsheet application. When implemented, a tender list of the digital quantities can be made within 10 minutes per software and even faster if making the data transfer from the software to the data file automaticly. The program code made is also able to manage if changes are made in the models.

Problem: Missing IDM for QTO Due to the ICT-requirements concerning digital tender, it seems like an IDM is needed to clarify who and how is this service delivered. An IDM in Denmark is meant to serve the purpose of ensuring the correlation between the additional choosen service by the owner and the actual delivered product as shown in Fig 4.5. An IDM consists of:

- Process map
- Specification of roles

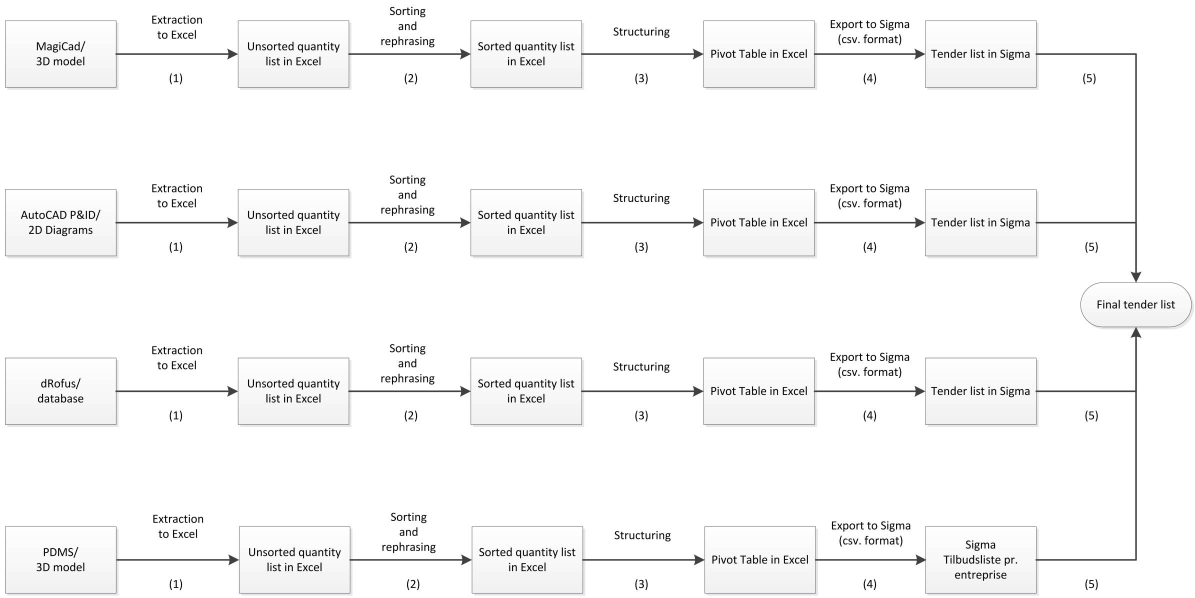


Figure 6.12: Measurement of digital quantities in the MB project (also shown in Appendix C)

- Specification of data objects
- Technical implementation MVD (software specific)

The process map has allready been started by DiKon (see Appendix B) with the overall process for a digital based on tenders after main project. The thing missing is a more specific process map of the QTO like the one developed in the MB project seen in Fig 6.12. This process shows specifically some clearly defined steps in order to execute QTO. Furthermore, in proportion to the projects investigated it seems like a necessity to define a role with the responsibility of QTO.

6.3.4 Delivery format of tender list

The practical delivery is also varying from project to project. A distinction is made between whether to deliver the tender list with quantities in editable formats (.xml, .xlsx) or in non-editable formats (.pdf). Currently there is no rules regarding, which format to deliver the tender list in. It is decided by the owner in the ICT-agreement.

In the MB project it was decided to deliver in both formats (.xlsx and .pdf), with the .pdf version as the legally binding document. Hereby the contractor still have the opportunity of using the .xlsx for calculation in other applications if wanted. In this way an intermediate between both interests was tried.

The DTU328 and the TechFac project tender lists was both only delivered in the .pdf format as showed in Table 6.6. In both cases the main reason was the lack of confidence due to the contractor managing an editable format.

Table 6.6: Partical delivery of tender list with quantities

	Delivered in .xlsx	Delivered in .pdf
MB	x	x
TechFac	x	
DTU328	x	

Designer perspective The designers are aware that contractors would like the tender list in editable formats. But the reason for not doing it is the prospects time spending for controlling the bids for mistakes. Moreover they do not trust that every contractor are able to handle an excel sheet:

> *The reason for not delivering in Excel was that then the bidding part would have had an oppurtunity to change the tender list with quantities. When sending as PDF, then you can be almost sure that they do not mix up the numbers or insert extra rows on the list. We know that they want it to be delivered in Excel as it makes it a lot easier for them to handle, but the consequence is that we would have to evaluate all the bids minutely..*
>
> *.. but the worst thing is if they accidentally deletes or hides rows or cells. Then the bidding part has suddently not bidden on the whole project and then he is out.*
>
> Martin Nielsen, Project manager at Moe & Brødsgaard

Several of problems can be caused of an error made of one of the bidding contractors. For instance the cheapest might be eliminated for making a mistake. Moreover the designer is also scared of not discovering a certain mistake in the Excel sheet made by the contractor. Moreover the designers are sceptical in relation to deliver a Excel sheet with pre-defined formulas for summation. Again the problem seems to be that the designers do not what to be responsible of how the contractors provides their bid.

Contractor perspective The contractor opinion is without a hitch from Flemming Grangaard regarding the delivery format of the tender list:

> *The tender list with quantities must be delivered in editable formats. It is that simple. Furtermore, it would be smart to develop IT systems to import XML files to calculation softwares*
>
> Flemming Grangaard, Consultant at The Danish Construction Association

The other contractors asked agreed with Flemming Grangaard on this point. They point out that by only providing a PDF, it is not a 'digital' hand over as the contractors has to type in all the quantities manually in their calculation softwares. Thus this simple practical issue becomes a point of disagreement.

Problem: Non-editable formats for tender list Based on the projects, there is a tendency that the tenderlist with quantities is delivered in non-editable formats. The designers has their reasons to do so, but it clearly does not agree to the vision of 'reusing data' through the different phases. The designer has concerns about the contractors ability to control the excel-sheets without hiding, deleting or changing quantity bidding related information. To meet these concerns the ICT conctracts (or IDM) needs to specify that the designer on behalf of the owner must deliver the quantities in editable formats to the bidding contractor. Possibly this could be done in Excel sheets with locked cells, which makes the possibility of making errors smaller. Moreover this contract should imply that any mistakes caused by the contractor due to making the bid in the editable format, which may lead to extra costs, are being paid by the bidding contractor. Specifically if the bidding contractor somehow manage to unlock cells and make changes, which will be detected later in process. However there is still a fundemental problem if the contractor who makes a mistake due to an editable format, actually are the cheapest contractor in the competitive bidding. In such a situation the present tender laws of competitive bidding excludes the bidding contractor and it is not possible to make a new bid (even if it was getting cheaper for the owner) because he has seen the other bids. Therefore it seems like the current solution is to provide both a .pdf as legally binding and a .xlsx providing the digital informations for further use.

6.3.5 Liability

The liability area concerning delivered quantities is characterized by vagueness. The current practice has no legal justification as there is no official agreement between the involved parts. It seems like the current practice is based on a note from the Danish Business Authority made in 2005 refering to five steps:

1. The designers has the liability for the delivered quantities
2. The contractors bids with unit prices on these quantities
3. Building owner chooses winning contractor
4. The contractor gets a couple of weeks to verify the quantities are correct. If neccessary the quantities are corrected and thus also the price
5. A contract is made with the winning contractor and the liability for the quantities is transfered to the contractor

(Danish Business Authority, 2005)

The above process is shown in Fig 6.13. This process corresponds to the one DiKon made (see Appendix B) and can on that basis be defined as the prevalent way of handling the liability issue in relation to quantities.

The process showed in Fig 6.13 was also followed in both MB, DTU328 and the TechFac project.

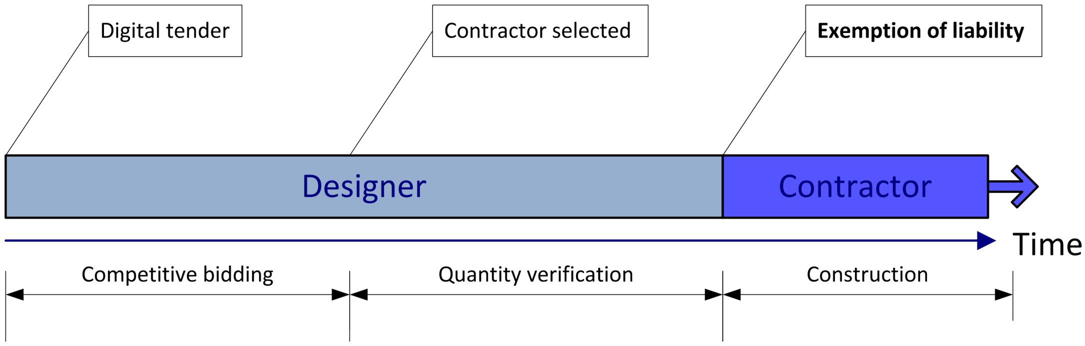


Figure 6.13: Liability for quantities

Designer perspective The designers are observant on the liability as the delivering of quantities are a new service to deliver. The concern is regarding for how long does the designer have the liability and what does this liability cover. Moreover Niels Treldal stats that it is a problem with the setup, where the contractors charges with invoices after the contractor has been selected. The point is that first after all the invoices has been delivered to the owner (and designer), it will be clarified what the actual bidding price is. The actual bidding price might not be the cheapest (if that is the dominating criteria), but that is first known after the agreement has been made with a contractor.

In addition, who is going to verify if the quantities are increased or decreased (in relation to delivered quantities from designer). The designers claims that if the quantities are increased, then the contractor will get paid for the extra cost. However if it is the other way around, then nothing happens. In general the designers argue, that when the quantities somehow are changed due to design changes (provoked by contractor), then there is a need for an authority to check the as-built quantities. Niels Treldal points at the Quantity Surveyors, which are used in among others in Englang and Germany. These are impartial officials hired to the purpose of clarifying the quantities.

Contractor perspective Flemming Grangaard acknowledge that transparency is missing on the liability in relation to quantities:

> *There is no transparency on this area. Right now the winnig contractor is verifying the quantities and then a exemption of liability from the designer to contractor is made. This process is based on a bad habit. The contractor might as well wait, construct the building and then measure when it is finished 'as built'..*
>
> *..legally this is not the right way of doing it. Legally the designer has the liability for that tender with quantities five years forward. But he avoid this by having another part (contractor, red) to accept liability. I really don't understand the contractors are willing to do so.*
>
> Flemming Grangaard, Consultant at The Danish Construction Association

The problem related can be if the contractors think that they do have the liability for the quantities. In that case they would be forced to calculate on the building project like in a traditional tender to know if the stated quantities are correct. Thus the quantity measurement is actually done twice. In response to this Morten Alsdorf states that the point is that only one of the bidding contractors (the seleceted contractor) are forced to do this traditional measurement compared to earlier where all the contractors had to do it. This means that the contractors bidding on a digital tender should trust the quantities stated and bid on those without doing a manual measurement. Furthermore, Morten Alsdorf disagrees with Flemming Grangaard about the fact that the contractor can avoid the verification and 'exemption of liability' before the construction period and do it as-built afterwards:

> *The bidding contractor must verify and undertake the liability a couple of weeks after competetive bidding. It is included in the contract, which the contractor signs when submitting a bid. If the contractor do not sign this, then he is not going to get the contract*
>
> Morten Alsdorf, Project manager at Rambøll

The HVAC contractor Carsten Kramer will not relate to the legal specifications, but states in stead that the whole quantity verification right now builts on a kind of 'fairness'. Implied that both parties will give and take in disagreements, which he do not think should be changed.

Problem: Liability vagueness As the above perspectives shows, there is fundemental vagueness and disagreement on this area. The liability issue is very complex as the delivery of measurering quantities has changed from the bidding contractor to the designer. But it still seems like the same liability has been kept at the contractor due to the 'exemption of liability' that happens after the competetive bidding phase, where the contractor verifies the measured quantities. The point is that the choosen contractor still will have to do the traditional quantity measurement, for which reason the designer only makes a preliminary quantity measurement. This means on the other hand that the non-choosen contractors are saving the time consuming traditional quantity measurement. A point of criticism from the contractor perspective is that the verification of quantities period is too short (often only 2 weeks), which gives the contractor poor requisites of making an careful verification.

The main problem is that the quantities changes from design to as-built. This means that the BIM model and the original quantity measurement is wrong. This implies the question about who to pay for these changes whether it goes up or down. Basically the quantities can be divided into three stages:

1. Tender quantities
2. Verified quantities
3. As-built quantities

The experience from the projects, is that every project has quantity changes during those three stages. The three quantities represents a contract price, thus the prices are changing even after the tender. Hence the building industry needs to have clear set of rules on this area. The Table 6.7 shows a framework of the current practice.

Table 6.7: Quantities in three stages

	Tender quantities	Verified quantities	As-built quantities
Delivered by	Designer	Designer and contractor	Contractor
Basis	Models/drawings	Models/drawings	Invoices and some manual measurement
Documentation	Known	Known	Unknown

The outlining of above problems gives rise to changes in the standard contract documents ABR89/AB92 as these appears contractual basis between the owner and respectively designer and contractor. Neither ABR89 or AB92 has a point regarding the digital quantity measurement from desinger to contractor in a digital tender, but those documents are still used as reference if experiencing problems on this area.

6.4 3D model

In a digital tender with quantities it is important to build the 3D model correct in accordance to the classification, thus the single building elements gets the right classification code. The model needs to be structured in a way that makes it rather easy to extract quantities, but also in a way where it is easy to retrieve the elements through the classification code. Before the modeling it is also important to clarify in relation to the specific ICT contract, including the software choice, the information level etc.

For the actual tender the finished 3D model can be delivered in the IFC-format to the bidding contractors. Moreover the winning contractor might, after the tender, get the 3D model in the original format, so the quantities can be verified.

In the MB project the 3D model was delivered in the IFC-format only to provide orientation to the building project and not to extract quantities. After the tender the model was delivered in the original format and it was the same case of DTU328. In the TechFac project the 3D model was not even included in the tender documents as it was shown in Table 6.1. The reason for that choice was foreboding regarding the following version control.

6.4.1 Information levels

The information levels are described on a general basis in Bips C102 (CAD Manual, 2008) and also shown in the theory chapter. Those levels are a paradigme for how detailed to deliver a 3D model in a specific phase of the building project.

In the MB project the owner required an object based building model in information level 4 for the HVAC systems. The owner's perception of information level 4 for HVAC, was among other that pipe- and duct systems are modelled from feed circuits insertion in building to the consumption site plus some other specific detail requirements of the 3D model. Moreover an illustration was made to give a visual idea of information level, which is shown in Fig 6.14.

Table 6.8: Information levels of the 3D model in the three projects

	Information level of 3D model
MB	Information level 4
TechFac	Information level 2
DTU328	Information level 4

The difference between the MB project and the other projects are shown in Table 6.8. In the TechFac project the original ICT agreement was changed in accordance with the owner. The modification was regarding the information level of the 3D model, as it was changed from an information level 4 model to an information level 2 model. The designer estimated that if they should finish within the timeframe and earn on the project then the 3D model needed to be simplified. This underlines the point that designers find it difficult to deliver detailed 3D models within the economic- and timeframe.

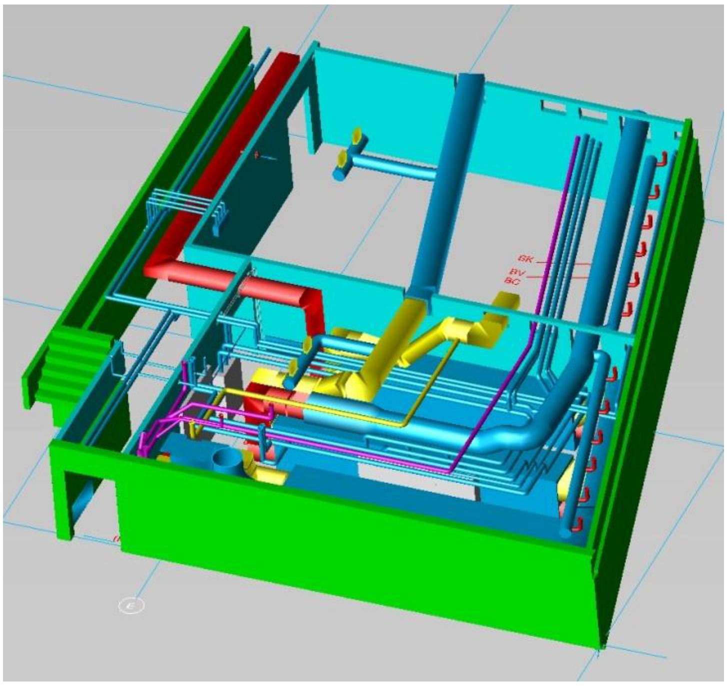


Figure 6.14: Illustration of information level 4 in the MB project

Designer perspective In general the designers experience inconsistency in the way that the owners interprets the different information levels. According to Niels Treldal it is not unusual that owners has different perceptions of information level 4, which are the common information level of a 3D model delivered after main project. Hence the owner and designer needs to discuss which HVAC elements are included in this specific information level. In addition to this, Morten Alsdorf states that Cuneco is about to change the Bips C102. Cuneco proposes a reorganization, which means that different kind of building components can be assigned to different information levels and MTA like the idea:

> *The varying information levels per bulding element is a good development. But it is important that we are making some standard information levels for the building elements and these needs to be connected to PAR & FRI's phases. Implied that there for a certain building element in a certain phase is a standardized information level description*
>
> Morten Alsdorf, Project manager at Rambøll

This means that for a valve there is a clear description of informations when having a late tender (after main project). In other words, building components can have different information levels in the same phase of the building project.

Contractor perspective The contractors are also noticing, that the 3D models for information level 4 are varying too much from project to project, but according to Flemming Grangaard they do not agree that the solution is to give building components different information levels in the same building phase. Regarding the revision of information levels Flemming Grangaard doubts if it is a good idea to have different information levels on building components:

> *They (Cunego) prepare the ground for varying information levels in a tender, which will imply that something is tendered on 'procurement based on operational needs*[2]*' and something is not. The danger is that the designer sneak 'procurement based on operational needs' in through the backdoor on contracts where the contractor do not expect it. That can be dangerous for the bidding contractor*
>
> Flemming Grangaard, Consultant at The Danish Construction Association

Furthermore, FGR doubts that a standardization of these information will help as it overall confuses that there can be different information levels on each phase depended on the building component.

Problem: Unclear information levels The problem in the current information levels is that the owner and designer needs to discuss at each project, which components are visible in a specific information level due to the general Bips description of information level. The general description from Bips leads to interpretations and those are different among owners and designers. Hence there is a need of specific information levels for each building components.

6.4.2 Software basis for modeling and QTO

The software choice is an important factor when it comes to BIM modelling and quantity take-off. The choice of software has to be based on the capability of managing and extracting information for QTO, but most of all the capability of showing the constructional concept. Moreover user friendlyness and price are also significant parameters. There is a distinction between two kind of tools when handling digital tender with quantities:

- Bim model tools
- QTO management tools

In the MB project it was chosen to use four tools (MagiCad, AutoCad P&ID, dRofus and PDMS) to measure the *digital quantities*. It is not unusual to use different kind of softwares to show or describe the 3D structure, the 2D flows etc. But in this case all four contributed to the QTO, which is shown in Table 6.9.

Normally only the quantities of the first row (MagiCad row) would be the digital quantities and the rest will be analog quantities (manual measurement), but in the case of the MB project the share of digital quantities was significant increased. This means that the digital quantities contributed with 96% (in relation to total of analog and digital quantities) based on the entries on the tender list with quantities for both ventilation and plumbing:

[2] Funktionsudbud

Table 6.9: Softwares used for QTO of digital quantities in the MB project for HVAC

Software	Description	QTO
MagiCad	The main 3D model with intelligent objects	Ducts, pipes, fixtures, chilled beams, hose reels, condensate pumps, roof wells, manifolds, radiators, sprinkler heads, storz couplings
AutoCad P&ID	Flow chart diagrams in 2D with intelligent objects	Valves, dampers, measurers, filters, Pumps, buffer tanks, cleansing bars, compressors, desiccant, mixing loops, heat fans, zone cooling coils, zone heating coils, humidifiers,
dRofus	Room database progam for commodities and special lab equipment	Mixer taps, spray faucets, showers, floor drains, toilets, washes, fancoils, fume cupboards, chemistry cabinet, security benchs, local exhaust ventilation, LAF benchs, range hoods
PDMS	3D model of a special system for flammable liquids	All pipes, valves, pumps etc. for this special system

$$\frac{Digital}{Digital + Analog} = \frac{1804}{1804 + 72} \approx 96\%$$

Thus there was respectively 1804 digtal and 72 analog entries on the tender list with quantities. This calculation gives an indication of the use of digital measurement, but it does not account for the use of implicit quantities as these are included and not explicit represented on the tender list. As comparacy this calculation would give a much lower percentage for both DTU328 and the TechFac project as those projects had more analog manual measures.

Besides the modelling and drawing softwares, there is also softwares used for the QTO management. Regarding the QTO management, the common way of doing it is to extract from the BIM model to Excel cf. point 1 from BIM Handbook [Chuck Eastman (2011)]. This was done in all the projects investigated. This procedure gives the designer the raw data in Excel, which gives the oppurtunity of setting a specific code up for managing the quantities. Though the problem can be that it is very time consuming to set up and furthermore the visual aspect is missing.

Designer perspective In general the designers are not satisfied with the current software solutions for BIM modeling in relation to HVAC digital tenders. The prefered softwares for pipe/duct systems are MagiCad and Revit MEP. According to Niels Treldal the most used software for HVAC contracts in Rambøll is MagiCad, whereas Revit was used in Moe & Brødsgaard according to Martin Nielsen. Both points at the fact that the softwares are lacking when reaching a certain file or project size. This means a lot of work of dividing and use of references/links. Still with the use of references/links the designers claims that with the information contained in each component, those specific softwares does not seem to be geared for the masssive load of information it needs to handle.

In relation to the practical delivery of BIM model, the desiggers incline to the view that an IFC-file should be a bidding basis for orietentation. The reason for not delivering the original format is first of all that the designers do not want to give preferencial treatment to contractors using the software of the original file (Tekla, MagiCad, Revit etc.). Hence the open IFC format is used for orientation only. Furthermore, there are specific software issues involved. If creating a BIM model in Revit MEP, the generic building objects and components are build on the Revit 'families'. Some of these families are home-made generic objects or a detailed component, which the designer has developed. By handing out the original Revit model MEP model, the designer will also hand out those home-made generic komponents. If using MagiCad the components are often not generic, but in stead build on trademark products. Thus, it is not possible due to tender laws to deliver these files in the original format either.

Contractor perspective According to Flemming Grangaard the common contractor are beginning to increase interest for the softwares used by the designer, since the models contain important information in relation to execution. In relation to the bidding stage, FGR claims that the tender document should include an IFC-file in stead of the original format due to competitive advantages. Moreover he is not satisfied with the way the BIM models is structured as all trades are often collected in one IFC-file. He suggest that the designer deliver both a general and a trade specific IFC-file as a bidding basis.

In general the use of the 3D models (IFC files) are mixed and depends on the individual contractor. Carsten Kramer do not use the model for much, but thinks it is 'good to have'. But he is in general against that BIM models should have to much impact on the tender documents. He points also that it could be a competition problem for smaller contractors:

> *3D models is used very little as they are often too heavy and slow. Moreover they are not detailed enough. Regardless it would be pleasant to with both a trade specific and a full model as it sometimes also is necessary to have everything to understand the complexity of the building project*
>
> *It can also be considered as a competition problem that the 3D models demands improved computers. It eliminates the contractors in the peripheral Denmark. It is a competition problem that they do not have the capacity of running these 3D models, hence these should nor attach too much importance*
>
> Carsten Kramer, Bid actuary at Henriksen & Jørgensen VVS

As opposed to this, Freddi Lading from Brøndum is using the models to a great extent. From his point view, the models are increasing the knowledge of a building project, hence the basis of calculation improves.

Problem: Software limitations and usability of 3D model and tender list It seems like the most common softwares used in relation to HVAC BIM models are MagiCad (file based) and Revit MEP (database based), whereas the QTO part often is handled in Excel. The general experience on both the designer and contractor side is that the BIM models are too heavy and slowed due to all the information they contain. This provides the general software limitation in relation to digital tenders.

Furthermore, the role of the BIM model as a bidding basis is undefined. In relation to bidding, the three purposes has been discovered about the role of the BIM model:

- For orientation (MB, DTU328)
- For quantity measurement (other projects)
- 3D model not included (TechFac)

On that basis a specific usability description needs to be made of the 3D model. Thereby it is avoided that the designer spends much time to complete a 3D model, which barely is being used. In particular if the designer makes an effort of making an automatic connection between 3D model and tender list with quantities. In that sense it is also relevant to consider if the BIM model is being used and how it should be used.

6.5 Bidding - and settlement basis

The *bidding - and settlement basis* is a document, which is clarifying how the quantities are measured (measurement rules) and what is included in that specific quantity (explicit/implicit quantities). Thus it helps to specify exactly what the contractor is bidding on for each building element. The *bidding - and settlement basis* document is used as a realisation that there are no common standards for such rules of quantities in Denmark.

6.5.1 Measurement rules

The measurement rules is provided to secure a rational tender list with quantities due to the digital tender and create a basis of development of tools, which in a productive way can make easy to both tender and submit bids on a equal basis.

The current basis of general measurement rules are published in Bips 'Measurement rules 2008 F111'. This document shows on an overall level how to measure different quantities measures such as: number, length, surface area, volume, weight, time etc. In relation to digital quatities in HVAC contracts, the relevant quantities measures are *number* and *length*.

For the *number* the quantity is stated as piece (pcs) of similar building components or services. Similar means components, which are the same type, material, dimensions and function or services of same kind. Similar components does not have to be equal in relation to assembling or location. Nor they have to be executed on the same time or distributed equally. The *number* quantity is simple and does not lead to further problems.

The *length* quantity is more complicated as there is three different ways of measurering a duct/pipe length:

- Through-going measurement by bend- and cross points (a)
- Through-going measurement by center lines (b)
- Separate parts summarised measurement (c)

The basis of all three methods are that a duct/pipe is stated as running metre.

Through-going measurement by bend- and cross points is measured from start building element to end building element or from and to contiguous building element of another composition or material. The quantity is measured as Through-going length by bend- and cross points. The length is measured as gross length where there is a sloping end or opening ends - that is without subtraction. Measurements are made through the center line as seen in Fig 6.15.

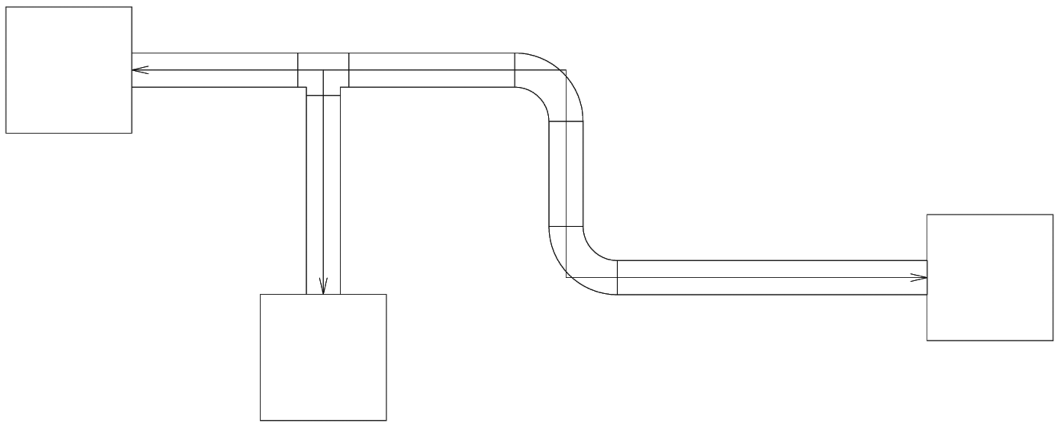


Figure 6.15: Through-going measurement by bend- and cross points (a)

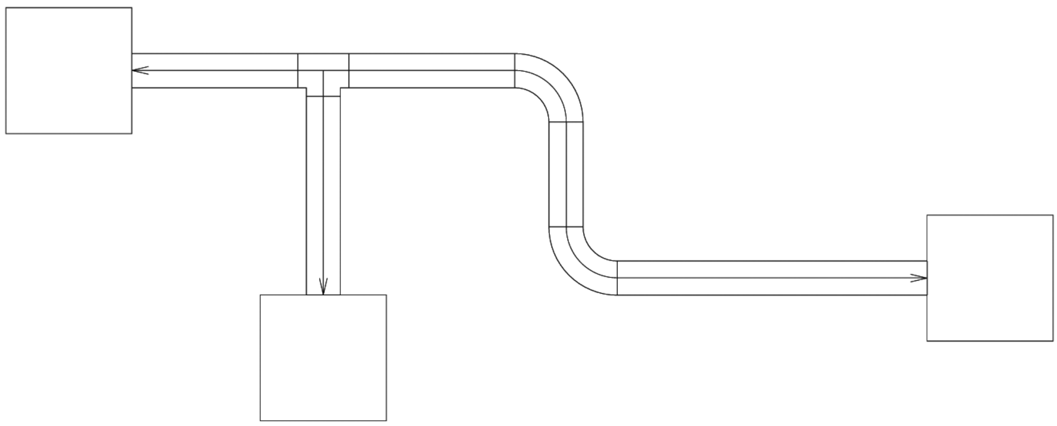


Figure 6.16: Through-going measurement by center lines (b)

Through-going measurement by center lines is also measured from start building element to end building element or from and to contiguous building element of another composition or material. The length is measured as gross length where there is a sloping end or opening ends - that is without subtraction. Measurements are made through the center line as seen in Fig 6.16.

Separate parts summarised measurement is measured from cross points and change of direction such as bendings, branches etc. The length is measured as netto length where there is a sloping end or opening ends - that is without subtraction. Measurements are made through the center line and summarised as seen in Fig 6.17.

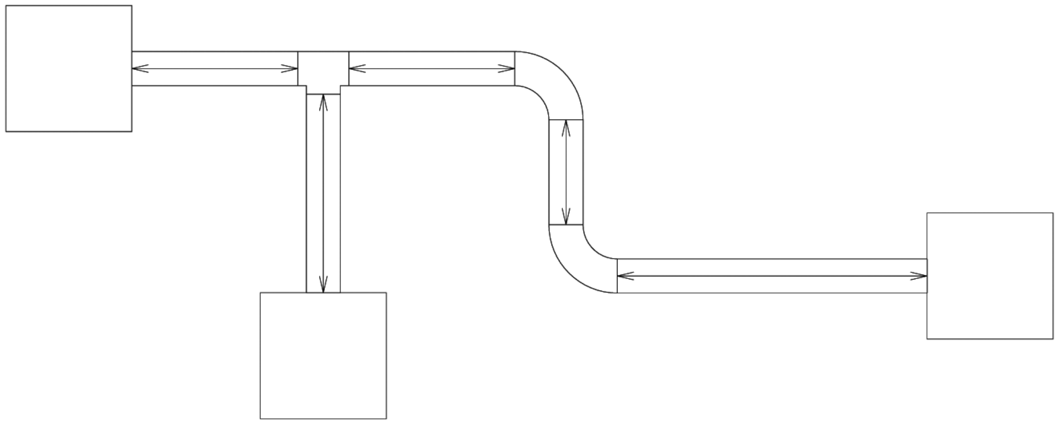


Figure 6.17: Separate parts summarised measurement (c)

In the investigated projects measurement rule (b) and (c) was used for measurering lenghts of ducts or pipes as shown in Fig 6.18 and Fig 6.19.

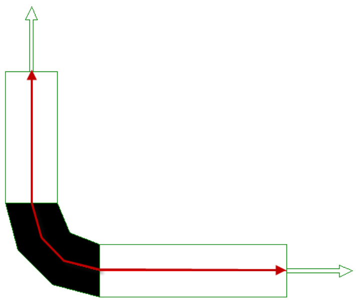


Figure 6.18: Measurement rules for ducts/pipes (TechFac) corresponding to measurement rule (b)

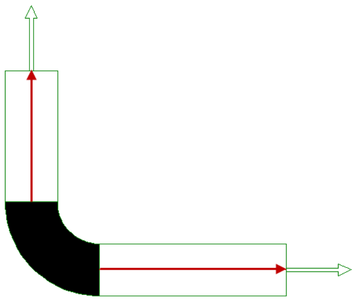


Figure 6.19: Measurement rules for ducts/pipes (MB) corresponding to measurement rule (c)

Both the TechFac and the MB project was omitting bendings, which is why that part of the drawing is black. In other words both project was only operating with straight pipe and duct lines, but the way of providing these lenghts was different. In the MB project only the actual netto straight length pipes and ducts (shown be red color) were used in tender list with quantities, whereas the TechFac project was including the length in the bending based on a center line to compensate of missing bending fittings:

> *We can see that the model extracts x number of bendings and then we made a conversion factor for each type of bending. Then we add this line length in the bending and gets some kind of equivalent*

> *length. For some systems it shown that if only measuring the straight line length (without the bending) it only corresponded to about 30% of the equivalent length. This is why the equivalent length has been used and we did highlight this fact in the specifications. Then the bidding contractor knows that it should be taken into account*
>
> Martin Nielsen, TechFac project

6.5.2 Implicit/explicit quantities

Beside the rules of measurement there is also differenties of what to include for each building elements as mentioned early in the level of detail section. For instance insulation on pipes should be included by the contractor in the TechFac project, whereas it was quantity shown in the tender list of MB. This shows inconsistency in the way quantities are measured and communicated. Moreover there is aforementioned problematic about fittings. At the current stage such rules does not exist, wherefore there again is no consistency in the delivered quantities. Hence it is important with a document like *Bidding - and settlement basis* to clarify for these informations.

In the MB project it was decided to use *Bidding - and settlement basis* as the designers did not see the content as a part of the *Specifications*. It was divided like that in order to give a better overview for the contractor. At both DTU328 and TechFac such document was not used, hence that information regarding the clarification of the different quantities was placed in the *Specifications* document.

Designer perspective As mentioned in the introduction to this chapter, the *Bidding - and settlement basis* is a rarity on building projects. The TechFac project did not use such a document as they thought it was better to collect the information in the *Specifications* document:

> *We did not use a 'Bidding - and settlement basis' document on the TechFac project. All the information regarding 'Bidding - and settlement basis' are placed under the specifications. This implies that the specifications are very long in this project*
>
> Martin Nielsen, TechFac project

From experience of the MB project there is not doubt that the *Bidding - and settlement basis* document provides an extra kind of work due to implementation. Specifically there is a distinguishing between what belongs to *bidding - and settlement basis* and what belongs to *specifications*. Morten Alsdorf (MAL) underlines that the *Bidding - and settlement basis* is not a new invention:

> *The use of the document is not new, but the way we use it by having a specific Bidding - and settlement basis per building component is new. It is the most important document as there is no common rules on this point*
>
> Morten Alsdorf, project manager

Furthermore, Morten Alsdorf stats that this document was not necessary use if properly measurement rules was present in Denmark.

Contractor perpsective The contractors are favourably disposed towards the introduction of *Bidding - and settlement basis*. Flemming Grangaard is a proponent to implement such document in the building industry and thinks that the construction industry should be taken into consideration:

> *..we should do as they do in construction projects. Unlike building projects, they are operating with a document called bidding- and delimitation basis to indicate what are contained in the different quantities and they are having good experience with that practice*
>
> Flemming Grangaard, 2013

Carsten Kramer and Freddi Lading are also agreeable to the thought of the *Bidding - and settlement basis* especially because it is diffucult to conclude what is included in each quantity presented.

Chapter 7
Discussion

This chapter will catch up the problems from the analysis and discuss possible solutions and consequences to each. The problems has different character as some are simple practical and others are fundemental - both kinds will be outlined. To get an overview of the different solutions on specific levels, the change management pyramide is used. As illustrated on Fig 2.4 the discussion will be focused on the tools - and methods/processes level and organisational level.

7.1 General

The analysis prepared the ground for the following specific problems in relation to digital tender for HVAC contracts:

- Insufficient classification
- Different information structure and pricing of quantities
- Limited level of detail and loss of information
- Missing IDM for QTO
- Non-editable formats for tender lists
- Liability vagueness
- Unclear information levels
- Software limititaions and usability of 3D model and tender list
- No general rule for explicit/implicit quantities

These problem topics demands some kind action on either a tool-, method/process, organisation or industry level. It should be mentioned that some of these are covered in the work done by Cuneco. Nevertheless the aim of this chapter is to come up with suggestions/solutions and perhaps affect the work done by Cuneco. All of above except the classification will be processed with basis of the analysis. The reason of neclecting the classification issue, is that Cunecos classification replacement CCS is just around the corner, hence it is not possible to affect this issue.

7.2 Tools changes

Tools are handled on the 1st level in the change management pyramide as the effort is lowest in relation to changing softwares to solve a problem. It often involves only the people working with the software, hence it in many cases will be the less costly solution to implement. Furthermore, tools are also important as they can change a process.

7.2.1 Bim modelling software improvements

Regarding the BIM modelling software the performance and capacity was criticised by both the designer and contractors. The actors involved in this thesis specifically pointed at MagiCad and Revit MEP as being those affected of these issues. Therefore it might be solution to consider alternative existing softwares - For instance PDMS from Aveva, which was tested on a single system on the MB project. PDMS is a 3D plant software with way more options in relation to designing than MagiCad and Revit MEP such as higher level of detail (down to bolts, packing etc.) and rapid modelling. Moreover it offers possibilities of extracting isometric working drawings for the contractor, which sounds attractive from a contractor perspective. Though it would give the designer improved requisites in order to make more detailed models and the contractor in relation to execution there is some framework conditions, which makes it impossible to utilize PDMS. The current tender laws and contractor depended quantities gives circumstances, that makes it difficult to improve the level of detail. Therefore it is simply not possible utilise present software capabilities, allthough the softwares are ready. The reason for not just profitting of the rapid modelling might be the fact that plant software (including PDMS) costs much more than MagiCad and Revit. Moreover it does not have a product or generic object library from the start as MagiCad and Revit, hence there will be a great time consumption for implement such library. Thus there is not an extensive potential on the BIM modelling softwares due to the framework conditions.

7.2.2 QTO software improvements

On the contrary, there seems to be a great potential in relation to QTO software. The common way of doing it right now (as it also was done on the MB, DTU328 and TechFac) is to extract from the BIM model to Microsoft Excel cf. point 1 from the BIM Handbook (REF). This gives the designer the raw data, which forces the designer to set up a specific code for managing the quantities and later structuring a tender in Excel, Sigma or another software. Though the problem can be that it is very time consuming to set up and most likely it will to a great extent be a project oriented code. Furthermore, the visual aspect is missing. In addition to that perception, softwares has been developed to manage and visualise in relation to present the quantities in a tender list. According to the BIM Handbook (Eastman, 2011) there exist a couple of softwares for that task: AutoDesk QTO, Exactal CostX, Innovaya and Vico Takeoff Manager. Therefore Vico Takeoff Manager was tested in relation of doing this task.

Vico Takeoff Manager is a part of the software package called Vico Office, which consists of very detailed tools in relation to execution, but in addition to this also a QTO tool. The import function in

Vico can read files from several of softwares such as Revit, Tekla, SketchUp, ArchiCad and IFC's. In relation to MagiCad the test showed that it was unfortuneatly only able to import one property from a bulding component at a time, thus it was not applicable on the MB project. Under the assumption that it was working it would have been possible to change the process from the one shown in Fig 6.12 to Fig 7.1.

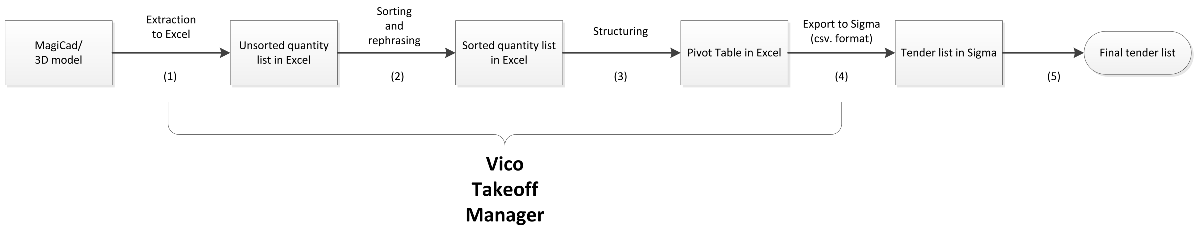


Figure 7.1: Change of process due to Vico Takeoff Manager

As illustrated on Fig 7.1, Vico is able to deal with *sorting* and *structuring* tasks, which would make Excel unnecessary in the new process. Moreover Vico provides a visual aspect in relation to the building components, thus it also has some benefits regarding quality assurance. In addition the theory of the BIM Handbook [Chuck Eastman (2011)] reports that softwares like Innovaya provides a visual mode of all objects that have been imported from the BIM model and highlights all the changed objects. However it does not seem to be possible to print a tender list, so the last step in the process remains as a link to Sigma or another software. There might allready exist a software able to deal with the whole process from model to complete tender list, thus there exist is great potential for saving time on this process and providing visual aspect for quality assurance.

7.3 Method changes

This section will provide suggestions in proportion to methods for dealing with the digital tender based on the analysis. There is not doubt that the digital tender is challenging the industry, in particular the designers as demands are increased for designing and structure of data within the BIM models. Moreover the end product of the tender documents are unclear in relation to level of detail and structure of information.

7.3.1 Information levels per building component

The point is that the quantity measurement should be connected to the information levels as Cuneco allready has suggested. Thus there should be standard information levels per building component and a set of standards per information level as shown in Fig 7.2.

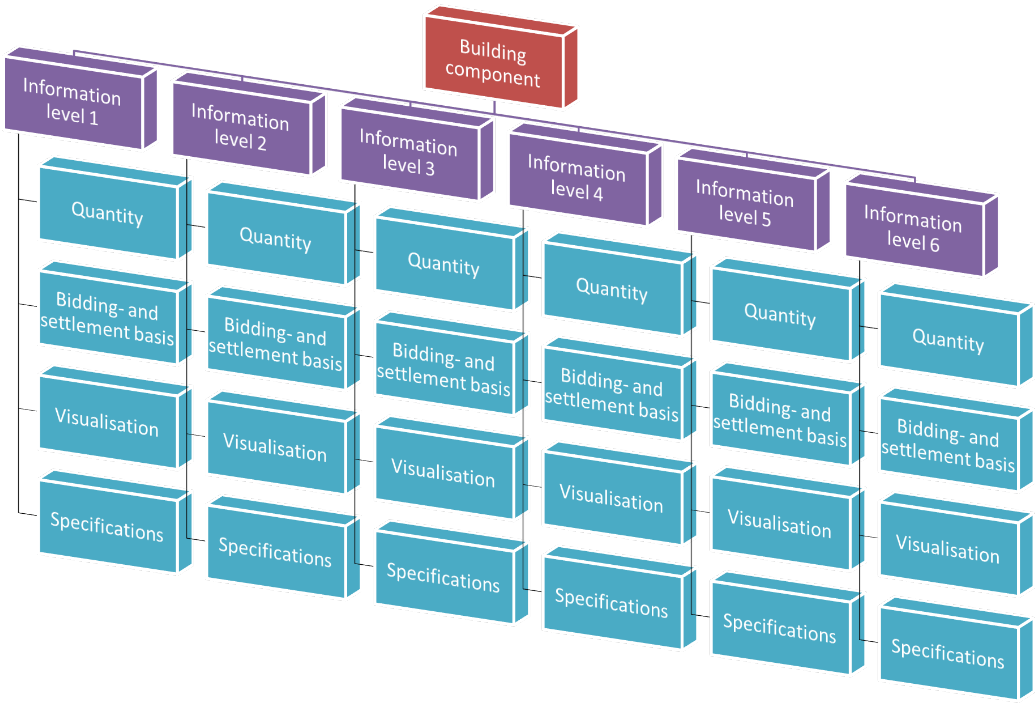


Figure 7.2: Building

Examples of how to fill the different boxes is stated below (among different building components)

Quantity : "Overall building area (m^2)", "Room volume (m^3)", "Running meter component (m)"

Bidding- and settlement basis : "The price should include supports and adjustment for ceiling system", "The price should include indicating instrument", "The price should include bendings, moulded pieces and branches"

Visualisation : "No graphical representation", "Symbolic representation with correct connection point", "All with outer diamater more than 50mm modelled", "All modelled"

Specifications : "Should be with double PTFE-packings", "Supports should be suited for lab gases and the material should be either plastics or stainless steel"

Therefore it is the information level that decides if a quantity is explicit or implicit, how it is stated, measured and visualised on the drawings/models. By making this division the information level goes from being general and vauge to specific and usable. Thus each building component is indisputable and the designer does not have to discuss what is included in a specific information level with the owner about this and the contractor knows what he gets after seing the information levels. Furthermore, this action will also eliminate the problem related to measurement rules as this information is included in the bidding- and settlement basis per building component. When the information for each component has been established, it should be considered how to connect the specific information level per component to a specific phase. Thus this will become a reference with a basis information level connected to each phase.

7.3.2 Structuring of tender list

There is also a need of a fixed standard structure of the tender list with quantities, which is being followed by all owners and designers. Allthough the building component is governing regarding information level with corresponding information, the overall structure of the tender list with quantities is still making sense to divide per system according to both designers and contractors due to a better overview. However the structure will still be depended on the information levels of the building elements as they decide how many details or price-determining parameters there has to be included on each entry as shown on Fig 7.3.

The example of structure illustrated in Fig 7.3 shows that the main system gives the overall structure. Under this comes the sub systems and the components. The reason for placing them at the same level is due to the fact that some HVAC sub systems are priced as a whole unit, for instance mixing loops for heating. The distinction between them is that sub system has a DBK code of 2 digits, whereas a component has a DBK code of 3 digits. Below those comes the price-determining paramters, which in this case are respectively: Reactangular (type), Lamella mat mounted (insulation) and 1000x2600 (dimension).

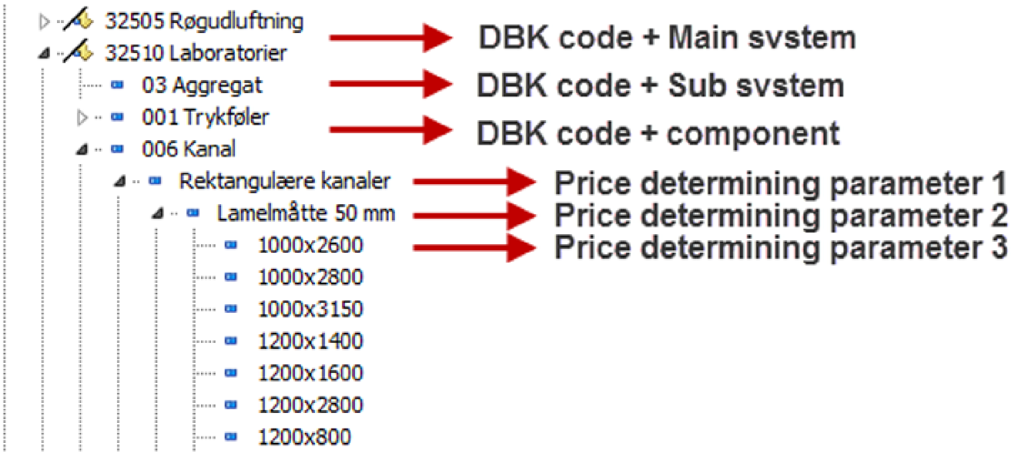


Figure 7.3: Structure of tender list for the MB project

As mentioned above the number of price-determining parameters is decided from the information level. Therefore it makes sense to only keep the two upper levels as fixed and let the price-determining parameters be depended of the information level (though it might be unnecessary to have structures on the lower information levels). Fig 7.3 could be an example of the structure for a duct in information level. In a similar way this should be done for valves, pipes and other components on the different information levels. When this is done the tender list with quantities should be standardized in relation to information levels of each component. Afterwards this structure should be set to a certain format, which can be exchanged with calculation software. Hereby the contractors will bid on a common basis.

7.3.3 Pricing per system

Regarding the pricing it make sense to bid on each main system in stead of the component in the shape of a unit price. The contractors agrees on this point as it follows the practice they are allready doing (when estimating they start out by price a main system and divide it out on the components). Moreover they see the components as being 'diffuse' as they covers implicit quanities and activities. Even though these implicit quanities and activities will be determined in relation information levels, the building components will still be covering them and therefore being kind of 'diffuse'. Therefore it makes sense to price the whole main system as it leads to lesser doubt about what is covering. Furthermore, it is also attractive that the contractor do not have to fill out more than 800 entries on the tender list. By pricing per main system this is reduced to 20-30 entries as shown on the tender list for ventilation of the MB project on Fig 7.4.

In addittion to the tender list seen in Fig 7.4 there will be a quantity list giving the quantities for each main system. Besides the contractors, this procedure also provides benefits for the owner and designer in relation to assessmnet of incoming bids. On this basis they will not have to examine the 800 entries for each bid, but only the 20-30 main system prices (and the other competive parameters). This would

Tilbudsliste for ventilationsteknik E12

Pos	Tekst	Enhed	Mængde	Samlet EP
	Mærsk Bygningen			
1.	**Ventilationsteknik**			
1.1.	32500 Friskluftindtag - Forsyning	sum	1	0,00
1.2.	32500 Ventilations afkast	sum	1	0,00
1.3.	32501 Trappe 1	sum	1	0,00
1.4.	32502 Trappe 2	sum	1	0,00
1.5.	32503 Trappe 3	sum	1	0,00
1.6.	32504 Backup-kølecentral	sum	1	0,00
1.7.	32505 Røgudluftning	sum	1	0,00
1.8.	32510 Laboratorier	sum	1	0,00
1.9.	32530 Kontorer	sum	1	0,00
1.10.	32531 Auditorium Stort	sum	1	0,00
1.11.	32532 Auditorium Lille	sum	1	0,00
1.12.	32533 Auditorium Mellem	sum	1	0,00
1.13.	32534 Køkken	sum	1	0,00
1.14.	32535 Kantine	sum	1	0,00
1.15.	32536 Substrat	sum	1	0,00
1.16.	32537 Basen	sum	1	0,00
1.17.	32538 Undervisning	sum	1	0,00
1.18.	32539 Repræsentation	sum	1	0,00
1.19.	32550 Isotop stinkskab	sum	1	0,00
1.20.	32551 Skraldesug	sum	1	0,00
1.21.	32552 Varegård	sum	1	0,00

Figure 7.4: Tender list of ventilation for the MB project

simultaneously also solve the problem regarding the delivery format of tender list as the quantities will be delivered in a separate quantity list. Therefore this list can without concerns be deliverd in an editable format, since the quantity list is not used in the assessment of the incoming bids.

7.3.4 Changing ABR89 and AB92

In relation to the liability issue about the quantities, it is evident to have a look at the contractual basis for both designers and contractors. For both ABR89 and AB92, the measurement change from designer to contractor due to the ICT executive order (BEK no 1381 of 13/12/2010), has not been taken into account.

The point is that it must be stated clearly what happens if the *preliminary quantities* $\neq$ *verified quantities*. In other words who is going to pay (or earn) for the change in the quantities between those two stages. In the current version of ABR89 the invoice is sent to the owner according to paragraph (6.2.1). The same thing is happening if *verified quantities* $\neq$ *as-built quantities*, then the invoice again is sent to the owner according to Freddi Lading. In that respect it can be discussed, when the designer and contractor can be hold responsible for wrong measurements of quantities. If the designer was held responsible for the preliminary quantities, then the consequence would be that the designer probably added 5-10% to the quantities to be on the safe side of paying in return, and the contractor has no incentive of reporting that quantities has decreased as it in the most cases would give him a lower profit. Therefore the rephrasing of ABR89 and AB92 needs to emphasize an incentive for correct measurement with a enclosed economical liability demand.

The alternative is to include a neutral part to control the measurement of quantities like the quantity surveyors as mentioned in the analysis. They would be able to give an impartial assessment of the quantities of the three stages. The problem is that also provides an extra cost for the owner to involve a third party like the quantity surveyors.

7.3.5 IDM for digital tenders for HVAC contracts

Based on the analysis there is a need of an IDM clarifying the processes and deliveries in a digital tender (after main project). The thesis has not be aimed against the development of IDM, but the experiences during the work has given inputs, in particular to the process oriented part.

Process map

There is a need of an overall process map describing the digital tender. This has (almost) allready been developed by DiKon as shown in Appendix B. This process forms an overview of how the deliveries are connected between the different parts.

Furthermore, a specific QTO process including the preparation before the modelling and the actual QTO flow also needs to be developed. For that reason the Fig 6.12 (also shown in higher scale in Appendix C) was created to contribute in that connection. It only shows how the QTO can be executed, hence it needs to be extended to cover preparation etc.

Roles

Based on the work done in the MB project, there seems to be a need of a specific role regarding the QTO and the creation of tender list. This role could be named *QTO coordinator* and could be a function under the *ICT manager*. This means that this role is ranked alongside with the *model coordinator* as illustrated on Fig 7.5. In general there might more roles assigned under the *ICT manager*, thus this is just illustrating an example.

The *QTO coordinator* will be a function who sets up and executes the QTO from the different BIM models/drawings. For that purpose a close collaboration with the technical assistants is needed. Moreover this role is also responsible of creating the tender list with quantities. The other roles in in that connection will be the following.

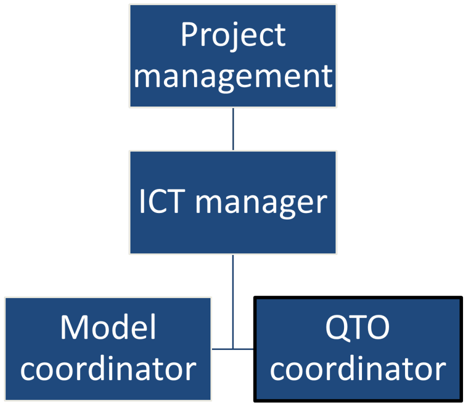


Figure 7.5: Role specification of the *QTO coordinator*

The Owner is responsible for demands in relation to the quantities is being determined in the ICT specifications. Following the suggestion regarding Information levels per building component, the owner will have to specify the information level for each building component. Moreover the owner has to make sure that all parts are informed and work in accordance with the ICT specification

The project management is responsible for the time schedule and thereby the overall plan for the content of the tender list with quantities

The ICT manager is a function, which has to handle the digital collaboration between the project participants. More to make sure that the ICT agreements are maintained.

Technical implementation

As mentioned earlier this technical implementation or Model View Definition (MVD) is software specific and deals with how the exchange of the required data element and constraints can be accomplished using IFC. An MVD itself could provide enough to constitute a thesis on only that area, thus a MVD was not developed in this project. Instead a practical technical implementation regarding the QTO process from MagiCad to Sigma (via Excel) was developed an represented in Appendix D.

7.4 Organisational changes

As the analysis and discussion has showed, the original perception of a tender (or digital tender with quantities) has limitations in proportion to level of detal, liability and BIM in general. Even though the tender serves the purpose of competitions between the bidding parts, it seems like there will be additional value for the owner to serve the purpose of BIM modeling for some projects. In order to achieve the greater benefits of BIM technology, among these industrial production advantages, a rethinking of the organisational form is needed.

Several cases from foreign countries points at a indisputable potential of performing an extensive use of BIM to execute cross-trade prefabrication and produce as-built installation execution models. Among others from the hospital building *USCF Mission Bay Medical Center* in San Francisco, which is only possible if creating a model that incorporates such fine details as seismic and gravity hangers, metal framing systems, and detailed models of components like rebar and supports for pipe and duct systems [construction (2012)].

The crucial point in order to achieve the postulated BIM potential is to go from performing the traditional tenders (DBB contracts) to perform collaborative forms of project delivery with an early integration of the contractor. This implies avoidance of a normal tender process and therefore makes it possible for the designer to specify type and supplier of components like the air handling units for ventilation and thereby produce a production orientated project. In addition this gives new opportunities in relation to estimate more predictable outcomes during the design phase and forecast the consequences of decisions are more clear based on the specific components. Hence the quantities are not used as bidding basis, but a basis for a project estimate towards the budget.

As mentioned in Section 3.2.2 the early tender is not a new phenomena, but in Denmark known as the traditional turnkey contract. However the turnkey contract has some bad sides for which reason, it is not the most desirable contract for both owners and designers. For instance the owner are less in touch with the project and the quality, since the design is executed by the turnkey contractor. On that basis it makes sense to discuss alternatives of early collaborations in relation to the turnkey contract. In that connection the american concept Integrated Project Delivery (IPD) are discussed with proportion of implementation in Denmark based on the theory and the american case studies publications from AIA.

7.4.1 Integrated project delivery implementation

According to [Chuck Eastman (2011)] the IPD aims to achieve close collaboration among all members of a project team. In addition to that it is claimed that BIM has been a key enabling technology for IPD teams. Compared to the turnkey contract, the owner has a more central and active role in a IPD collaborations. Hence the owner is taking part in the decision-making at all levels. Besides the early involvement of contractor and giving the owner an active role, the IPD covers many aspects. A cornerstone is the creation of a limited-liability company (LLC) called a single-purpose entity (SPE) as

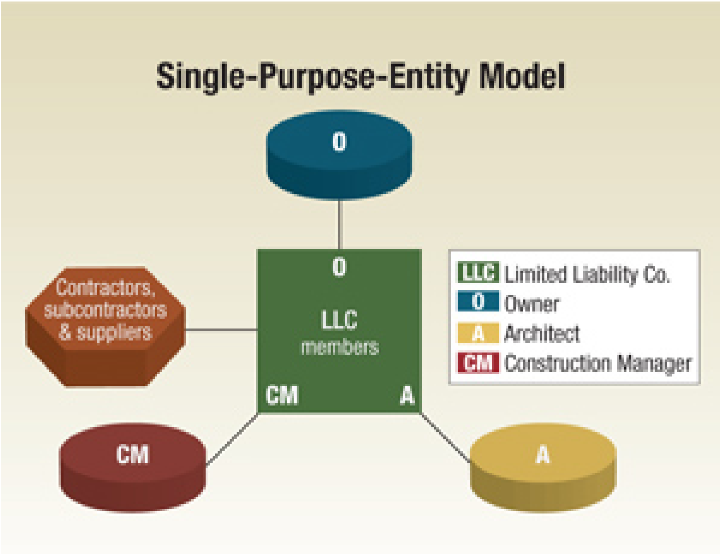


Figure 7.6: Illustration of the "pure" IPD with creation of a Single Purpose Entity (SPE)

shown in Fig 7.6.

However according to [AIA (2012)], it is becomming clear that there are only a few "pure" IPD projects (including the Single Purpose Entity and other aspects) has been carried out in America. Hence this section will only focus on the princips relevant in relation to BIM, quantities, process and designer motivation which are:

- Early tender based on a scheme design
- Target costing as starting point
- Shared risks and shared rewards
- Use of quantities during design

Furthermore the barriers will also be discussed.

Early tender based on a scheme design

The basis of an IPD collaboration is that a *conceptualization* is made for the building project by an architecht on behalf of the owner as shown in Fig 7.7. According to [Chuck Eastman (2011)] the *conceptualization* can be compared the traditional term *scheme design*[1], which in a Danish context means a limited level of detail and further design and cost estimation has not been done. Therefore the *conceptualization* cotains a clarification of the projects final shape in relation to regulatory requirements,

[1] Forprojekt

comprising a description of the architechture, structural choice, material choice and technical installations. Thus the point about a *conceptualization* is that all significant conditions has been determined, but several of details in proportion to the design are assigned to the following IPD team, which often will have a general contractor (GC) as the leader of a coalition of architechts, engineers and subcontractors (SUBS). Thus the IPD team are responsible of the remaining design and the execution of the building.

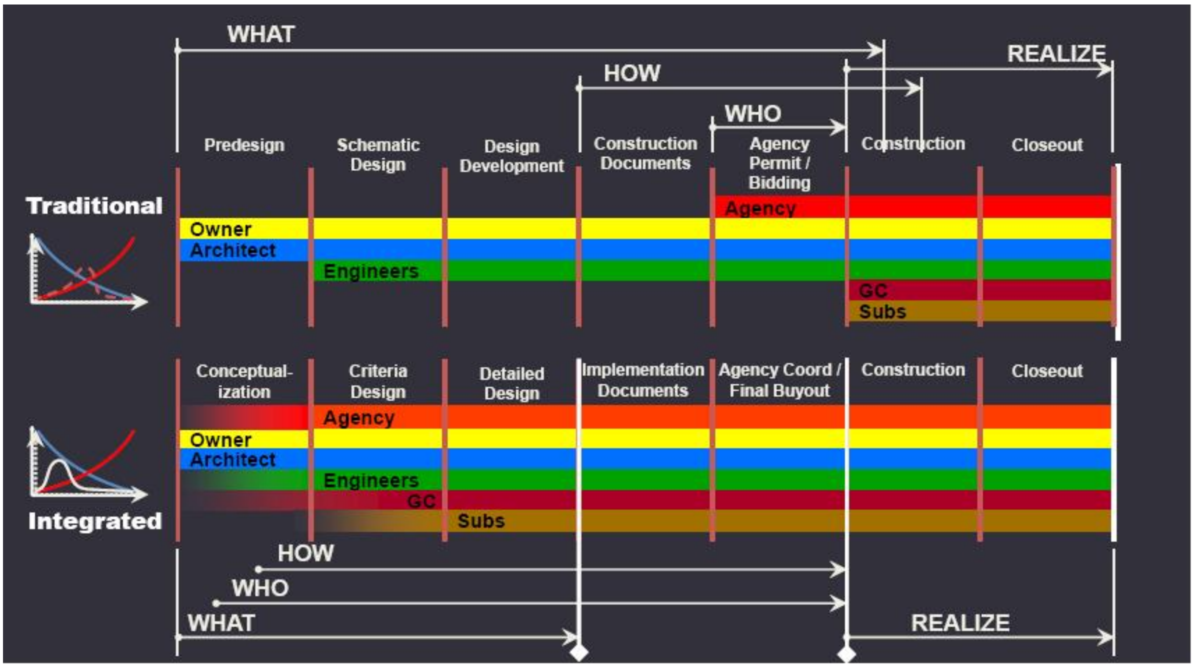


Figure 7.7: Comparacy of traditional and the IPD process in relation to phases [innovatechbuild (2012)]

In order to select the specific GC with coalition (IPD team), the architecht and owner will perform an early tender based on the *conceptualization*. Since the IPD team covers all the trade contracts, this basis are crosswise trades. The competitive bidding among different IPD coalitions is important to keep the competition and it will specify the so-called *taget price* (TP). The TP is created on the basis of the selected IPD team's bid on the project and will become the focal point of the whole IPD collaboration.

Target costing as starting point

The term TP is essential in an IPD collaboration and it also change the perception of designing. As shown in Fig 7.8, the traditional designing process has the design as basis and moves forward toward a Target Profit. If (or when) the cost estimation shows an unacceptable Cost Estimat, the process often goes backwards in an iterative process through Value Engineering (VE). VE is a planned approach to cost reduce (or extend), comprising cost reduction and increasing value without sacrifying quality.

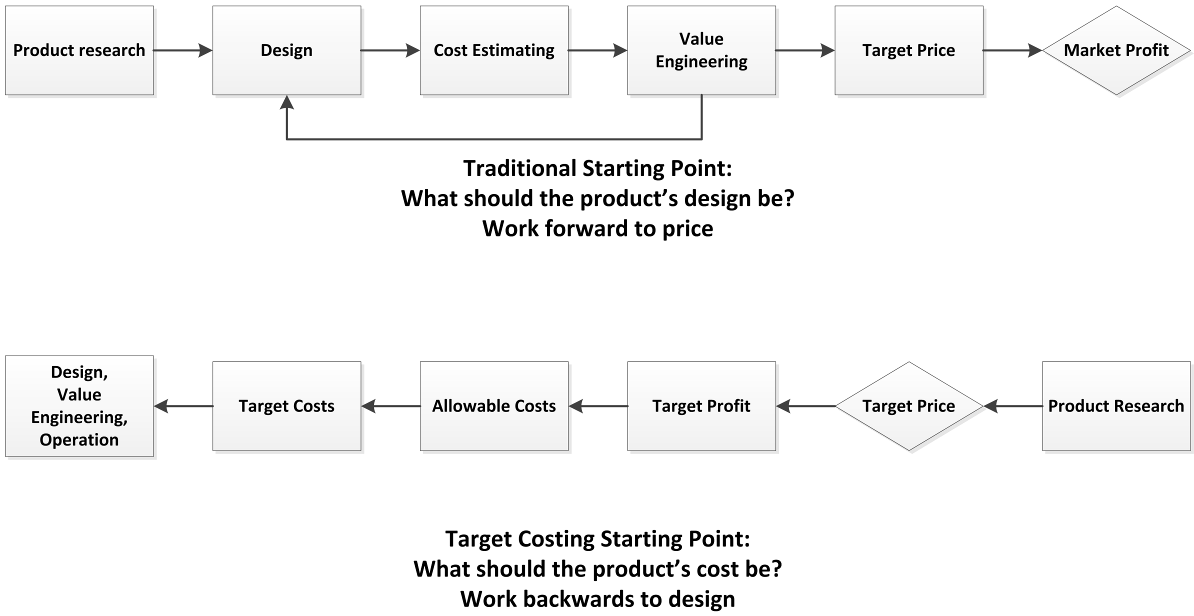


Figure 7.8: IPD process change in the design phase

On the other hand the IPD concept supports a process based on the TP and then working backwards to design, which is possible due to early integration of all parts. As mentioned the TP will be the bid as the IPD coalition submitted in connection to the competitive bidding. Afterwards the target profits (how much will we earn) and the allowable costs and target costs set (based on the target profit). Therefore the price of the building is allready explicit in mind when deciding design value adding etc. An important factor to make this process doable is the princip of reward/risk sharing, which gives all the parts of the IPD coalition an incentive of finding savings in relation to the construction price. This incentive is not present for a designer in a traditional process where practice often is a standard fee of 12% of the construction costs (cf. Morten Alsdorf), which actually leads to an incentive in the other direction.

Shared rewards and risks

In order for all parties to collaborate on an even playing field, it is crucial for shared risk and reward implementation. The princip of reward/risk sharing uses the TP as benchmark for whether there is a reward/risk economically as illustrated in Fig 7.9. If ending up on the TP, there will still be the standard profit to each part (for instance 12% for the design team).

The point is that when all parties are equally vested, it is in the best interest of everyone to problem solve efficiently because the success of the project depends on this philosophy. The traditional methods of passing along blame and responsibility are almost eliminated from the equation and replaced with working environments that encourage mentalities that seek for project prosperity. During the design phase there will be estimated on the basis of QTO's periodically to navigate towards the agreed budget.

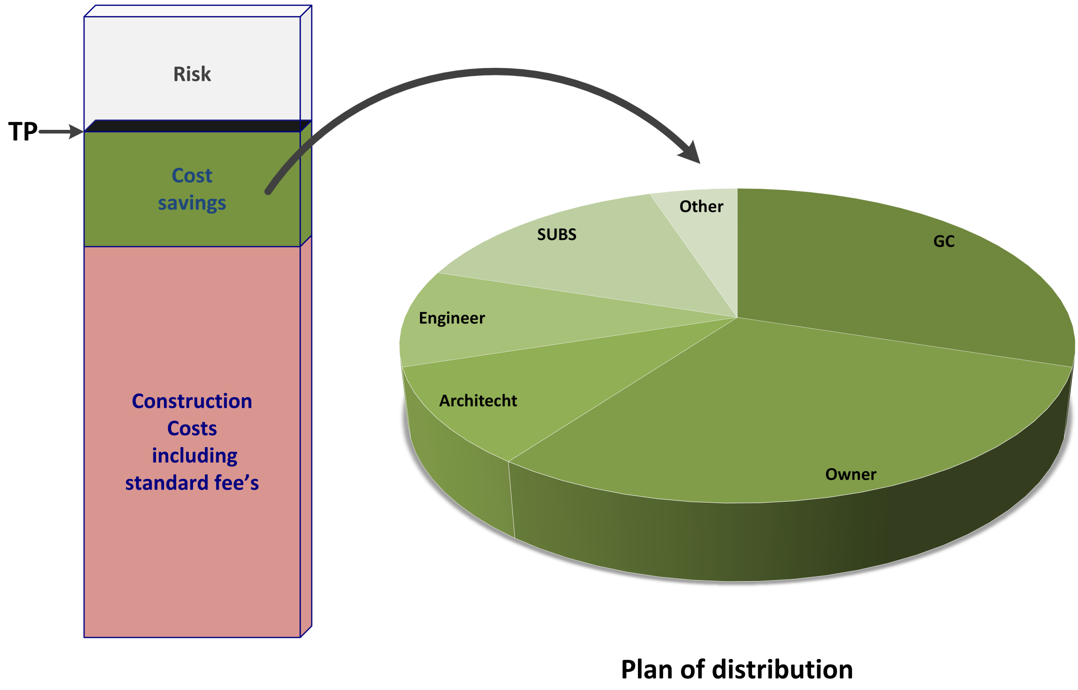


Figure 7.9: The IPD reward/risk sharing princip

Use of quantities during design

The kind of quantities as used in the cases investigated will, in an IPD collaboration process, play another role than in a traditional tender. In stead of constituting a bidding basis, they will serve the purpose of cost estimation in relation to cost predictability. In proportion to cost estimation for HVAC on the MB project, it was all based on square meters and rooms even though early stage BIM models were created. Hence there was no running cost predictability on the MB project and the two other projects as well. As the cost predictability is a key point of the IPD, the BIM models are used extensively for QTO and estimation during the design. Thus the cost predictability also becomes a signification tool in relation to the owner's project decision process.

As illustrated on Fig 7.10 the BIM trade models is used to see if the TP has been reached on the specific trade. It gives the owner and the rest of the IPD team an overview in order to make design decisions.

IPD barriers

The first and most essential IPD barrier for implementing in Denmark is the cultural barrier. This barrier refers to the unwillingness of the industry to change from its traditional methods. Especially because the IPD implies changes to the mindset about tenders and in general it also incite changes to the

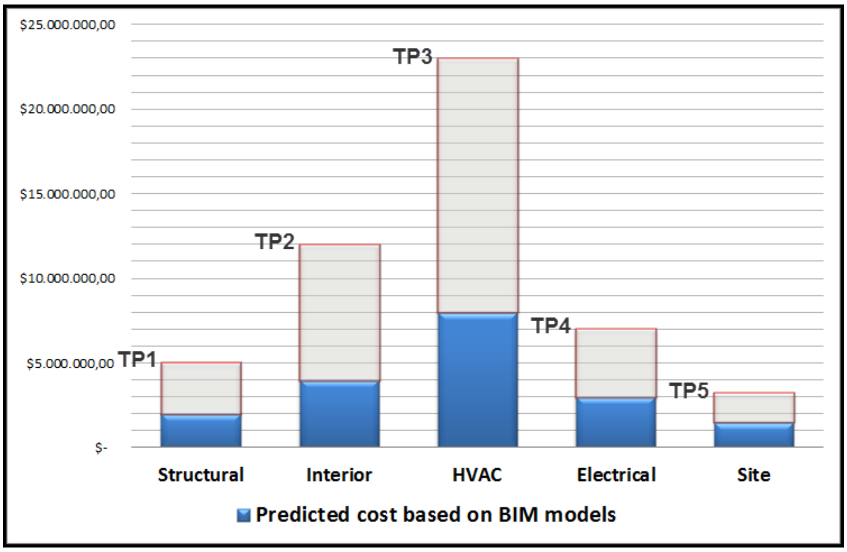


Figure 7.10: Cost prediction through BIM models

building phases as they are known in Denmark. Furthermore, it will also be a challenge to see if the different parts in an IPD would be able to have a united approach as the IPD concept demands.

Secondly the QTO processes needs to be standardized before it will make sense to introduce IPD with the cost predictable aspect. At the moment the process is undefined and regarding cost estimation there is uncertainties how to include the implicit quantities, connection to price databases like 'V & S Prisdata' and market mechanisms.

Furthermore, there is the question regarding laws and liability. With the trouble in mind that the 'digital tender' causes due to quantity measurement change from contractor to designer, there is a lot more legal considerations regarding the IPD concept. Even though IPD will prevent lawsuits and litigations through the 'Liability waivers', the case studies from AIA shows that they are not used. Thus the IPD contracts have not been judicially tested in the areas of indemnification, licensing, and insurance, leaving them susceptible to conflicting interpretations and enforcements.

Chapter 8
Conclusion

This chapter provides a summary of the results of the studies and analyses, which has been caried out in this thesis. The thesis has been based on the digital handover of data and model from designer to contractor, comprising a specific study of quantities in the tender documents in relation to a digital tender. The main purpose of the digital tender is to ensure that the contractors are bidding on an equal basis and that the informations from the tender documents are reused. Thereby the contractors would save time in the bidding stage and only compete on the contribution margin[1] instead of the quantities. However this scenario was far from the real world [Flemming Grangaard (2012)], thus the initiating problem was to identify issues in relation to the HVAC tender documents in a digital tender. This was followed up with suggested solutions for the given circumstances of DBB contracts (late tender), while the third point was to investigate if new collaborative forms of project delivery could enhance the construction process through utilisation of BIM.

8.1 Digital tender problems

In order to identify the issues related to digital tenders in HVAC contracts, the work has been done in proportion to produce a tender list with quantities for a specific project called Mærsk Bygningen. The 'hands on' experience in relation to the QTO from BIM models gives a detailed insight into the problems that may exist during this process. This work was supplemented with interviews of both designers and contractors and two other cases in order to have a reasonable basis for the analysis.

Based on the analytical results it can be concluded, that the current condition of the information handover in a digital tender with quantities for HVAC contracts has many unresolved issues regarding the tools and in particular the methods, processes and framework conditions of the DBB contracts. The basis of making a standardised tender list with precise tender quantities is not present due to insufficiency of classification, structure of information, level of detail and measurement rules. Thus a tender list with quantities is just as different as the projects are. Furthermore, there is no defined process for the digital tender or transparency regarding the liability in relation to the tender quantites.

[1] Dækningsbidraget

The reason is to a large extent missing methods and paradigms to create a common perception of the quantities. Due to this fact the presented tender quantities is in a state of a 'diffuse' nature, which means that it is hard to know as a contractor what to include as implicit quantities when making a bid. This implies that the contractors are not only competing on the contribution margin, but also on the quantities which is not the intention. Furthermore, the structure of information on the tender list with quantities is also variable, which makes it very difficult to set up a system to handle the tender documents.

8.2 Suggested solutions for DBB contracts

Based on the problems identified in the analysis, the discussion tried to outline suggested solutions to the specific problem within the circumstances of the DBB contracts. As implied the solution is to create methods and paradigms in order to clarify how the end product of a digital tender should look like. The discussion led to five specific suggested solutions, which would add transparency to the delivery of a digital tender:

- The tender list with quantities for HVAC contracts should be structured per main system
- The pricing basis should be each main system and not as unit prices on the building components
- Definition of information levels per building components comprising information regarding how to deliver the quantity with a given measurement rule, visual representation and specifications
- Changing ABR 89 and AB 92 to clarify in relation to liability of the tender quantities and verified quantities. Especially with a focus of holding the designers and contractors responsible for respectively the tender quantities and the verified quantities. Supplemented with a measurement strategy for the as-built quantities
- Define a process specific IDM for digital tender in order to specify how and who should execute the QTO and create the tender list with quantities

With the implementation of above, the next step would be to set up tools to import the tender list with quantities. This means that the contractors could only compete on the contribution margin which, all things being equal, would imply slightly predictable prices and greater competition among contractors.

Even though a lot problems can be solved by providing the right methods and paradigms, the conclusion is also that it is not possible to satisfy the demand for a higher level of detail (production specific level) within the conditions of a DBB contract. Due to the tender laws and the contractor depend building components it will not possible. The tender laws and a tender in general are important as it provides the free competition.

8.3 Utilisation of BIM in an IPD collaboration

This last section is presented as a consequence of the fact it does not seem possible to utilise the potential of BIM in the current contract forms like DBB (or DB). According to the theory [Chuck Eastman (2011)] there is an opportunity of utilising BIM in new ways if applying a collaborative form of project delivery like IPD. It is important to state that the utilisation of BIM is not a goal, but a remedy to enhance the construction process. In addition, it can be discussed if BIM actually is changing design process cf. Fig 4.4 or that it provides the opportunity if choosing the right collaboration forms. The conclusion might be both, but it is possible that the real potential of BIM given the right circumstances still has not reached the bar.

Regarding IPD, the study showed that the application of it is able to give some significant opportunities in relation to manage the cost of a building during the design phase. The concept of 'predictable costs' gives the owner and the rest of the IPD team a totally different basis of making decisions, which affects the design of the building if comparing to a DBB project. Since the DBB projects in relation to HVAC during the design phase builts on an early square metre estimation there is no actual cost control. Whereas the IPD emphasises the use of specific quantities in order to do running estimations with an increasing level of detail in the calculations.

Based on the discussion one of the problems about the IPD is that it compromise on the tender basis. Since the point is early involvement of key participants, the early tender in relation to the IPD contract has to be on a loss basis (conceptualisation) compared to a regular DBB contract (main project). All things being equal, the basis of finding the favourable contractor (or the 'right' contractor) is bigger in a DBB contract. With that in mind it is worth considering if it is possible to find the favourable contractor on a loss basis. If that is the case the IPD collaboration will have a promissing future.

Appendix A - Tender list with quantities of ventilation contract of Mærsk Bygningen

Tilbudsliste for ventilationsteknik E12

Pos	Tekst	Enhed	Mængde	Samlet EP
	Mærsk Bygningen			
1.	**Ventilationsteknik**			
1.1.	32500 Friskluftindtag - Forsyning	sum	1	0,00
1.2.	32500 Ventilations afkast	sum	1	0,00
1.3.	32501 Trappe 1	sum	1	0,00
1.4.	32502 Trappe 2	sum	1	0,00
1.5.	32503 Trappe 3	sum	1	0,00
1.6.	32504 Backup-kølecentral	sum	1	0,00
1.7.	32505 Røgudluftning	sum	1	0,00
1.8.	32510 Laboratorier	sum	1	0,00
1.9.	32530 Kontorer	sum	1	0,00
1.10.	32531 Auditorium Stort	sum	1	0,00
1.11.	32532 Auditorium Lille	sum	1	0,00
1.12.	32533 Auditorium Mellem	sum	1	0,00
1.13.	32534 Køkken	sum	1	0,00
1.14.	32535 Kantine	sum	1	0,00
1.15.	32536 Substrat	sum	1	0,00
1.16.	32537 Basen	sum	1	0,00
1.17.	32538 Undervisning	sum	1	0,00
1.18.	32539 Repræsentation	sum	1	0,00
1.19.	32550 Isotop stinkskab	sum	1	0,00
1.20.	32551 Skraldesug	sum	1	0,00
1.21.	32552 Varegård	sum	1	0,00
1.22.	32553 Truck ladestation	sum	1	0,00
1.23.	32554 Transformerrum, niveau 01	sum	1	0,00
1.24.	32555 Transformerrum, niveau 02	sum	1	0,00
1.25.	325XX Demontering og ombygning i eksisterende bygning	sum	1	0,00
1.26.	325XX Indeklimamålinger	sum	1	0,00
2.	**CTS**			
2.1.	325XX CTS	sum	1	0,00
3.	**Byggeplads**			
3.1.	900XX Tilrigning af egen byggeplads	sum	1	0,00
3.2.	900XX Drift af egen byggeplads	sum	1	0,00
4.	**Diverse**			
4.1.	Commisioning	sum	1	0,00
4.2.	D&V	sum	1	0,00
4.3.	Kvalitetsstyring	sum	1	0,00
4.4.	Øvrige	sum	1	0,00
5.	**Ændringsarbejder**			
5.1.	Svendetimer, indenfor normalarbejdstid	timer	250	0,00

Mængdeliste for ventilationsteknik E12

Pos	Tekst	DBK	Mængden	Enhed
	Mærsk Bygningen			
1.	**Ventilationsteknik**			
1.1.	**32500 Friskluftindtag - Forsyning**		**1**	**sum**
1.1.1.	**006 Kanal**			
1.1.1.1.	**Rektangulære kanaler**			
1.1.1.1.1.	**Lamelmåtte 50 mm**			
1.1.1.1.1.1.	1000x1200	-32500.XXXX.006	3	m
1.1.1.1.1.2.	1000x1800	-32500.XXXX.006	6	m
1.1.1.1.1.3.	1200x1500	-32500.XXXX.006	18	m
1.1.1.1.1.4.	1200x2000	-32500.XXXX.006	1	m
1.1.1.1.1.5.	1200x2500	-32500.XXXX.006	1	m
1.1.1.1.1.6.	1500x1500	-32500.XXXX.006	7	m
1.1.1.1.1.7.	1500x800	-32500.XXXX.006	7	m
1.1.1.1.1.8.	2000x2000	-32500.XXXX.006	8	m
1.1.1.1.1.9.	2200x1200	-32500.XXXX.006	2	m
1.1.1.1.1.10.	2200x1400	-32500.XXXX.006	9	m
1.1.1.1.1.11.	2500x3000	-32500.XXXX.006	22	m
1.1.1.1.1.12.	2600x1400	-32500.XXXX.006	2	m
1.1.1.1.1.13.	2800x1300	-32500.XXXX.006	2	m
1.1.1.1.1.14.	2800x1800	-32500.XXXX.006	18	m
1.1.1.1.1.15.	2800x2000	-32500.XXXX.006	1	m
1.1.1.1.1.16.	3000x3000	-32500.XXXX.006	2	m
1.1.1.1.1.17.	600x1500	-32500.XXXX.006	4	m
1.1.1.1.1.18.	800x1400	-32500.XXXX.006	10	m
1.1.1.1.1.19.	800x1500	-32500.XXXX.006	9	m
1.1.1.1.2.	**Lamelmåtte 100 mm**			
1.1.1.1.2.1.	2300x1400	-32500.XXXX.006	15	m
1.2.	**32500 Ventilations afkast**		**1**	**sum**
1.2.1.	**006 Kanal**			
1.2.1.1.	**Rektangulære kanaler**			
1.2.1.1.1.	**Lamelmåtte 50 mm**			
1.2.1.1.1.1.	1000x1200	-32500.XXXX.006	2	m
1.2.1.1.1.2.	1000x2000	-32500.XXXX.006	1	m
1.2.1.1.1.3.	1200x2500	-32500.XXXX.006	31	m
1.2.1.1.1.4.	1500x1500	-32500.XXXX.006	29	m
1.2.1.1.1.5.	1500x1600	-32500.XXXX.006	1	m
1.2.1.1.1.6.	1500x700	-32500.XXXX.006	1	m
1.2.1.1.1.7.	1500x800	-32500.XXXX.006	144	m

Pos	Tekst	DBK	Mængden	Enhed
1.2.1.1.1.8.	2000x1500	-32500.XXXX.006	16	m
1.2.1.1.1.9.	2000x2250	-32500.XXXX.006	2	m
1.2.1.1.1.10.	2000x800	-32500.XXXX.006	22	m
1.2.1.1.1.11.	2200x1400	-32500.XXXX.006	2	m
1.2.1.1.1.12.	2200x1600	-32500.XXXX.006	4	m
1.2.1.1.1.13.	2200x600	-32500.XXXX.006	2	m
1.2.1.1.1.14.	2400x1600	-32500.XXXX.006	3	m
1.2.1.1.1.15.	2400x900	-32500.XXXX.006	1	m
1.2.1.1.1.16.	2500x1500	-32500.XXXX.006	19	m
1.2.1.1.1.17.	2800x1800	-32500.XXXX.006	3	m
1.2.1.1.1.18.	3000x2000	-32500.XXXX.006	1	m
1.2.1.1.1.19.	3150x1000	-32500.XXXX.006	7	m
1.2.1.1.1.20.	3150x2250	-32500.XXXX.006	16	m
1.2.1.1.1.21.	4000x3000	-32500.XXXX.006	7	m
1.2.1.1.1.22.	700x1500	-32500.XXXX.006	8	m
1.2.1.1.1.23.	800x1500	-32500.XXXX.006	9	m
1.2.1.1.1.24.	800x800	-32500.XXXX.006	1	m
1.2.1.1.1.25.	900x800	-32500.XXXX.006	14	m
1.2.1.1.2.	**Brandisolering 60 mm**			
1.2.1.1.2.1.	1000x500	-32500.XXXX.006	12	m
1.2.1.2.	**Runde, spiro kanaler**			
1.2.1.2.1.	**Lamelmåtte 50 mm**			
1.2.1.2.1.1.	ø1000	-32500.XXXX.006	4	m
1.2.1.2.1.2.	ø1250	-32500.XXXX.006	8	m
1.2.1.2.1.3.	ø500	-32500.XXXX.006	4	m
1.2.1.2.1.4.	ø630	-32500.XXXX.006	8	m
1.2.1.2.1.5.	ø800	-32500.XXXX.006	4	m
1.2.1.2.2.	**Kondensisolering 30 mm**			
1.2.1.2.2.1.	ø315	-32500.XXXX.006	26	m
1.2.1.2.3.	**Ingen isolering**			
1.2.1.2.3.1.	ø800	-32500.XXXX.006	92	m
1.3.	**32501 Trappe 1**		**1**	**sum**
1.3.1.	03 Aggregat	-32501.03XX	1	stk
1.3.2.	04 Ventilator	-32501.04XX	1	stk
1.3.3.	**006 Kanal**			
1.3.3.1.	**Rektangulære kanaler**			
1.3.3.1.1.	**Lamelmåtte 50 mm**			
1.3.3.1.1.1.	1600x1000	-32501.XXXX.006	18	m
1.3.3.1.1.2.	1600x1600	-32501.XXXX.006	1	m
1.3.3.1.1.3.	2800x1000	-32501.XXXX.006	1	m
1.3.3.1.1.4.	2800x1600	-32501.XXXX.006	2	m
1.3.3.1.2.	**Lamelmåtte 100 mm**			
1.3.3.1.2.1.	2200x600	-32501.XXXX.006	5	m
1.3.3.1.2.2.	2300x1400	-32501.XXXX.006	1	m
1.3.3.2.	**Runde, spiro kanaler**			

Pos	Tekst	DBK	Mængden	Enhed
1.3.3.2.1.	**Ingen isolering**			
1.3.3.2.1.1.	ø630	-32501.XXXX.006	79	m
1.3.4.	**001 Trykføler**			
1.3.4.1.	**Type 10**			
1.3.4.1.1.		-32501.XXXX.001	2	stk
1.3.5.	**007 Motorspjæld_spring_return**			
1.3.5.1.	**Type 06**			
1.3.5.1.1.		-32501.XXXX.007	17	stk
1.4.	**32502 Trappe 2**		**1**	**sum**
1.4.1.	03 Aggregat	-32502.03XX	1	stk
1.4.2.	**006 Kanal**			
1.4.2.1.	**Rektangulære kanaler**			
1.4.2.1.1.	**Lamelmåtte 50 mm**			
1.4.2.1.1.1.	2500x1500	-32502.XXXX.006	3	m
1.4.2.1.2.	**Lamelmåtte 100 mm**			
1.4.2.1.2.1.	1200x1400	-32502.XXXX.006	13	m
1.4.2.1.2.2.	2300x1400	-32502.XXXX.006	2	m
1.4.2.2.	**Runde, spiro kanaler**			
1.4.2.2.1.	**Lamelmåtte 50 mm**			
1.4.2.2.1.1.	ø1400	-32502.XXXX.006	2	m
1.4.3.	**001 Trykføler**			
1.4.3.1.	**Type 10**			
1.4.3.1.1.		-32502.XXXX.001	1	stk
1.5.	**32503 Trappe 3**		**1**	**sum**
1.5.1.	03 Aggregat	-32503.03XX	1	stk
1.5.2.	**006 Kanal**			
1.5.2.1.	**Rektangulære kanaler**			
1.5.2.1.1.	**Lamelmåtte 100 mm**			
1.5.2.1.1.1.	1200x1400	-32503.XXXX.006	4	m
1.5.2.1.1.2.	2300x1400	-32503.XXXX.006	1	m
1.6.	**32504 Backup-kølecentral**		**1**	**sum**
1.6.1.	04 Ventilator	-32504.04XX	1	stk
1.6.2.	**007 Motorspjæld**			
1.6.2.1.	**Type 02**			
1.6.2.1.1.		-32504.XXXX.007	2	stk
1.6.3.	**359 Brand_og_røgspjæld**			
1.6.3.1.	**Type 01**			
1.6.3.1.1.		-32504.XXXX.359	1	stk
1.6.4.	**Rumtype:**			
1.6.4.1.	Type NA1	-32504.XXXX.	3	stk
1.6.4.2.	Type NK1	-32504.XXXX.	1	stk
1.7.	**32505 Røgudluftning**		**1**	**sum**

Pos	Tekst	DBK	Mængden	Enhed
1.7.1.	04 Ventilator	-32505.04XX	2	stk
1.7.2.	**006 Kanal**			
1.7.2.1.	**Rektangulære kanaler**			
1.7.2.1.1.	**Lamelmåtte 50 mm**			
1.7.2.1.1.1.	1500x800	-32505.XXXX.006	1	m
1.7.2.1.2.	**Ingen isolering**			
1.7.2.1.2.1.	1000x1200	-32505.XXXX.006	1	m
1.7.2.1.2.2.	1000x600	-32505.XXXX.006	10	m
1.7.2.1.2.3.	800x600	-32505.XXXX.006	7	m
1.7.2.2.	**Runde, spiro kanaler**			
1.7.2.2.1.	**Lamelmåtte 50 mm**			
1.7.2.2.1.1.	ø1000	-32505.XXXX.006	8	m
1.7.2.2.2.	**Ingen isolering**			
1.7.2.2.2.1.	ø500	-32505.XXXX.006	34	m
1.7.3.	**007 Motorspjæld**			
1.7.3.1.	**Type 02**			
1.7.3.1.1.		-32505.XXXX.007	2	stk
1.7.4.	**007 Spjæld**			
1.7.4.1.	**Type 07**			
1.7.4.1.1.		-32505.XXXX.007	4	stk
1.8.	**32510 Laboratorier**		**1**	**sum**
1.8.1.	03 Aggregat	-32510.03XX	10	stk
1.8.2.	**006 Kanal**			
1.8.2.1.	**Rektangulære kanaler**			
1.8.2.1.1.	**Lamelmåtte 50 mm**			
1.8.2.1.1.1.	1000x2600	-32510.XXXX.006	2	m
1.8.2.1.1.2.	1000x2800	-32510.XXXX.006	2	m
1.8.2.1.1.3.	1000x3150	-32510.XXXX.006	3	m
1.8.2.1.1.4.	1200x1400	-32510.XXXX.006	9	m
1.8.2.1.1.5.	1200x1600	-32510.XXXX.006	6	m
1.8.2.1.1.6.	1200x2800	-32510.XXXX.006	1	m
1.8.2.1.1.7.	1200x800	-32510.XXXX.006	34	m
1.8.2.1.1.8.	1400x1400	-32510.XXXX.006	27	m
1.8.2.1.1.9.	1400x2200	-32510.XXXX.006	2	m
1.8.2.1.1.10.	1900x1400	-32510.XXXX.006	20	m
1.8.2.1.1.11.	2000x2200	-32510.XXXX.006	1	m
1.8.2.1.1.12.	2000x2250	-32510.XXXX.006	4	m
1.8.2.1.1.13.	2300x1400	-32510.XXXX.006	14	m
1.8.2.1.1.14.	2500x1200	-32510.XXXX.006	6	m
1.8.2.1.1.15.	2500x1800	-32510.XXXX.006	28	m
1.8.2.1.1.16.	2500x3000	-32510.XXXX.006	45	m
1.8.2.1.1.17.	2600x2000	-32510.XXXX.006	4	m
1.8.2.1.1.18.	2600x2250	-32510.XXXX.006	4	m
1.8.2.1.1.19.	2600x2500	-32510.XXXX.006	2	m
1.8.2.1.1.20.	2700x1400	-32510.XXXX.006	4	m

Pos	Tekst	DBK	Mængden	Enhed
1.8.2.1.1.21.	2800x1200	-32510.XXXX.006	10	m
1.8.2.1.1.22.	2800x1400	-32510.XXXX.006	7	m
1.8.2.1.1.23.	2800x1800	-32510.XXXX.006	42	m
1.8.2.1.1.24.	3150x1000	-32510.XXXX.006	1	m
1.8.2.1.1.25.	3150x2250	-32510.XXXX.006	7	m
1.8.2.1.1.26.	3150x2500	-32510.XXXX.006	24	m
1.8.2.1.1.27.	3150x3000	-32510.XXXX.006	2	m
1.8.2.1.1.28.	4000x2250	-32510.XXXX.006	2	m
1.8.2.1.1.29.	5000x2500	-32510.XXXX.006	4	m
1.8.2.1.1.30.	700x900	-32510.XXXX.006	20	m
1.8.2.1.1.31.	900x1400	-32510.XXXX.006	20	m
1.8.2.1.2.	**Ingen isolering**			
1.8.2.1.2.1.	1400x1400	-32510.XXXX.006	130	m
1.8.2.1.2.2.	300x200	-32510.XXXX.006	5	m
1.8.2.1.2.3.	300x250	-32510.XXXX.006	127	m
1.8.2.1.2.4.	300x300	-32510.XXXX.006	23	m
1.8.2.1.2.5.	400x300	-32510.XXXX.006	960	m
1.8.2.1.2.6.	400x350	-32510.XXXX.006	1	m
1.8.2.1.2.7.	400x400	-32510.XXXX.006	139	m
1.8.2.1.2.8.	500x400	-32510.XXXX.006	532	m
1.8.2.1.2.9.	900x700	-32510.XXXX.006	2839	m
1.8.2.2.	**Runde, spiro kanaler**			
1.8.2.2.1.	**Lamelmåtte 50 mm**			
1.8.2.2.1.1.	ø160	-32510.XXXX.006	19	m
1.8.2.2.1.2.	ø400	-32510.XXXX.006	10	m
1.8.2.2.1.3.	ø500	-32510.XXXX.006	11	m
1.8.2.2.2.	**Lamelmåtte 20 mm**			
1.8.2.2.2.1.	ø125	-32510.XXXX.006	132	m
1.8.2.2.3.	**Ingen isolering**			
1.8.2.2.3.1.	ø100	-32510.XXXX.006	65	m
1.8.2.2.3.2.	ø125	-32510.XXXX.006	3303	m
1.8.2.2.3.3.	ø160	-32510.XXXX.006	1409	m
1.8.2.2.3.4.	ø200	-32510.XXXX.006	805	m
1.8.2.2.3.5.	ø250	-32510.XXXX.006	1384	m
1.8.2.2.3.6.	ø315	-32510.XXXX.006	607	m
1.8.2.2.3.7.	ø400	-32510.XXXX.006	1682	m
1.8.2.2.3.8.	ø80	-32510.XXXX.006	11	m
1.8.3.	**358 Armatur**			
1.8.3.1.	U-04	-32510.XXXX.358	307	stk
1.8.3.2.	I-20	-32510.XXXX.358	258	stk
1.8.4.	**001 Trykføler**			
1.8.4.1.	**Type 10**			
1.8.4.1.1.		-32510.XXXX.001	48	stk
1.8.5.	**007 Motorspjæld_modulerende**			
1.8.5.1.	**Type 04**			
1.8.5.1.1.	800x500	-32510.XXXX.007	72	stk

Pos	Tekst	DBK	Mængden	Enhed
1.8.6.	**359 Brand_og_røgspjæld**			
1.8.6.1.	**Type 01**			
1.8.6.1.1.	800x500	-32510.XXXX.359	72	stk
1.9.	**32530 Kontorer**		**1**	**sum**
1.9.1.	03 Aggregat	-32530.03XX	1	stk
1.9.2.	**006 Kanal**			
1.9.2.1.	**Rektangulære kanaler**			
1.9.2.1.1.	**Lamelmåtte 50 mm**			
1.9.2.1.1.1.	1500x1200	-32530.XXXX.006	72	m
1.9.2.1.1.2.	1600x1000	-32530.XXXX.006	18	m
1.9.2.1.1.3.	2800x1000	-32530.XXXX.006	1	m
1.9.2.1.1.4.	2800x1600	-32530.XXXX.006	5	m
1.9.2.1.2.	**Lamelmåtte 20 mm**			
1.9.2.1.2.1.	250x250	-32530.XXXX.006	120	m
1.9.2.1.2.2.	300x200	-32530.XXXX.006	142	m
1.9.2.1.2.3.	600x300	-32530.XXXX.006	346	m
1.9.2.1.2.4.	600x400	-32530.XXXX.006	96	m
1.9.2.1.2.5.	800x300	-32530.XXXX.006	36	m
1.9.2.1.3.	**Ingen isolering**			
1.9.2.1.3.1.	1500x1200	-32530.XXXX.006	72	m
1.9.2.1.3.2.	500x200	-32530.XXXX.006	80	m
1.9.2.1.3.3.	600x400	-32530.XXXX.006	108	m
1.9.2.2.	**Runde, spiro kanaler**			
1.9.2.2.1.	**Ingen isolering**			
1.9.2.2.1.1.	ø100	-32530.XXXX.006	192	m
1.9.2.2.1.2.	ø125	-32530.XXXX.006	749	m
1.9.2.2.1.3.	ø160	-32530.XXXX.006	2006	m
1.9.2.2.1.4.	ø200	-32530.XXXX.006	276	m
1.9.2.2.1.5.	ø250	-32530.XXXX.006	180	m
1.9.3.	**358 Armatur**			
1.9.3.1.	I-20	-32530.XXXX.358	260	stk
1.9.3.2.	U-20	-32530.XXXX.358	60	stk
1.9.4.	**001 Trykføler**			
1.9.4.1.	**Type 10**			
1.9.4.1.1.		-32530.XXXX.001	26	stk
1.9.5.	**007 Motorspjæld_modulerende**			
1.9.5.1.	**Type 04**			
1.9.5.1.1.	600x400	-32530.XXXX.007	39	stk
1.9.6.	**359 Brand_og_røgspjæld**			
1.9.6.1.	**Type 01**			
1.9.6.1.1.	600x400	-32530.XXXX.359	26	stk
1.9.7.	**361 Måleblende**			
1.9.7.1.	**Type 01**			
1.9.7.1.1.		-32530.XXXX.361	26	stk
1.9.8.	**Rumtype:**			

Pos	Tekst	DBK	Mængden	Enhed
1.9.8.1.	Type KK1	-32530.XXXX.	132	stk
1.9.8.2.	Type KK2	-32530.XXXX.	13	stk
1.9.8.3.	Type KM1	-32530.XXXX.	25	stk
1.9.8.4.	Type KT1	-32530.XXXX.	13	stk
1.9.8.5.	Type KT2	-32530.XXXX.	12	stk
1.10.	**32531 Auditorium Stort**		**1**	**sum**
1.10.1.	03 Aggregat	-32531.03XX	1	stk
1.10.2.	**006 Kanal**			
1.10.2.1.	**Rektangulære kanaler**			
1.10.2.1.1.	**Lamelmåtte 50 mm**			
1.10.2.1.1.1.	1000x1200	-32531.XXXX.006	10	m
1.10.2.1.1.2.	1100x1000	-32531.XXXX.006	1	m
1.10.2.1.1.3.	1200x1000	-32531.XXXX.006	15	m
1.10.2.1.1.4.	1500x700	-32531.XXXX.006	20	m
1.10.2.1.1.5.	1500x800	-32531.XXXX.006	2	m
1.10.2.1.1.6.	2500x1800	-32531.XXXX.006	1	m
1.10.2.1.1.7.	2500x800	-32531.XXXX.006	2	m
1.10.2.1.1.8.	2800x1200	-32531.XXXX.006	2	m
1.10.2.1.1.9.	700x1500	-32531.XXXX.006	15	m
1.10.2.1.2.	**Ingen isolering**			
1.10.2.1.2.1.	1200x1000	-32531.XXXX.006	14	m
1.10.3.	**001 Temperaturføler**			
1.10.3.1.	**Type 08**			
1.10.3.1.1.		-32531.XXXX.001	2	stk
1.10.4.	**005 Niveauvisning**			
1.10.4.1.	**Type XX**			
1.10.4.1.1.		-32531.XXXX.005	1	stk
1.10.5.	**007 Motorspjæld_modulerende**			
1.10.5.1.	**Type 04**			
1.10.5.1.1.		-32531.XXXX.007	1	stk
1.10.6.	**359 Brand_og_røgspjæld**			
1.10.6.1.	**Type 01**			
1.10.6.1.1.		-32531.XXXX.359	2	stk
1.11.	**32532 Auditorium Lille**		**1**	**sum**
1.11.1.	03 Aggregat	-32532.03XX	1	stk
1.11.2.	**006 Kanal**			
1.11.2.1.	**Rektangulære kanaler**			
1.11.2.1.1.	**Lamelmåtte 50 mm**			
1.11.2.1.1.1.	2500x1500	-32532.XXXX.006	1	m
1.11.2.1.1.2.	2500x800	-32532.XXXX.006	1	m
1.11.2.1.1.3.	800x400	-32532.XXXX.006	34	m
1.11.2.1.1.4.	800x800	-32532.XXXX.006	2	m
1.11.2.1.2.	**Lamelmåtte 20 mm**			
1.11.2.1.2.1.	800x400	-32532.XXXX.006	5	m

Pos	Tekst	DBK	Mængden	Enhed
1.11.2.1.3.	**Ingen isolering**			
1.11.2.1.3.1.	2500x1500	-32532.XXXX.006	1	m
1.11.2.1.3.2.	2500x800	-32532.XXXX.006	1	m
1.11.2.1.3.3.	800x400	-32532.XXXX.006	52	m
1.11.2.1.3.4.	800x800	-32532.XXXX.006	1	m
1.11.3.	**001 Niveauføler**			
1.11.3.1.	**Type 06**			
1.11.3.1.1.		-32532.XXXX.001	1	stk
1.11.4.	**001 Temperaturføler**			
1.11.4.1.	**Type 08**			
1.11.4.1.1.		-32532.XXXX.001	1	stk
1.11.5.	**359 Brand_og_røgspjæld**			
1.11.5.1.	**Type 01**			
1.11.5.1.1.		-32532.XXXX.359	2	stk
1.12.	**32533 Auditorium Mellem**		**1**	**sum**
1.12.1.	03 Aggregat	-32533.03XX	1	stk
1.12.2.	**006 Kanal**			
1.12.2.1.	**Rektangulære kanaler**			
1.12.2.1.1.	**Lamelmåtte 50 mm**			
1.12.2.1.1.1.	1000x500	-32533.XXXX.006	77	m
1.12.2.1.2.	**Lamelmåtte 20 mm**			
1.12.2.1.2.1.	1000x500	-32533.XXXX.006	21	m
1.12.2.1.2.2.	250x200	-32533.XXXX.006	3	m
1.12.2.1.2.3.	400x250	-32533.XXXX.006	10	m
1.12.2.1.2.4.	500x250	-32533.XXXX.006	14	m
1.12.2.1.2.5.	500x400	-32533.XXXX.006	3	m
1.12.2.1.3.	**Ingen isolering**			
1.12.2.1.3.1.	1000x500	-32533.XXXX.006	17	m
1.12.2.1.3.2.	250x200	-32533.XXXX.006	2	m
1.12.2.1.3.3.	400x250	-32533.XXXX.006	3	m
1.12.2.1.3.4.	500x1000	-32533.XXXX.006	10	m
1.12.2.1.3.5.	500x250	-32533.XXXX.006	2	m
1.12.2.1.3.6.	800x500	-32533.XXXX.006	4	m
1.12.2.2.	**Runde, spiro kanaler**			
1.12.2.2.1.	**Ingen isolering**			
1.12.2.2.1.1.	ø200	-32533.XXXX.006	39	m
1.12.2.2.1.2.	ø250	-32533.XXXX.006	16	m
1.12.3.	**001 Niveauføler**			
1.12.3.1.	**Type 06**			
1.12.3.1.1.		-32533.XXXX.001	1	stk
1.12.4.	**001 Temperaturføler**			
1.12.4.1.	**Type 08**			
1.12.4.1.1.		-32533.XXXX.001	1	stk
1.12.5.	**359 Brand_og_røgspjæld**			
1.12.5.1.	**Type 01**			

Pos	Tekst	DBK	Mængden	Enhed
1.12.5.1.1.		-32533.XXXX.359	2	stk
1.13.	**32534 Køkken**		**1**	**sum**
1.13.1.	03 Aggregat	-32534.03XX	1	stk
1.13.2.	**006 Kanal**			
1.13.2.1.	**Rektangulære kanaler**			
1.13.2.1.1.	**Lamelmåtte 50 mm**			
1.13.2.1.1.1.	1000x1200	-32534.XXXX.006	3	m
1.13.2.1.1.2.	1200x1000	-32534.XXXX.006	2	m
1.13.2.1.1.3.	1200x1200	-32534.XXXX.006	3	m
1.13.2.1.1.4.	3000x1200	-32534.XXXX.006	1	m
1.13.2.1.1.5.	3000x1700	-32534.XXXX.006	3	m
1.13.2.1.2.	**Ingen isolering**			
1.13.2.1.2.1.	1000x1200	-32534.XXXX.006	9	m
1.13.2.1.2.2.	1000x500	-32534.XXXX.006	181	m
1.13.2.1.2.3.	1000x800	-32534.XXXX.006	21	m
1.13.2.1.2.4.	3000x1700	-32534.XXXX.006	3	m
1.13.2.1.2.5.	400x250	-32534.XXXX.006	7	m
1.13.2.1.2.6.	500x250	-32534.XXXX.006	73	m
1.13.2.1.2.7.	500x400	-32534.XXXX.006	37	m
1.13.2.1.2.8.	800x600	-32534.XXXX.006	20	m
1.13.2.2.	**Runde, spiro kanaler**			
1.13.2.2.1.	**Ingen isolering**			
1.13.2.2.1.1.	ø100	-32534.XXXX.006	29	m
1.13.2.2.1.2.	ø125	-32534.XXXX.006	13	m
1.13.2.2.1.3.	ø160	-32534.XXXX.006	70	m
1.13.2.2.1.4.	ø200	-32534.XXXX.006	56	m
1.13.2.2.1.5.	ø250	-32534.XXXX.006	130	m
1.13.2.2.1.6.	ø315	-32534.XXXX.006	127	m
1.13.2.2.1.7.	ø400	-32534.XXXX.006	1	m
1.13.2.2.1.8.	ø500	-32534.XXXX.006	24	m
1.13.3.	**358 Armatur**			
1.13.3.1.	I-20	-32534.XXXX.358	22	stk
1.13.3.2.	U-20	-32534.XXXX.358	13	stk
1.13.3.3.	U-01	-32534.XXXX.358	3	stk
1.13.4.	**001 Temperaturføler**			
1.13.4.1.	**Type 08**			
1.13.4.1.1.		-32534.XXXX.001	6	stk
1.13.5.	**007 Motorspjæld**			
1.13.5.1.	**Type 02**			
1.13.5.1.1.	200	-32534.XXXX.007	6	stk
1.13.5.1.2.	100	-32534.XXXX.007	3	stk
1.13.5.1.3.	160	-32534.XXXX.007	2	stk
1.13.6.	**007 Motorspjæld_modulerende**			
1.13.6.1.	**Type 04**			
1.13.6.1.1.	500	-32534.XXXX.007	9	stk

Pos	Tekst	DBK	Mængden	Enhed
1.13.6.1.2.	315	-32534.XXXX.007	8	stk
1.13.6.1.3.	200	-32534.XXXX.007	10	stk
1.13.6.1.4.	160	-32534.XXXX.007	1	stk
1.13.6.1.5.	250	-32534.XXXX.007	2	stk
1.13.6.1.6.	400	-32534.XXXX.007	12	stk
1.13.7.	**007 Volumenstrømsregulator_volustat**			
1.13.7.1.	**Type 027**			
1.13.7.1.1.	200	-32534.XXXX.007	6	stk
1.13.7.1.2.	100	-32534.XXXX.007	3	stk
1.13.7.1.3.	160	-32534.XXXX.007	2	stk
1.13.8.	**013 Generel_måler_2**			
1.13.8.1.	**Type XX**			
1.13.8.1.1.		-32534.XXXX.013	12	stk
1.13.9.	**361 Måleblende**			
1.13.9.1.	**Type 01**			
1.13.9.1.1.	500	-32534.XXXX.361	10	stk
1.13.9.1.2.	315	-32534.XXXX.361	6	stk
1.13.9.1.3.	200	-32534.XXXX.361	10	stk
1.13.9.1.4.	160	-32534.XXXX.361	1	stk
1.13.9.1.5.	250	-32534.XXXX.361	2	stk
1.13.9.1.6.	400	-32534.XXXX.361	13	stk
1.14.	**32535 Kantine**		**1**	**sum**
1.14.1.	03 Aggregat	-32535.03XX	1	stk
1.14.2.	**006 Kanal**			
1.14.2.1.	**Rektangulære kanaler**			
1.14.2.1.1.	**Lamelmåtte 50 mm**			
1.14.2.1.1.1.	1000x1000	-32535.XXXX.006	28	m
1.14.2.1.1.2.	1200x800	-32535.XXXX.006	59	m
1.14.2.1.1.3.	2200x1400	-32535.XXXX.006	2	m
1.14.2.1.1.4.	2500x1500	-32535.XXXX.006	2	m
1.14.2.1.1.5.	2500x800	-32535.XXXX.006	1	m
1.14.2.1.1.6.	800x600	-32535.XXXX.006	8	m
1.14.2.1.2.	**Ingen isolering**			
1.14.2.1.2.1.	1000x1000	-32535.XXXX.006	26	m
1.14.2.1.2.2.	1000x600	-32535.XXXX.006	3	m
1.14.2.1.2.3.	800x600	-32535.XXXX.006	4	m
1.14.2.2.	**Runde, spiro kanaler**			
1.14.2.2.1.	**Lamelmåtte 50 mm**			
1.14.2.2.1.1.	ø800	-32535.XXXX.006	89	m
1.14.2.2.2.	**Ingen isolering**			
1.14.2.2.2.1.	ø315	-32535.XXXX.006	35	m
1.14.2.2.2.2.	ø800	-32535.XXXX.006	40	m
1.14.3.	**001 Temperaturføler**			
1.14.3.1.	**Type 08**			

Pos	Tekst	DBK	Mængden	Enhed
1.14.3.1.1.		-32535.XXXX.001	2	stk
1.14.4.	**007 Motorspjæld_modulerende**			
1.14.4.1.	**Type 04**			
1.14.4.1.1.	800	-32535.XXXX.007	2	stk
1.14.4.1.2.	315	-32535.XXXX.007	5	stk
1.14.5.	**359 Brand_og_røgspjæld**			
1.14.5.1.	**Type 01**			
1.14.5.1.1.	800	-32535.XXXX.359	2	stk
1.14.5.1.2.	500	-32535.XXXX.359	1	stk
1.14.6.	**361 Måleblende**			
1.14.6.1.	**Type 01**			
1.14.6.1.1.	800	-32535.XXXX.361	1	stk
1.14.6.1.2.	315	-32535.XXXX.361	6	stk
1.15.	**32536 Substrat**		**1**	**sum**
1.15.1.	03 Aggregat	-32536.03XX	1	stk
1.15.2.	**006 Kanal**			
1.15.2.1.	**Rektangulære kanaler**			
1.15.2.1.1.	**Lamelmåtte 50 mm**			
1.15.2.1.1.1.	1200×1000	-32536.XXXX.006	18	m
1.15.2.1.1.2.	1200×2500	-32536.XXXX.006	3	m
1.15.2.1.1.3.	1200×500	-32536.XXXX.006	1	m
1.15.2.1.1.4.	1200×800	-32536.XXXX.006	2	m
1.15.2.1.1.5.	2500×1800	-32536.XXXX.006	1	m
1.15.2.1.1.6.	600×500	-32536.XXXX.006	21	m
1.15.2.1.2.	**Ingen isolering**			
1.15.2.1.2.1.	1000×1200	-32536.XXXX.006	2	m
1.15.2.1.2.2.	1000×800	-32536.XXXX.006	8	m
1.15.2.1.2.3.	1200×1000	-32536.XXXX.006	14	m
1.15.2.1.2.4.	1200×1200	-32536.XXXX.006	3	m
1.15.2.1.2.5.	1200×2400	-32536.XXXX.006	1	m
1.15.2.1.2.6.	1200×800	-32536.XXXX.006	1	m
1.15.2.1.2.7.	2400×1600	-32536.XXXX.006	2	m
1.15.2.1.2.8.	500×500	-32536.XXXX.006	1	m
1.15.2.1.2.9.	600×500	-32536.XXXX.006	5	m
1.15.2.1.2.10.	800×800	-32536.XXXX.006	7	m
1.15.2.2.	**Runde, spiro kanaler**			
1.15.2.2.1.	**Ingen isolering**			
1.15.2.2.1.1.	ø100	-32536.XXXX.006	43	m
1.15.2.2.1.2.	ø125	-32536.XXXX.006	59	m
1.15.2.2.1.3.	ø160	-32536.XXXX.006	27	m
1.15.2.2.1.4.	ø200	-32536.XXXX.006	74	m
1.15.2.2.1.5.	ø250	-32536.XXXX.006	65	m
1.15.2.2.1.6.	ø315	-32536.XXXX.006	56	m
1.15.2.2.1.7.	ø400	-32536.XXXX.006	68	m
1.15.2.2.1.8.	ø500	-32536.XXXX.006	74	m

Pos	Tekst	DBK	Mængden	Enhed
1.15.2.2.1.9.	ø630	-32536.XXXX.006	11	m
1.15.2.2.1.10.	ø800	-32536.XXXX.006	39	m
1.15.3.	**358 Armatur**			
1.15.3.1.	I-20	-32536.XXXX.358	22	stk
1.15.3.2.	U-20	-32536.XXXX.358	18	stk
1.15.3.3.	U-Lab	-32536.XXXX.358	11	stk
1.15.3.4.	I-23	-32536.XXXX.358	4	stk
1.15.3.5.	U-13	-32536.XXXX.358	5	stk
1.15.4.	**362 Fan filter unit**			
1.15.4.1.	FFU	-32536.XXXX.362	7	stk
1.15.5.	**005 Differenstrykindikator**			
1.15.5.1.	**Type 09**			
1.15.5.1.1.		-32536.XXXX.005	7	stk
1.15.6.	**007 Motorspjæld**			
1.15.6.1.	**Type 02**			
1.15.6.1.1.	315	-32536.XXXX.007	2	stk
1.15.6.1.2.	250	-32536.XXXX.007	2	stk
1.15.6.1.3.	125	-32536.XXXX.007	6	stk
1.15.7.	**007 Motorspjæld_modulerende**			
1.15.7.1.	**Type 04**			
1.15.7.1.1.		-32536.XXXX.007	2	stk
1.15.7.1.2.	500	-32536.XXXX.007	5	stk
1.15.7.1.3.	250	-32536.XXXX.007	14	stk
1.15.7.1.4.	400	-32536.XXXX.007	6	stk
1.15.8.	**007 Volumenstrømsregulator_volustat**			
1.15.8.1.	**Type 08**			
1.15.8.1.1.	315	-32536.XXXX.007	2	stk
1.15.8.1.2.	250	-32536.XXXX.007	5	stk
1.15.8.1.3.	125	-32536.XXXX.007	12	stk
1.15.9.	**361 Måleblende**			
1.15.9.1.	**Type 01**			
1.15.9.1.1.	500	-32536.XXXX.361	5	stk
1.15.9.1.2.	250	-32536.XXXX.361	8	stk
1.15.9.1.3.	400	-32536.XXXX.361	6	stk
1.16.	**32537 Basen**		**1**	**sum**
1.16.1.	03 Aggregat	-32537.03XX	1	stk
1.16.2.	**006 Kanal**			
1.16.2.1.	**Rektangulære kanaler**			
1.16.2.1.1.	**Lamelmåtte 50 mm**			
1.16.2.1.1.1.	1000x1000	-32537.XXXX.006	14	m
1.16.2.1.1.2.	1200x1000	-32537.XXXX.006	2	m
1.16.2.1.1.3.	1200x800	-32537.XXXX.006	56	m
1.16.2.1.1.4.	2200x1400	-32537.XXXX.006	2	m
1.16.2.1.1.5.	2400x1200	-32537.XXXX.006	3	m

Pos	Tekst	DBK	Mængden	Enhed
1.16.2.1.2.	**Ingen isolering**			
1.16.2.1.2.1.	250x200	-32537.XXXX.006	60	m
1.16.2.1.2.2.	300x150	-32537.XXXX.006	31	m
1.16.2.1.2.3.	400x200	-32537.XXXX.006	1	m
1.16.2.1.2.4.	400x350	-32537.XXXX.006	56	m
1.16.2.1.2.5.	500x350	-32537.XXXX.006	45	m
1.16.2.1.2.6.	500x400	-32537.XXXX.006	2	m
1.16.2.1.2.7.	500x500	-32537.XXXX.006	16	m
1.16.2.1.2.8.	600x300	-32537.XXXX.006	9	m
1.16.2.1.2.9.	600x500	-32537.XXXX.006	9	m
1.16.2.1.2.10.	700x500	-32537.XXXX.006	9	m
1.16.2.1.2.11.	800x350	-32537.XXXX.006	59	m
1.16.2.1.2.12.	800x450	-32537.XXXX.006	34	m
1.16.2.1.2.13.	800x600	-32537.XXXX.006	54	m
1.16.2.1.2.14.	800x800	-32537.XXXX.006	5	m
1.16.2.1.2.15.	900x1100	-32537.XXXX.006	36	m
1.16.2.2.	**Runde, spiro kanaler**			
1.16.2.2.1.	**Lamelmåtte 50 mm**			
1.16.2.2.1.1.	ø630	-32537.XXXX.006	176	m
1.16.2.2.2.	**Ingen isolering**			
1.16.2.2.2.1.	ø100	-32537.XXXX.006	138	m
1.16.2.2.2.2.	ø125	-32537.XXXX.006	85	m
1.16.2.2.2.3.	ø160	-32537.XXXX.006	254	m
1.16.2.2.2.4.	ø200	-32537.XXXX.006	119	m
1.16.2.2.2.5.	ø250	-32537.XXXX.006	80	m
1.16.2.2.2.6.	ø315	-32537.XXXX.006	11	m
1.16.2.2.2.7.	ø400	-32537.XXXX.006	13	m
1.16.2.2.2.8.	ø630	-32537.XXXX.006	93	m
1.16.2.3.	**Runde, rustfri spiro kanaler**			
1.16.2.3.1.	**Ingen isolering**			
1.16.2.3.1.1.	ø400	-32537.XXXX.006	18	m
1.16.2.3.1.2.	ø500	-32537.XXXX.006	14	m
1.16.3.	**358 Armatur**			
1.16.3.1.	I-20	-32537.XXXX.358	37	stk
1.16.3.2.	U-20	-32537.XXXX.358	30	stk
1.16.3.3.	U-01	-32537.XXXX.358	8	stk
1.16.3.4.	I-05	-32537.XXXX.358	34	stk
1.16.4.	**001 Trykføler**			
1.16.4.1.	**Type 10**			
1.16.4.1.1.		-32537.XXXX.001	10	stk
1.16.5.	**007 Motorspjæld_modulerende**			
1.16.5.1.	**Type 04**			
1.16.5.1.1.		-32537.XXXX.007	8	stk
1.16.6.	**359 Brand_og_røgspjæld**			
1.16.6.1.	**Type 01**			
1.16.6.1.1.		-32537.XXXX.359	8	stk

Pos	Tekst	DBK	Mængden	Enhed
1.16.7.	**Rumtype:**			
1.16.7.1.	Type BD1	-32537.XXXX.	17	stk
1.16.7.2.	Type BD2	-32537.XXXX.	2	stk
1.16.7.3.	Type BG1	-32537.XXXX.	1	stk
1.16.7.4.	Type BK1	-32537.XXXX.	17	stk
1.16.7.5.	Type BO1	-32537.XXXX.	5	stk
1.16.7.6.	Type BO2	-32537.XXXX.	3	stk
1.16.7.7.	Type BT1	-32537.XXXX.	5	stk
1.16.7.8.	Type BT2	-32537.XXXX.	1	stk
1.16.7.9.	Type BT3	-32537.XXXX.	1	stk
1.16.7.10.	Type BT4	-32537.XXXX.	2	stk
1.16.7.11.	Type BT5	-32537.XXXX.	1	stk
1.16.7.12.	Type BV1	-32537.XXXX.	1	stk
1.17.	**32538 Undervisning**		**1**	**sum**
1.17.1.	03 Aggregat	-32538.03XX	1	stk
1.17.2.	**006 Kanal**			
1.17.2.1.	**Rektangulære kanaler**			
1.17.2.1.1.	**Lamelmåtte 50 mm**			
1.17.2.1.1.1.	1000x1000	-32538.XXXX.006	22	m
1.17.2.1.1.2.	1100x900	-32538.XXXX.006	21	m
1.17.2.1.1.3.	1200x1100	-32538.XXXX.006	1	m
1.17.2.1.1.4.	1200x800	-32538.XXXX.006	1	m
1.17.2.1.1.5.	2200x1400	-32538.XXXX.006	1	m
1.17.2.1.1.6.	2400x1200	-32538.XXXX.006	1	m
1.17.2.1.2.	**Lamelmåtte 20 mm**			
1.17.2.1.2.1.	1200x800	-32538.XXXX.006	52	m
1.17.2.1.2.2.	400x800	-32538.XXXX.006	2	m
1.17.2.1.2.3.	600x800	-32538.XXXX.006	1	m
1.17.2.1.2.4.	800x400	-32538.XXXX.006	78	m
1.17.2.1.2.5.	800x600	-32538.XXXX.006	32	m
1.17.2.1.3.	**Ingen isolering**			
1.17.2.1.3.1.	1000x1000	-32538.XXXX.006	15	m
1.17.2.1.3.2.	1200x1000	-32538.XXXX.006	1	m
1.17.2.1.3.3.	1200x800	-32538.XXXX.006	22	m
1.17.2.1.3.4.	300x200	-32538.XXXX.006	18	m
1.17.2.1.3.5.	800x400	-32538.XXXX.006	88	m
1.17.2.1.3.6.	800x600	-32538.XXXX.006	144	m
1.17.2.1.3.7.	800x800	-32538.XXXX.006	5	m
1.17.2.2.	**Runde, spiro kanaler**			
1.17.2.2.1.	**Lamelmåtte 50 mm**			
1.17.2.2.1.1.	ø315	-32538.XXXX.006	31	m
1.17.2.2.2.	**Lamelmåtte 20 mm**			
1.17.2.2.2.1.	ø200	-32538.XXXX.006	217	m
1.17.2.2.2.2.	ø250	-32538.XXXX.006	93	m
1.17.2.2.2.3.	ø315	-32538.XXXX.006	90	m

Pos	Tekst	DBK	Mængden	Enhed
1.17.2.2.2.4.	ø400	-32538.XXXX.006	9	m
1.17.2.2.3.	**Ingen isolering**			
1.17.2.2.3.1.	ø400	-32538.XXXX.006	29	m
1.17.3.	**358 Armatur**			
1.17.3.1.	I-20	-32538.XXXX.358	1	stk
1.17.4.	**001 Trykføler**			
1.17.4.1.	**Type 10**			
1.17.4.1.1.		-32538.XXXX.001	2	stk
1.17.5.	**359 Brand_og_røgspjæld**			
1.17.5.1.	**Type 01**			
1.17.5.1.1.		-32538.XXXX.359	4	stk
1.17.6.	**Rumtype:**			
1.17.6.1.	Type UD1	-32538.XXXX.	1	stk
1.17.6.2.	Type UL1	-32538.XXXX.	2	stk
1.17.6.3.	Type UT2	-32538.XXXX.	1	stk
1.17.6.4.	Type UU1	-32538.XXXX.	17	stk
1.18.	**32539 Repræsentation**		**1**	**sum**
1.18.1.	03 Aggregat	-32539.03XX	1	stk
1.18.2.	**006 Kanal**			
1.18.2.1.	**Rektangulære kanaler**			
1.18.2.1.1.	**Lamelmåtte 80 mm**			
1.18.2.1.1.1.	800x450	-32539.XXXX.006	6	m
1.18.2.1.2.	**Lamelmåtte 50 mm**			
1.18.2.1.2.1.	1200x1600	-32539.XXXX.006	1	m
1.18.2.1.2.2.	1200x700	-32539.XXXX.006	33	m
1.18.2.1.2.3.	1200x800	-32539.XXXX.006	7	m
1.18.2.1.2.4.	2400x1600	-32539.XXXX.006	3	m
1.18.2.1.3.	**Lamelmåtte 20 mm**			
1.18.2.1.3.1.	1200x1200	-32539.XXXX.006	1	m
1.18.2.1.3.2.	1200x600	-32539.XXXX.006	5	m
1.18.2.1.3.3.	400x200	-32539.XXXX.006	10	m
1.18.2.1.3.4.	400x300	-32539.XXXX.006	6	m
1.18.2.1.3.5.	500x400	-32539.XXXX.006	17	m
1.18.2.1.3.6.	800x450	-32539.XXXX.006	155	m
1.18.2.1.4.	**Ingen isolering**			
1.18.2.1.4.1.	1000x350	-32539.XXXX.006	16	m
1.18.2.1.4.2.	1000x450	-32539.XXXX.006	2	m
1.18.2.1.4.3.	1200x1400	-32539.XXXX.006	1	m
1.18.2.1.4.4.	1200x600	-32539.XXXX.006	9	m
1.18.2.1.4.5.	1200x700	-32539.XXXX.006	31	m
1.18.2.1.4.6.	1200x800	-32539.XXXX.006	5	m
1.18.2.1.4.7.	2200x1400	-32539.XXXX.006	3	m
1.18.2.1.4.8.	300x200	-32539.XXXX.006	5	m
1.18.2.1.4.9.	400x300	-32539.XXXX.006	13	m
1.18.2.1.4.10.	700x300	-32539.XXXX.006	6	m

Pos	Tekst	DBK	Mængden	Enhed
1.18.2.1.4.11.	800x450	-32539.XXXX.006	165	m
1.18.2.2.	**Runde, spiro kanaler**			
1.18.2.2.1.	**Lamelmåtte 20 mm**			
1.18.2.2.1.1.	ø100	-32539.XXXX.006	43	m
1.18.2.2.1.2.	ø125	-32539.XXXX.006	101	m
1.18.2.2.1.3.	ø160	-32539.XXXX.006	83	m
1.18.2.2.1.4.	ø200	-32539.XXXX.006	89	m
1.18.2.2.1.5.	ø250	-32539.XXXX.006	44	m
1.18.2.2.1.6.	ø315	-32539.XXXX.006	27	m
1.18.2.2.1.7.	ø400	-32539.XXXX.006	10	m
1.18.2.2.2.	**Ingen isolering**			
1.18.2.2.2.1.	ø100	-32539.XXXX.006	5	m
1.18.2.2.2.2.	ø200	-32539.XXXX.006	20	m
1.18.2.2.2.3.	ø250	-32539.XXXX.006	6	m
1.18.2.2.2.4.	ø315	-32539.XXXX.006	12	m
1.18.3.	**358 Armatur**			
1.18.3.1.	I-20	-32539.XXXX.358	58	stk
1.18.3.2.	U-01	-32539.XXXX.358	13	stk
1.18.4.	**001 Trykføler**			
1.18.4.1.	**Type 10**			
1.18.4.1.1.		-32539.XXXX.001	2	stk
1.18.5.	**359 Brand_og_røgspjæld**			
1.18.5.1.	**Type 01**			
1.18.5.1.1.	600x400	-32539.XXXX.359	2	stk
1.18.6.	**Rumtype:**			
1.18.6.1.	Type RK1	-32539.XXXX.	1	stk
1.18.6.2.	Type RL1	-32539.XXXX.	5	stk
1.18.6.3.	Type RL2	-32539.XXXX.	1	stk
1.18.6.4.	Type RM1	-32539.XXXX.	11	stk
1.18.6.5.	Type RT1	-32539.XXXX.	1	stk
1.18.6.6.	Type RT2	-32539.XXXX.	1	stk
1.18.6.7.	Type RT3	-32539.XXXX.	1	stk
1.19.	**32550 Isotop stinkskab**		**1**	**sum**
1.19.1.	04 Ventilator	-32550.04XX	1	stk
1.20.	**32551 Skraldesug**		**1**	**sum**
1.20.1.	03 Aggregat	-32551.03XX	1	stk
1.20.2.	**006 Kanal**			
1.20.2.1.	**Rektangulære kanaler**			
1.20.2.1.1.	**Lamelmåtte 80 mm**			
1.20.2.1.1.1.	500x700	-32551.XXXX.006	1	m
1.20.2.1.2.	**Brandisolering 60 mm**			
1.20.2.1.2.1.	500x700	-32551.XXXX.006	27	m
1.20.2.2.	**Runde, spiro kanaler**			
1.20.2.2.1.	**Lamelmåtte 80 mm**			

Pos	Tekst	DBK	Mængden	Enhed
1.20.2.2.1.1.	ø160	-32551.XXXX.006	1	m
1.20.2.2.1.2.	ø500	-32551.XXXX.006	4	m
1.20.2.2.2.	**Brandisolering 60 mm**			
1.20.2.2.2.1.	ø200	-32551.XXXX.006	3	m
1.20.2.2.2.2.	ø500	-32551.XXXX.006	365	m
1.21.	**32552 Varegård**		**1**	**sum**
1.21.1.	04 Ventilator	-32552.04XX	1	stk
1.22.	**32553 Truck ladestation**		**1**	**sum**
1.22.1.	04 Ventilator	-32553.04XX	1	stk
1.23.	**32554 Transformerrum, niveau 01**		**1**	**sum**
1.23.1.	04 Ventilator	-32554.04XX	1	stk
1.24.	**32555 Transformerrum, niveau 02**		**1**	**sum**
1.24.1.	04 Ventilator	-32555.04XX	1	stk
1.25.	325XX Demontering og ombygning i eksisterende bygning		1	sum
1.26.	325XX Indeklimamålinger		1	sum

Pos	Tekst	DBK	Mængden	Enhed
2.	**CTS**			
2.1.	325XX CTS		1	sum

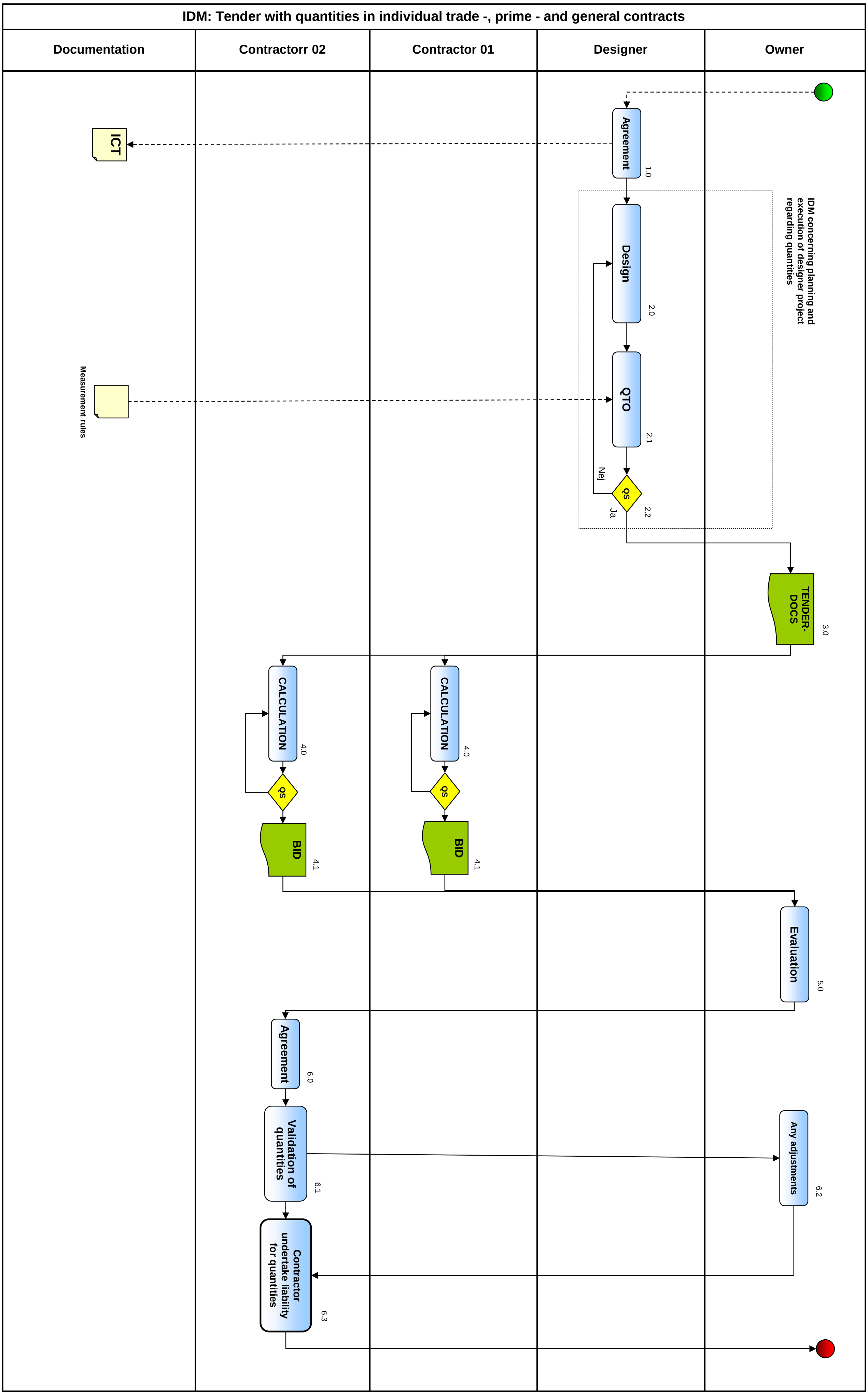
Pos	Tekst	DBK	Mængden	Enhed
3.	**Byggeplads**			
3.1.	900XX Tilrigning af egen byggeplads		1	sum
3.2.	900XX Drift af egen byggeplads		1	sum

Pos	Tekst	DBK	Mængden	Enhed
4.	**Diverse**			
4.1.	**Commisioning**		**1**	**sum**
4.1.1.	CE-mærkning		1	sum
4.1.2.	Samprojektering		1	sum
4.1.3.	Kollisionskontrol af 3D modeller		1	sum
4.1.4.	Drift af tekniske anlæg, efter aflevering - driftsforpligtelse		1	sum
4.1.5.	Indregulering, afprøvning og idriftsætning		1	sum
4.1.6.	Brugerinstruktion		1	sum
4.1.7.	Service		1	sum
4.1.8.	Øvrige ydelser		1	sum
4.2.	D&V		1	sum
4.3.	Kvalitetsstyring		1	sum
4.4.	**Øvrige**		**1**	**sum**
4.4.1.	Hultagning og -lukning		1	sum
4.4.2.	ID nummering og mærkning		1	sum

Pos	Tekst	DBK	Mængden	Enhed
5.	**Ændringsarbejder**			
5.1.	Svendetimer, indenfor normalarbejdstid		250	timer
5.2.	Svendetimer, udenfor normalarbejdstid		100	timer
5.3.	Lærlingetimer, indenfor normalarbejdstid		150	timer
5.4.	Lærlingetimer, udenfor normalarbejdstid		100	timer

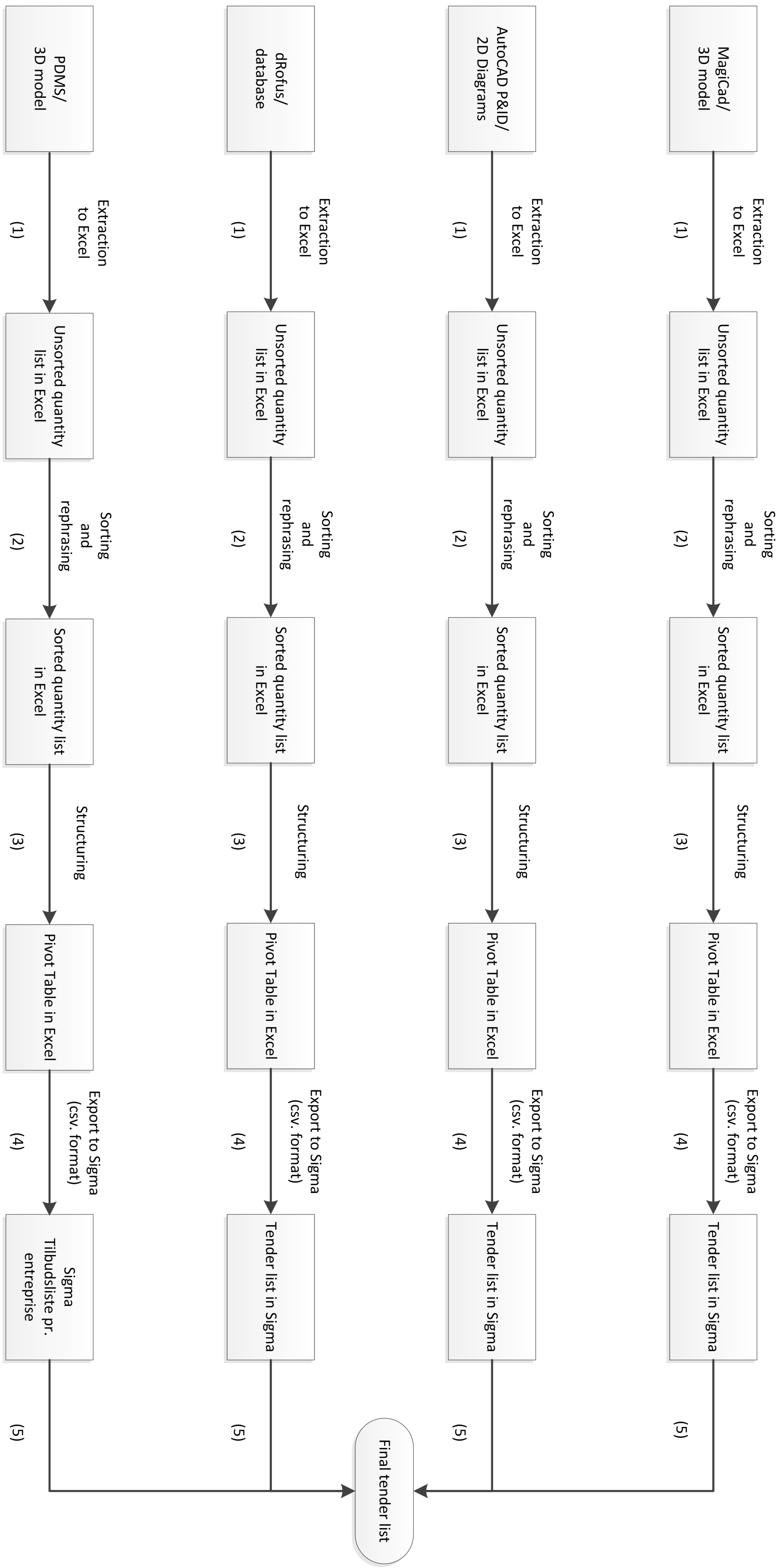
Pos	Tekst	Enhed	Mængde	Samlet EP
5.2.	Svendetimer, udenfor normalarbejdstid	timer	100	0,00
5.3.	Lærlingetimer, indenfor normalarbejdstid	timer	150	0,00
5.4.	Lærlingetimer, udenfor normalarbejdstid	timer	100	0,00

Appendix B - Process map for digital tender (DiKon)



IDM: Tender with quantities in individual trade -, prime - and general contracts
Documentation
Contractorr 02
Contractor 01
Designer
Owner
ICT
Agreement
1.0
IDM concerning planning and execution of designer project regarding quantities
Design
2.0
QTO
2.1
Measurement rules
Nej
QS
Ja
2.2
TENDER-DOCS
3.0
CALCULATION
4.0
QS
BID
4.1
CALCULATION
4.0
QS
BID
4.1
Evaluation
5.0
Agreement
6.0
Validation of quantities
6.1
Any adjustments
6.2
Contractor undertake liability for quantities
6.3

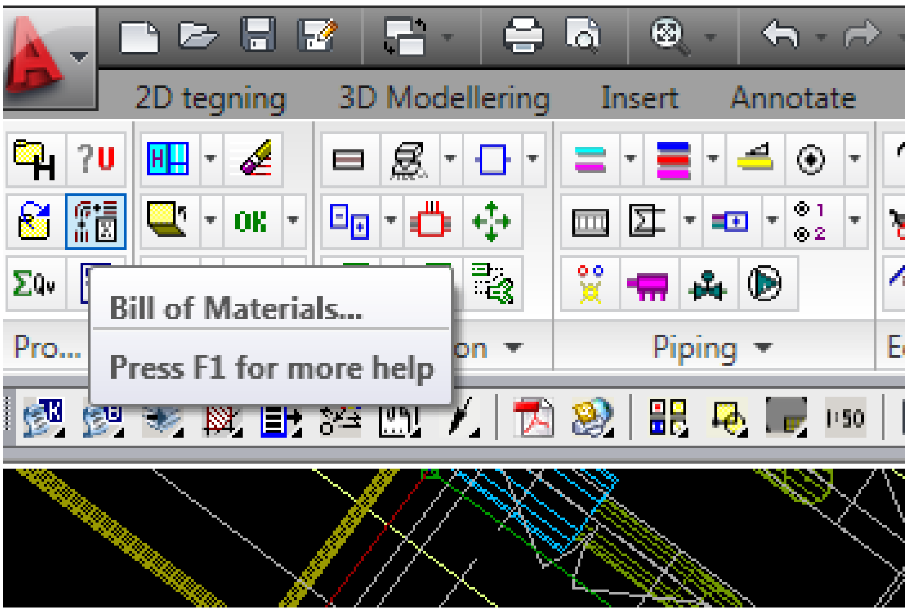
Appendix C - Specific process of QTO


MagiCad/
3D model
AutoCAD P&ID/
2D Diagrams
dRofus/
database
PDMS/
3D model
Extraction
to Excel
(1)
Unsorted quantity
list in Excel
Sorting
and
rephrasing
(2)
Sorted quantity list
in Excel
Structuring
(3)
Pivot Table in Excel
Export to Sigma
(csv. format)
(4)
Tender list in Sigma
Sigma
Tilbudsliste pr.
entreprise
(5)
Final tender list

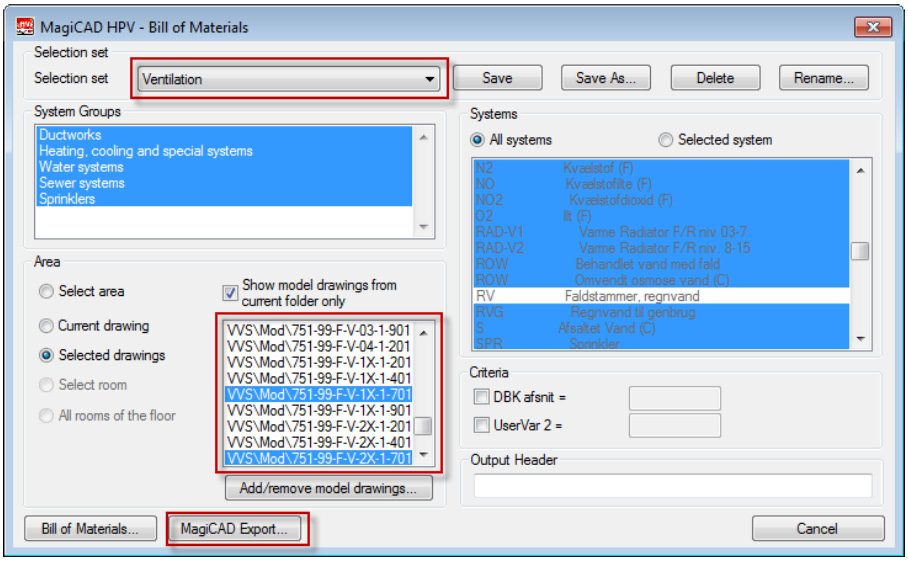
Appendix D - Technical implementation of QTO for MagiCad 2011

This is a guideline for how to carry out the QTO from MagiCad. Similar technical processes was also developed for dRofus (database for equipment) and AutoCad P&ID (Flow diagrams), but since the MagiCad model contained most object and was the governing 3D model it is the only included in this section. The process will in general follow the steps from 'Appendix B - Specific process of QTO'.

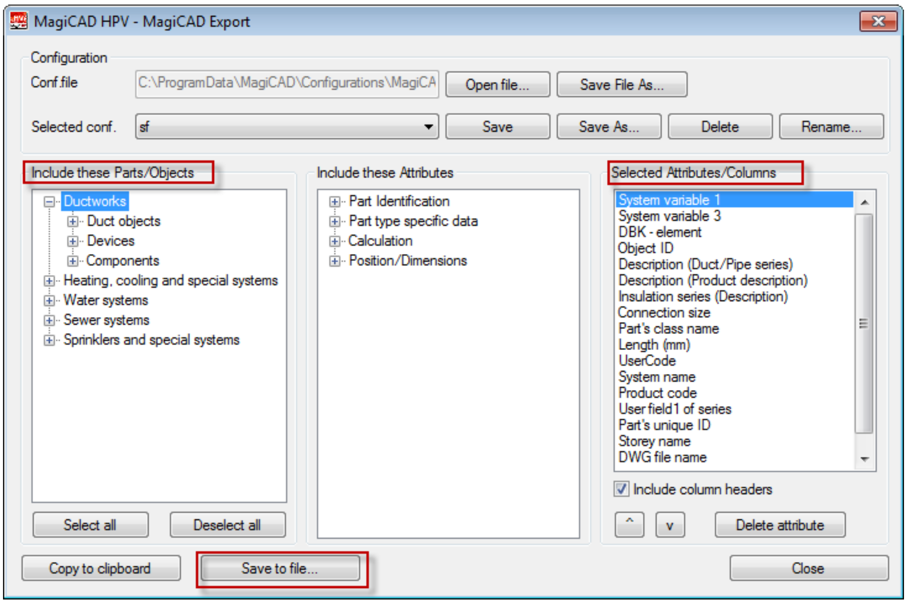
(1) This step refers to the data extraction from MagiCad. In MagiCad this is done from the ribbon **MagiCad VVS**, when dealing with HVAC systems. In there it is possible to click a button called **Bill of materials** under the project panel as illustrated below.



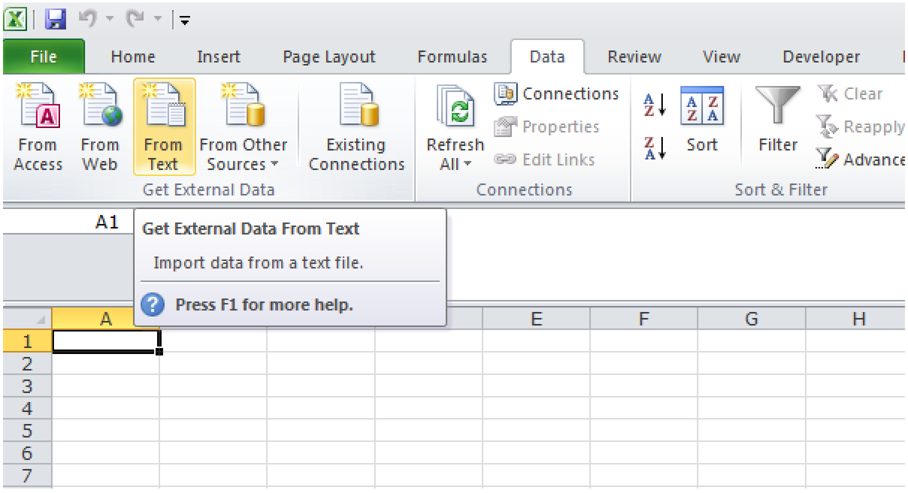
In there it possible to set up a **selection set**, which corresponds to the wanted trade contract. In this case **Ventilation** was choosed. This **selection set** can be assigned to all the relevant **model drawings** and simultaneously assign the wanted **systems**. To be on the safe side all **systems** can be choosen, but that is not possible in relation to the **model drawings** since a general rule in this version of MagiCad says that it is not possible to extract from more than one **model drawing** per storey. When settings are right click **MagiCad Export**.



Afterwards the extraction configuration window will appear. In here it is possible to choose which **parts/objects** to extract and also specify the corresponding **Attributes**. The relevant **Attributes** depends on how the project parameters has been set up. By clicking **Save to file...** it is possible to save to a .txt format. It might be possible to set up a script, which makes this extraction periodically (every hour for instance), but that was not investigated during this project.



(2) This step deals with the initial sorting and rephrasing. First the data from the .txt file is loaded in Excel



Due to the MagiCad problem regarding the limit of one extraction per storey as clarified above, the HVAC model has to be divided in more extractions. For ventilation it is divided into 'Ventilation701' (refering to the ventilation at at each storey) and 'Skakt701' (refering to the ventilation ducts in the shafts). Those two .txt files are gathered by the following macro (VBScript):

```
Attribute VB_Name = "Module2"
Sub collect_sheets_Ventilation():
Dim sheet_names
Dim names
Dim target_sheet      As String
Dim target_row        As Long
Dim target_col        As Long
Dim start_row         As Long
Dim start_col         As Long
Dim end_row           As Long
Dim end_col           As Long
Dim values()
Dim nRows             As Long
Dim running_time(1)     As Double

running_time(0) = Timer
'running_time(1) = 0

target_sheet = "SamletVentilation"
```

```
Call create_sheet(target_sheet)
sheet_names = Array("1.DataVentilation701", "Skakt701")
nRows = 0

For Each names In sheet_names
    With Worksheets(names)
        Call find_start(CStr(names), start_row, start_col)
        Call find_end(CStr(names), start_row, start_col, end_row, end_col)
        Call find_start(target_sheet, target_row, target_col)
        Call find_end(target_sheet, target_row, target_col, target_row,
            target_col)

        Worksheets(target_sheet).Range(.Cells(target_row + 1, 1).Address, .
            Cells(target_row + 1 + end_row - start_row, end_col).Address).
            Formula = Worksheets(names).Range(.Cells(start_row, start_col),
             .Cells(end_row, end_col)).Formula

    End With
Next names

running_time(1) = Timer

Debug.Print "Running time of sub routine: " & running_time(1) -
    running_time(0) & " s"

End Sub

Sub find_start(wsht As String, ByRef lrow As Long, ByRef lcol As Long)
Dim i            As Long
For i = 1 To Worksheets(wsht).Range("aa1").Column
    For j = 2 To 100
        If Worksheets(wsht).Cells(j, i) <> vbNullString Then
            lcol = i
            lrow = j
            Exit Sub
        End If
    Next
Next i
lcol = 1
lrow = 1
```

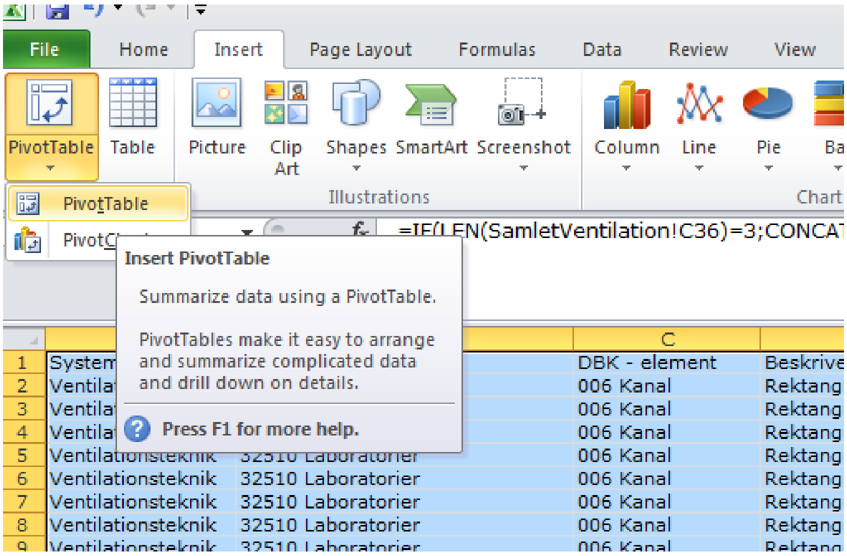
```
End Sub

Sub find_end(wsht As String, start_row As Long, start_col As Long, ByRef
    end_row As Long, ByRef end_col As Long)
end_row = Worksheets(wsht).Cells(200000, start_col).End(xlUp).Row
end_col = Worksheets(wsht).Cells(start_row, 100).End(xlToLeft).Column
End Sub

Sub create_sheet(wsht As String)
Dim names
Dim new_sheet
Dim sheet_exists          As Boolean

Application.DisplayAlerts = False

sheet_exists = False

For Each names In ThisWorkbook.Worksheets
    If names.Name = wsht Then
        names.Cells.ClearContents
        sheet_exists = True
    End If
Next names

If Not sheet_exists Then
    Set new_sheet = Worksheets.Add(After:=Worksheets(Worksheets.Count))
    new_sheet.Name = wsht
    new_sheet.Tab.Color = 8421504
    new_sheet.Range("a1").Value = "System␣variable␣1"
    new_sheet.Range("b1").Value = "System␣variable␣3"
    new_sheet.Range("c1").Value = "DBK␣−␣element"
    new_sheet.Range("d1").Value = "Object␣ID"
    new_sheet.Range("e1").Value = "Description␣(Duct/Pipe␣series)"
    new_sheet.Range("f1").Value = "Description␣(Product␣description)"
    new_sheet.Range("g1").Value = "Insulation␣series␣(Description)"
    new_sheet.Range("h1").Value = "Connection␣size"
    new_sheet.Range("i1").Value = "Part's␣class␣name"
    new_sheet.Range("j1").Value = "Length␣(mm)"
    new_sheet.Range("k1").Value = "UserCode"
    new_sheet.Range("l1").Value = "System␣name"
```

```
    new_sheet.Range("m1").Value = "Product code"
    new_sheet.Range("n1").Value = "User field1 of series"
    new_sheet.Range("o1").Value = "Part's unique ID"
    new_sheet.Range("p1").Value = "Storey name"
    new_sheet.Range("q1").Value = "DWG file name"
Else
    Worksheets(wsht).Range("a1").Value = "System variable 1"
    Worksheets(wsht).Range("b1").Value = "System variable 3"
    Worksheets(wsht).Range("c1").Value = "DBK - element"
    Worksheets(wsht).Range("d1").Value = "Object ID"
    Worksheets(wsht).Range("e1").Value = "Description (Duct/Pipe series)"
    Worksheets(wsht).Range("f1").Value = "Description (Product description)"
    Worksheets(wsht).Range("g1").Value = "Insulation series (Description)"
    Worksheets(wsht).Range("h1").Value = "Connection size"
    Worksheets(wsht).Range("i1").Value = "Part's class name"
    Worksheets(wsht).Range("j1").Value = "Length (mm)"
    Worksheets(wsht).Range("k1").Value = "UserCode"
    Worksheets(wsht).Range("l1").Value = "System name"
    Worksheets(wsht).Range("m1").Value = "Product code"
    Worksheets(wsht).Range("n1").Value = "User field1 of series"
    Worksheets(wsht).Range("o1").Value = "Part's unique ID"
    Worksheets(wsht).Range("p1").Value = "Storey name"
    Worksheets(wsht).Range("q1").Value = "DWG file name"
End If

Application.DisplayAlerts = True

End Sub
```

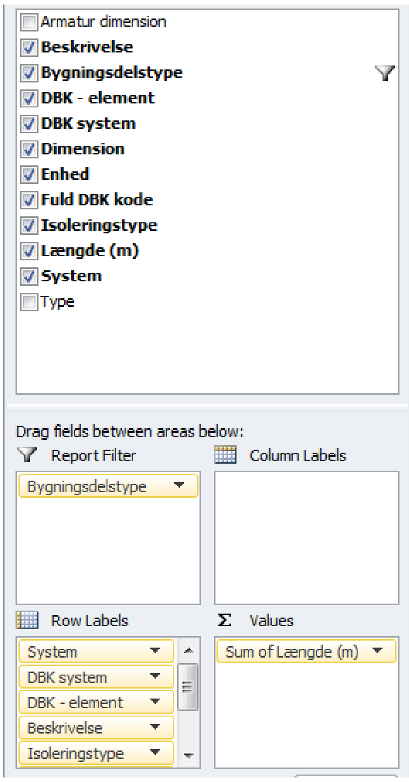
Thereby a full dataset is gathered in one sheet. This sheet is being sorted and rephrased by Excel standard formulas as **if** and **vlookup**, which leads to a sheet with a sorted dataset.

	A	B	C	D	
1	System	DBK system	DBK - element	Beskrivelse	Isolerir
2	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
3	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
4	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
5	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
6	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
7	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
8	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
9	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i
10	Ventilationsteknik	32510 Laboratorier	006 Kanal	Rektangulære kanaler	Ingen i

(3) This step structures the data into informaton for the tender list through a **PivotTable** in Excel. This is done by selecting all data and open the **insert** ribbon and click on **PivotTable**.



Afterwards the structure of information is decided through the **PivotTable Field List**



Which will create the given structure of tender list. Notice that the tree structure easily can be changed through the **PivotTable Field List**.

Bygningsc Kanal								
Kanaler (netto længder excl fittings)								
Row La	DBK system	DBK - ele	Beskrivels	Isolering	Dimension	Fuld DBK kode	Enh	Sum c
Ventilationsteknik								
	32500 Friskluftindtag - Forsyning							
		006 Kanal						
			Rektangulære kanaler					
				Lamelmåtte 50 mm				
					1000x1200	-32500.XXXX.006	m	3
					1000x1800	-32500.XXXX.006	m	6
					1200x1500	-32500.XXXX.006	m	18
					1200x2000	-32500.XXXX.006	m	1
					1200x2500	-32500.XXXX.006	m	1
					1500x1500	-32500.XXXX.006	m	7
					1500x800	-32500.XXXX.006	m	7
					2000x2000	-32500.XXXX.006	m	8
					2200x1200	-32500.XXXX.006	m	2
					2200x1400	-32500.XXXX.006	m	9
					2500x3000	-32500.XXXX.006	m	22
					2600x1400	-32500.XXXX.006	m	2
					2800x1300	-32500.XXXX.006	m	2
					2800x1800	-32500.XXXX.006	m	18
					2800x2000	-32500.XXXX.006	m	1
					3000x3000	-32500.XXXX.006	m	2
					600x1500	-32500.XXXX.006	m	4
					800x1400	-32500.XXXX.006	m	10
					800x1500	-32500.XXXX.006	m	9
				Lamelmåtte 100 mm				
					2300x1400	-32500.XXXX.006	m	15
	32500 Ventilations afkast							
		006 Kanal						
			Rektangulære kanaler					
				Lamelmåtte 50 mm				
					1000x1200	-32500.XXXX.006	m	2

The problem of the **PivotTable** is that it cannot handle different levels in the tree structure. This delimitation is not appropiate as the different builing components has a different number of price-determining parameters. Hence a distinction is made between **Ducts** (kanaler) and **Air devices** (armaturer).

Komponenter						
Row Labels	DBK system	DBK - eleme	Type	Fuld DBK kode	Enh	Count of
Ventilationsteknik						
	32510 Laboratorier					
		358 Armatur				
			U-04	-32510.XXXX.358	stk	307
			I-20	-32510.XXXX.358	stk	258
	32530 Kontorer					
		358 Armatur				
			I-20	-32530.XXXX.358	stk	260
			U-20	-32530.XXXX.358	stk	60
	32534 Køkken					
		358 Armatur				
			I-20	-32534.XXXX.358	stk	22
			U-20	-32534.XXXX.358	stk	13
			U-01	-32534.XXXX.358	stk	3

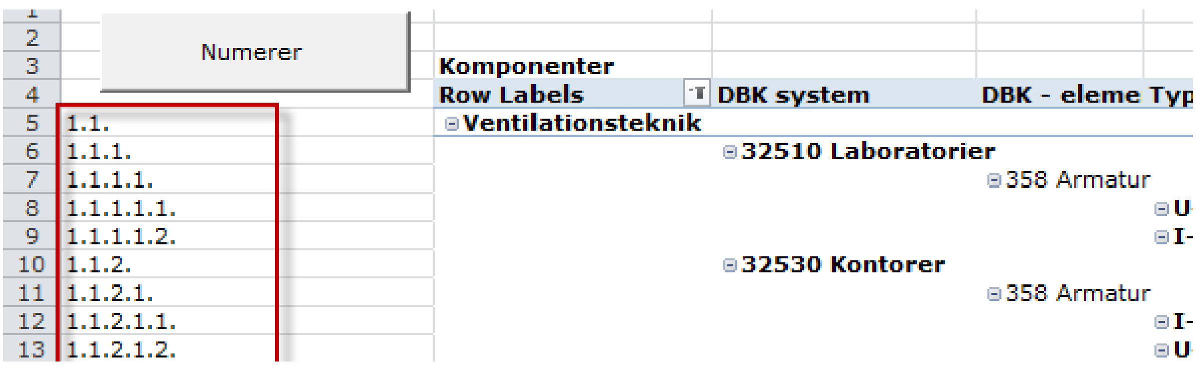
Therefore both of these **PivotTables** is going to be the calculation software Sigma.

(4) The exportation to Sigma is handled through a macro (VBscript) and the .csv format. The VBscript makes sure that the given structure of the **PivotTable** get the right numbering in relation to import it to Sigma. The VBscript looks like this:

```
Attribute VB_Name = "Module1"
Sub Enumerate()
Dim start_row As Long, start_col As Long, end_row As Long, end_col As Long
Dim i As Long
Dim sStr As String
start_row = 4: start_col = 2:

Call EnableApplications(False)



With ActiveSheet
    end_col = .Cells(start_row, start_col).End(xlToRight).Column
    end_row = .Cells(65536, end_col).End(xlUp).Row - 1
    start_row = start_row + 1
    'end_col = end_col -1
    .Range(.Cells(start_row, 1), .Cells(65536, 1).End(xlUp).Address).Clear
    Call AssignNumber(ActiveSheet.Name, start_col, start_row, end_col,
       end_row)
    For i = start_row To end_row
        sStr = Replace(.Cells(i, 1).Value, ",", ".")
        .Cells(i, 1).Value = sStr & "."
    Next i
End With

Call EnableApplications

End Sub

Sub EnableApplications(Optional enable As Boolean = True)
With Application
    .ScreenUpdating = enable
    .EnableEvents = enable
End With
End Sub
```

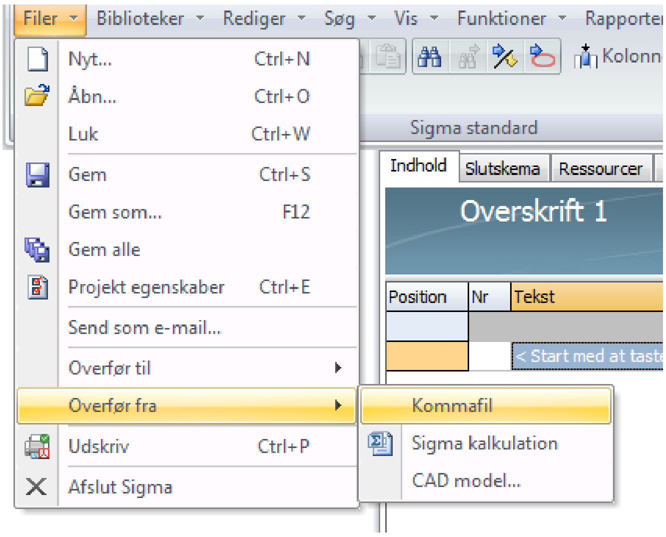
```
Function AssignNumber(sht_name As String, start_col As Long, start_row As
    Long, end_col As Long, end_row As Long, Optional current_string = "1")
    As String
Dim i As Long, j As Long
j = 0
i = start_row
With Worksheets(sht_name)
For i = start_row To end_row
    If .Cells(i, 1) = vbNullString Then
        If .Cells(i, start_col) <> vbNullString Then
            j = j + 1
            .Cells(i, 1) = current_string & "." & j
        Else
            If (.Cells(i, start_col + 1) <> vbNullString) And (Not
                start_col + 1 >= end_col) Then
                Call AssignNumber(sht_name, start_col + 1, i, end_col,
                    end_row, current_string & "." & j)
            Else
                Exit For
            End If
        End If
    End If
Next i
j = 1
End With
End Function
```

As seen below this script gives the **PivotTable** the **numbering** on the left side, which corresponds to the levels of the Table.

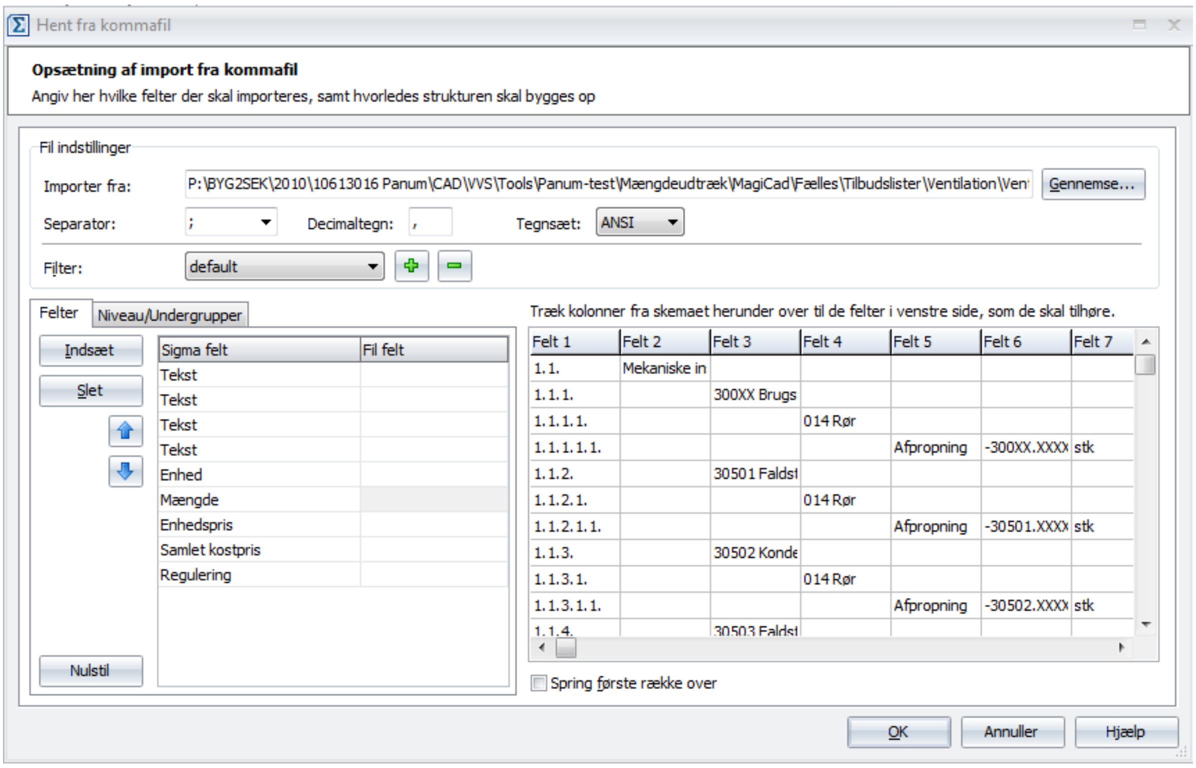


Afterwards the **numbering** and **PivotTable** is selected (marked) and saved as a .csv format.

(5) The import in Sigma is handled by importing an .csv file



This gives the oppurtunity of setting up the import of tender list.



Appendix E - Interviews

Interview with Morten Alsdorf, Rambøll

1. Do you think that in general there is a profit to providing tender quantities? - And who do you think has this profit?

Well there is no doubt about that as it is right now then I would say that the client in the long run have a profit in the provision with the quantities. In the projects we have right now we see it maybe not yet, but in time, it would be such that exactly what material the contractor gets , he relies . It is only adviser who give quantities, not the contractor, that is, the price is sharper compared to the contractors themselves be measuring quantities and interpret all sorts of things and might have misunderstood all sorts of things in the material. So he gets some tender lists now where there are quantities which are equal described - how it is to be defined and interpreted to say that there an equal interpretation and the same price on the same basis. It might be the fact that the contractor right now, are sitting and measuring up, etc., because he does not quite trust it, but in the long run in 5-10 years, it should not be that way. But the developer will be the ultimate winner in the long term. Then we can say that we are sitting with the adviser glasses on, so right now we have to convince the developer that he must pay extra for us to do this job. And this is the major problems we are dealing with right now, because we must have extra money to supply these quantities, as we have not measured it earlier There are some currently uncertainties which resulting in that some developers may not prefer using it. For some, it is because they have to and others because they want to. I would not say that right now it is an advantage for the contractor, because there are some uncertainties, and it applies to all parties at the moment. The advantage also benefits to the contractor because he did not have to sit and measure all quantities. Right now, if the digital tender will work, then it is both the developer and the contractor, who takes most advantage of it. In the end it is the developer who gets the cheapest price for his product when the market is adjusted

2. Is it your impression that you will experience a rising or falling demand for tender with quantities?

That's a good question because right now it gets a little more optional. It is not a requirement which I hear the new IKT. I have an experience with a private developer at the moment that says 'it not really meaning that we need to do it right?' and others are saying that there is no reason to do it yet. Let the others take the consequences. But I think in the long run, if it's going to work for public buildings, then the private developers also will using it, although in the beginning it will not be the ones who take the lead. Perhaps only some of the really big developers who have lots of money, whereas a normal developer, is not usually the ones who take the lead. They can see the benefit of it here, with the contractor to use less to make tenders, but on the other hand, they may also be aware *that the consultant must have more money for doing it. So I think that right now that we do not see as many private, but in the long run they think that the private will follow once the major battles it is taken about tender with quantities. However, it lacks some similar guidelines for how to do it, so I think the particular are waiting for Cunegos work if I have to be honest*

3. Have you in Rambøll a paradigm for how to perform digital tender?

It is still very new to us. What we tried with the DTU project was an experiment rooted in what we really could and now we are trying with Panum, to write some method documents describing how a digital tender is carried out in Rambøll

4. Have you been investigated how much extra it costs for the consultant to provide a digital tender compared to a traditional tender?

We have not made this analysis. But we try to structure our projects in the future, so they are able to meet future obligations for measuring quantities. Then in the long run, will all of our objects have a DBK or CCS code, so it will not lead to a major extra cost. We are about to implement such a structure and therefore it is expensive right now, but I do not think it is in the long term. The use of TAG is not new, but actually quite old. But the way we use it, by having a specific TAG per. building is very new. The tag is the most important document right now, because among other things, there are no common measurement rules and structure, but we Cunego is by now, on the way to developing it. You could say that when Cunego have created the right conditions for uniformity and uniqueness, then the TAG is superfluous. The TAG is right now a temporary solution, since there is no common measurement rules for the individual building

5. How do you see the development that is in terms of levels of information may vary per building element type?

It is a really good thing with varying levels of information per building element. But the most important is that we make some standard levels of information for our building elements. And ie. that you go in and do a building element, you find out what it contains purely descriptively, clean surveying usually wise, and the fact that you attach an information level. For example, the main project is information level 4. The idea is so that FRI and PAR must go according to their stage description and define which of these building elements in a given phase, has which level of information

6. Have the consultant a financial incentive to make an extra effort in terms of detail of the model or quantities tender list?

There is not an economic incentive because we do not get paid to make an extra effort. It is incredibly important to get these additional services into our contracts that we have to have money for it, otherwise it may be dangerous and we may end up with the normal 12% of the total and we will have to deliver the whole thing. That is why it is so important that we are aware and writes exactly in the IKT agreement what comes. Right now the developer just cross out all possible services and we need to be sharp to tell what each service costs. The developer often thinks that such digital tender with quantities is a normal service, but it is not. My suggestion in relation to the consultant's economic incentive is that we are making an IPD from a Danish partnering model where we outline it simple. We have these building data that we use here in Rambøll for each phase. This means that it is some due date parts, were we go in and put some money in each phase and we link them up in relation to these due date parts. If the architect does not comply what is within their due date part, then the architect is not getting the pool of money that is connected to them. That's how I see it could be really smart. Right now it's just the large pool at the end and *therefore there is no incentive for the architect to honor its agreements. Right now it is only the contractor who gets something out of doing it cheap. Partnering does not change the fee distribution, but is just more cooperation. I would prefer to go in and change the service distribution in relation to it*

7. How do you look at reports that the new IKT publication gives the public builder to choose whether he wants quantities or not?

I think it is a problem that it should be optional because there are many who will not do it. It undermines Cunegos work. Therefore, it is more important that the thing Cunego comes with is usable, then there are more pressure on Cunegos work

8. Does the contractor in the theory fail to verify quantities and only take responsibility for them afterwards?

No, it is a part of the contract, the contractor shall sign when he submitting a tender and when he has verified the quantities. If he will not sign it, then he does not get the contract

Interview with Martin Nielsen, Moe & Brødsgaard

1. How was the plumbing/ventilation tendered (subject - or main contractor)?

The project has been generally offered in a variety of prime contracts. Ventilation contract and plumbing contract is bid out as separate contracts.

2. Which contractor was selected?

It is Brøndum, who has won both the plumbing and ventilation unit. It was tendered at the end of August and the bidders had 40 days.

3. What are the general problems that you had in association with QTO and the process in general?

The way we have chosen to make our project, it is to make a Revit MEP model only made the main duct series, then when we come out of the rooms, then we have drove all the way out to among other radiators, and finally we have just driven down to a defined boundary such as half a meter above the floor. And we are finished right there and we have not shown outlets or anything. And the pipes, those we have just run into some suggested dimensions, then we have for example been running some max size out in the main lead and when we ran down, we run one or another dimension, although we have shown insulation on the tubes, but we have in the coordination just known that something needs to be room for, so there is some minimum distance to the next installation. In The tender list with quantities, is the isolation a part of the pipe sizes. We have then made additional level diagrams, where these sizes are on. When we did the amount of drag, we just got a whole bunch of different pipe sizes out, and has subsequently gone out and looked at a sample of building representative. Then we found out from the graphs and quantities, what the key distribution figures they reasonably should be, so there is such 50m 20mm steel tube, which is thus representative of the building and which then become subject to some certain percentage on top. We have not modeled it all, as this would have taken too much time. We had big problems with our Revit model when we reached a certain size, because it took just several minutes just to change one little thing and we might have 20km pipes and 20 km sprinkler. We would never have got through if we had to sit and lay the right pipe sizes into the right duct series , so we have had to choose such a simple way and do it. And it's really fairly representative of the rest of it, since the building is very similar. So it has not really taken so long to make counts and I think we are fairly close. We have put a percentage on top of the amount depending on the type of installation it is, approximately 5-10% on top, so we have some profit in it. We bother, at least not to get behind and then they say that we are missing something. It is cheaper to get it now than it is afterwards. We might have unit prices on it now, but you know, it's just simpler just to have a little extra included - it pays not so terribly much for now. And then we agree on some quantities related to some initial meetings because we are then sure that now all just nodded to it, and no one should fight over it afterwards. We only have figured straight pipe lengths and so we have written it to be including bends, tees, reduction. It is a massive job behind making a full detailed model, It is 3,4,5 times the time that we would normally spend on such a type of project and whether we get something out of it, I do not know

4. How did your process for the quantity extraction look like?

We have in Revit created something called schedules and you can then choose to differentiate the various types of systems and work sets, so we could differentiate on it when we decided to make quantity extension, so all cooling pipes for themselves and sprinkler pipes for themselves. The different types of gases were also subdivided so that we could get all the volumes out and differentiated into different types. It exported to a format which renamed then *you can get it into Excel. On the ventilation portion, we used 15-20 hours to get it moved around in excel. It has taken some time to develop the tender list and it is so beyond that we have spent some time there. And on the VVS I have used something similar to 10 hours. I've had to sit and modify any errors contained in Excel, because what I got directly from Revit was not particularly useful. Some of it was, for example, in millimeters, because I had not set it properly when we exported. There was a little trouble with it so I had to even sit and do some setup, so the following were useful in relation to the evidence of what it was I had done. We have not had a man seated to check out our quantity extraction. It's something I just had to spend a few hours at a time in between and otherwise just continue with the project. But then something like radiators were also a little bit difficult because we had a radiator numbering, R01, R02, etc. As so referred to some radiator details. But inside the Revit they had another number / code, so when I exported all these radiators, I have to do some reconversions to R01, R02. So when it was called a large type of number, then I knew that it was a radiator. So I did some L-lookup in Excel to make this conversion. It requires that the person who makes the quantity extraction is an expert to Excel to get it not just pulled out of Revit. You have to make some effort. In addition, we have created a breakdown of all that was above ground, which was designed as a 3D Revit MEP model and everything under is made in AutoCad, and therefore had the breakdown under land to be counted separately. Then there are also some sheds which are left out and there are either no 3D model, therefore they are counted separately. So it has been different how things have been spoken*

5. What preparation did you have on the quantity extraction before you began modeling?

There are many things you just have to be thought about, because the tube side you have all those tees, bends etc.. But is it what you want? Or is it such run by any equivalent length where you just count all the way through and that is too why we have had to put something on top because then we had to ignore all the pieces which are not included anywhere and there are many - especially on the ventilation. There we have made a distribution key too. In the lab ventilation we have may have to put 100% on top because there are many bends / tees / transitional pieces that we did not get into the lengths. We have about 30 ventilation systems and we have evaluated each individual. We can see that it pulls x-number of bending out and then we made a conversion factor of the type of bending. So we have put this on top and therefore received some equivalent length. It turned out that for some systems was one examines the lengths, in only 30% of the equivalente length. That's why the equivalente we use and we have done so much attention in the beginning of our descriptions that that's what they should expect. That it is what the quantities are from. We do not use the TAGs. It's all in the descriptions. Which causes that our descriptions are very long. We have been governed to all had to be DBK coded and these DBK codes must be able to retrieve the drawings. We have used Rambøll DBK converter as inspiration, but still named a little different in some places. They are up to you make such some building partly leaves - We have not really been up on the VVS and the ventilation. There, we just made it, what the as you would normally do after the old SfB codes. The DBK has some weaknesses, for example, such things as building site stuff - How do you get it into a DBK code. When we started up with this stuff that we knew of course that there was a requirement for it to be information level 4. It usually we do not provide a model in. It is brand new and it requires that you, for example, runs all the way to the tap. So we sat down and tried to get an overview of what we actually could compared to the programs and its weaknesses. In the beginning you just have a model that just does it all. To be on the safe side, we started out by making a note we were sending to our customer and explained what it was that we wanted to do. We were immediately determined to be a cross between level 1 and level 2 and they went along. So we made an expectation vote immediately. We could immediately see that the first if we should look to get goals and if we just should *have roughly the opportunity to earn a little money on this, then we simply have to simplify this task. Then we started. To begin with we tried all the time to make some collections and getting it into a structure. You can call it a paradigm. In order to know what the real end result had to be we should try getting a few quantity extracts and put the tender list up to begin with and put descriptions up too as well. Things we didn't had in Revit we have had on the charts and counted manually from here*

6. Was your structure, classification and level of information required from BYGST (IKT contract) or was it your own choice?

BYGST has not required for classification or structure on the tender list but we have had our proposal provides for approval by them. We came with a presentation and then commented on it. In general, the IKT Agreement is something you need a lot of energy to begin with because otherwise you really can get caught. The small document is essential in relation to how the final product will be.

7. How much and which software has you been used compared to modeling and the quantity extraction?

Revit MEP and Excel

8. How did you supply the tender list with quantities - PDF or Excel?

It was sent as a PDF. The reason it was not Excel was that so would contractors have had the opportunity to change it. That can be really dangerous. You send it as a PDF, then you can be assured that they cannot mess up the numbers or put extra rows into it. So it has simply been for us to be sure that they suddenly do not do somewhere that makes them run themselves checkmate at somewhere. They do like to have it in Excel, because it makes it much easier for them to count up. But it does have so that when you have to sit and evaluate the offers coming in, then you should sit and watch it all minutely through. From an industry point of view, it would be easier if we could just send it out in Excel, as it makes it much easier for them. But the worst thing is of course if they accidentally delete or hide some rows or cells, for example, if someone who are not good at Excel, just happen to make a mistake. Then the tenderer has suddenly not given the price of everything and then he is out, because they have to fill it all. That may turn out to be really bad if it happens. If you then have to sit and check through from 5-6 bidders about everything now with. It is something you must do away with yourself

9. What feedback did you get from the developer and the contractor (s) compared to the drawn up tender list with quantities?

We've heard amazing little I would say. There have been some general questions on how we have solved the cooling and things like that. We must have an initial meeting with them where we get settled the quantities and agreed that this is what we will continue to run after. Especially on something like sprinkling that one can never so completely determine the sizes and things like that, because they are subsequent to their own calculations, so we must agree on certain quantities. There we have bid on some quantities for the contractor could make a common tender basis, so that we have to run to the finish. We have not given 3D model it for the the bidders. It runs so that they offers for the subscription basis and the quantities and not on the model. So the model is indicative and we are first going to use it for the actual execution. One of the reasons that it is not included is that now that we at some point begin to make revisions, so are the making of revisions within Revit, very heavy. What we do not need now that it is part of what it is that we can make some revisions contained in the model without it being something that turns visually through on our plans. This means that we can just send a new model out, without us having to explain the audit. You can not send a project out where everything is 100% coordinated. It is almost impossible.

There will always be something the fails. Revisions in Revit is not something where someone has 100% control. It is certainly a very heavy process. We can sit and make all sorts of changes in the model without actually having to change our project material. It can be a little difficult to grasp when both things must be kept up to date: both the drawings and model. It may well be a heavy task. Things ought to fit together, but they do not work

Interview with Freddi Lading, Brøndum

1. What is the way forward in relation to quantities

For my sake you could easily just send drawings out without quantities. For making this work with quantities there must be other things besides the runningmeter ducts, which will be abandoned. Something like silencers and that sort of thing instead. The silencers is a lot more crucial in terms of price than the runningmeter ducts. But the point is generally the way it was designed properly in, so it was just as easy to measure up as it is entering into runningmeter ducts

2. What are your experiences with negotiated volume?

The past year we have received amounts from the public, so we have actually quite a lot of experience with this type of project. Among other things, we have given suggestions for TechFac project, and here were largely abandoned running meter ducts in the amounts. So there was not some fittings in their amount of inventory, so you had to include them in the runningmeter ducts. It makes me to sit and measure up anyway to various bends and tees in my charge. So the quantities actually change the way that I did this in the past. In addition, it is very cumbersome to have to provide rate for each pipe size and for this include various fittings and bearings. It is virtually impossible to get it to make sense in this way. That's why we are actually often finding a price for the entire system and share it looked then at the individual unit prices. By having to provide unit prices on everything, you get an incredible number of items on the tender list. In TechFac project we had 800-1000 points to be given a price. And they did not even fittings and various things that could have made the list even bigger. In summary, one can say that right now it is no great advantage for us to get the quantities. Although philosophy may be that all of us tenderer should spend less time on the quotation stage, then we just need something more useful, which can also be handled faster. There are missing a direct digital implementation, for at the moment we must somehow still enter the data we receive somewhere. That is what you are missing if you do it faster and then it becomes real only margin we bidders compete and not quantity too. And, of course, it will also give us a more equal basis

3. How do you relate to verify quantities?

In relation to the verification, we make a survey more, which is even more precise. We believe that after verification, then we're still only responsible for the 'new' verified quantities. If, for instance, is 1000m extra duct relative to the verified amounts, then it is something the developer must pay. So in this way is not really the big risk by taking over the responsibility for the quantities. If used less than verified quantities, then we're earning because of it. I do not know how this problem would be solved if it was. Quantity Surveyors would be hopeless, because they could use several days and it's not just to get to all the places. The problem of verification the quantities is the amount of time you have for it. 15-20 days is not enough for projects exceeding 20.000kvm

4. Measuring Rules - what is included?

When there are so many things included, as fittings and brackets etc then you just get some random prices for the various components. It makes you know that Ø900 ducts have different unit prices in the different systems. This makes these unit prices very diffuse and not very useful in relation to the comparison. They therefore does not make sense to share dimensions, then you might as well say round or rectangular ducts

5. How do you think the structure should be? And how do you think the structuring factors should be applied?

I think it's fine to structure per system in the quantity list. It provides a good overview for us. We have had experience with projects where you have structured per component. You do not have a chance to figure it out and it *gives a very complicated equation when there is to be calculated unit prices. And the same goes for projects which are arranged per floor. Additionally, it will also make sense when just giving a price on the system and not as unit prices of all the diffuse components. In fact, it is true sometimes that we actually make a price for the entire system and then share it on all the diffuse component unit prices. I do not see it as a problem that there must then be regulation entries in the tender list, because I do not believe that you would be able to use unit prices anyway to regulate afterwards. For example. if missing 10 bends, then we had to find a price based on the total price of the duct meters, bends, tees, brackets, etc., because it is what the unit price actually covers*

6. What do you think about the use of the TAG?

Using the TAG sounds like a good way to do it, because in this way separates what's description and what is settlement basis. Again, it seems to give a better overview

7. What do you think about prices?

If we made a price of TechFac where we failed to include fittings there would be missing a lot. We're talking more than a 50% change in the price when counted. There is of course a difference between round and rectangular ducts, but 50% is not too low. On rectangular ducts, it is just before we talk it 2-3 times the price, for example if you look at the equipment rooms, etc. So it is so large items that they must be included in the duct meters

8. How are you using the 3D model?

We always use the 3D model to get an overview. We actually tried to use 3D models in relation to surveying, but we are still struggling to get to work. We use Solibri as viewer

9. What is your opinion to the delivery format?

It does not make sense to get a tender list with 1000 points in PDF. It is no longer than it must be delivered in Excel and then there are locked cells, which may not be corrected. If the contractor still going to change anything, then he's just out of the tender. There should almost be a law about the quantity list to be sent out as an Excel sheet

10. What level of detail do you think the tender list should be?

It would benefit from, in relation to price, if the tender list was detailed down to a level of activity. For example, recesses and closures with fire dampers in accordance with the new brand standard. For it is also a fairly sharp line you could say. It's just a note that is finally punching and closure included in the contract. It might even be an advantage if you separate closures and made an outright closure contract. Whatever it will be fine with the quantities (especially fire closure around vents), since we cannot close them and therefore must pass the task to another

11. What do you think of DBK codes?

I do not know anything about the numbers they add the components

Interview with Flemming Grangaard, The Danish Construction Association

1. What is DB's general attitude to the engineer to make measurements over contractor?

We believe it is a quality that you get some amounts from the adviser and as noted in the report, there are huge saving. If you can save 2.5 billion because it costs eg. 300-500 million to let the consultant provide quantities, they may need some extra fee. We have never said that they should not. It is quite reasonable, since they make an extra job. I just cannot understand that advisers do not rush to figure it out and find out that there is a new business, so we can earn some more money, which may result in higher turnover. Which can lead to much more work. And it is still cheaper for the client, because every time the adviser he expects once, then there fast can be 300 involved. For example, a main contract with 10. I have no doubt that it is because the consultant supplying quantities as to provide cheaper prices. If you think contractor puts money in your pocket, then you are wrong. It's the type of man they are. If your quote made cheaper for the contractor, then the money saved may not pocketed. They are used to provide new services and to compete with and can thus be a tad cheaper than the others. It has nothing to do with the counselors do not know enough about it. When you're on thin ice, you will often not do it. The construction industry has been doing it for the last 50 years. We must get away from all the sum records. They are useless

2. Do you have general experience with digital tender with quantities?

No

3. How should tender list be structured? Why? It seems that each advisor has its own way of doing this?

There is no doubt that a standard in this area will provide value. We have identified it in a long time. There must to make a tender list generator. I proponent the use of TAG's if you get it structured in a way so you do not have doubts. I have not seen the TAG used in a construction project before. I only know TAG's related to civil engineering

4. Which information (level of detail) should the quantities be broken in? How much should be included?

It's a poor excuse. The channels available in standard lengths. Distinguish between whether it is functioning supply or whether it is another form of tender. It most often characterize ventilation and plumbing, is that it is often offered as a function supply. I think that you can use quantities in the function range. What is this amount that is interesting? For example, if we are at the top of the pyramid, we're talking volume as an airflows. Where there is a whiff of operation range, they are slightly problematic. It must be realized, how do we function range. I think it can be done, but you just have to realize - what is the amount? The amount is so not a pipe, the amount is something else. They prepare the ground for the information level can vary for each bulding component in a tender, the something is porcurement based on operational needs and something isen't. Then you put the porcurement based on operational needs through the back door on some of the parts of the lots, where you do not expect it - it is as dangerous. The problem is for information levels, that they are not connected to the phases. I think that when you have a trade contracts tender, you can expect that as things are resolved.

5. Is it necessary to have a connection between specifications, 3D model and tender list with quantities - as IKT requirements prescribe

It is important to have a relation. The things in the model must been showed in the tender list too. There must be a clear connection. Use of a Quote Generator

6. Why should tender list be editable formats (Excel)? Why would the engineers don't do it? Is it because the contractor will change or just use it?

It must be delivered so it can be edited. It is that simple. The smartest thing would be if there came XML files that could be imported/exported to calculation programs. By using EU supply via a portal will solve the problem. The problem is that they wont take responsibility of what they are doing

7. Could you imagine an early tender where you had set a number of parameters up to find the cheapest contractor (eg 10m channel, 20 valves, etc.), then you could specify the details and be product specific and extract precise amounts?

It is a framework contract. We specify that it is a function of tender. You probably have to make a reasonable realistic quantity. The problem is that you might speculate to put a little higher price for something they assumed would come several times and a lower price on something that did not come so many times

8. What consideration has DB done in relation to legal / liability for the quantities delivered?

There is no transparency on the area. The winning contractor must then verify the quantities and then he will lock onto them. It is a tradition based on myths, it is nowhere. It is the same as if you wait and then say 'now we do it' and so do we measure up when it finished as built and then take the model and see how much is there. It could, in principle, might as well do. It is a tradition that probably comes from DiKons report a few years ago. There is no doubt that we should have done away with it in one way or another. And then you agree that now you lock it into place. And then the contractor takes the responsibility and risk but that is not the procedure if you take it legally - That's why I say it's myths. Legally the adviser liable to the procedure 5 years, but it is clear that the release he is because when he gets one to assume liability. It is no doubt that this is a problem Danish Construction will handle. You can not find this tradition in the law or regulations anywhere. It's myths. It is tradition and bad habits there are no legally justification for it. But it is clear when you sign up, then there is freedom of contract in Denmark. But actually the contractors are stupid that they do it. The question is about the time when contractors sign, are they so far in the base that they are safe on the quantities. If they are lucky then it is good enough but if they are unfortunate it is a bad business. Legally, it should be the consultant who was responsible for volumes but he is not liable, which is really smart by the consultant. It must take my hat off to. The consultant has great interest in it

9. What do you think is the future in relation to the development of the digital supply with quantities?

It is clear that if the Order is going to be 'may' instead of 'must'. We have been out and tell that it is unfortunate, and we everybody so to the consultation this summer. It is very unfortunate that you don't listen to the contractors about the opportunity to save 2.5 billion. It's a shame that we're making a report showing that there is something potential that they will not exploit. This IKT is helping to push the industry to become more productive. Now, we buy it. This means that the improvements we are heading forward to, is blowing out again - which I really mean, is the weakness. It is also critical/sin in relation to Cunego's work and it's actually BYGST which helps to finance cunegos work, so you invest with one hand but is relaxed with the other. Basically it's all about reuse of data, which means that we can use the following quotation phase to production and finally also about delivery. The level of detail is not high enough, the level which has been put up in the DBK is not adequate. It has simply lain down on a too rough even. So rough that by example plaster walls, cannot see it two or more layers of plaster. It is the same DBK code no matter how many layers of plaster that is. About the pyramid. It is for estimates use - it's not something you use to bid on. We should do as they do in civil engineering who is working with the *named Offers - and settlement basis. The characterizes (for example, Herlev hospital, etc) is that quantities are operational. They are to use. DBK codes are not as precise as a product number. It is not unique. It has been DBK classification, which has set the limit. There are simply not taken into account subjects and was not detailed enough in the existing gauging rules. And that is what has set the limit. There should be signaled what kind of level we're talking about. There is no doubt that it can be a barrier. Is the consultant skilled enough to even pill quantities out? Do they know what to use? Are they even good enough to take them out at the level they should be used in the performance?*

Interview with Carsten Kramer, Henriksen & Jørgensen VVS

1. What is the general attitude to the engineer to make measurements over contractor?

digital measurement is the way forward because, again engineer deliver what they get paid, just like the rest of us have done for the last 20 years. The engineer has now come to the level where they should deliver what they get paid, and where they previously provided they worked through projects. And which could be measured up to the drawings. Today's drawings are so blurry made from AutoCad so you almost have to have volumes on it. Those people modeling are able to see the drawings in a higher scale, thus they are able to see the details clearly on their monitors but when it is plotted out, you cannot tell the difference between various things such as line widths, etc. The possibility of making mistakes is considerably larger. So if you want some prices based on similar basis (offer), where one can say that competitive conditions are right under AB92 Section 2: Clear and unambiguous contract documents. Then drawing quality either be better or else the engineers deliver some quantities in one form or another. You have to go one of these two ways

2. Is it your impression that some information is redundant or do you prefer so much information as possible?

No, I do not think immediately there is

3. Is it necessary to have a connection between specifications, 3D model and tender list with quantities - as IKT requirements prescribe?

3D models aren't often used. They are often very heavy and slow but it is good to have. The ventilation people will probably use it more than plumbing people. Because they can see where the ducts are. Either way, it would be good with a subject-specific 3D model but sometimes, it is necessary to have it all to see the complexity of the building. The problem is also that various components such as control circuits, etc. will not be drawn on the 3D model

4. Why should tender list be editable formats (Excel)? Why would the engineers don't do it?

Excel will be an optimal solution because then you can take it out and put it into other programs. Excel, you can additionally send to wholesalers and you can treat volumes in several different ways. Whereas if it is PDF it is locked, unless you go in and suggests that everybody must have an Adobe Pro, so everybody is able to open it and to write in it. The cells which are not to be used have to be locked and there have to be made user-friendly formulas for those who are not an Excel expert

5. Mixed opinions

3D models require heavy and fast computers. Therefore, the problem in public procurement (which usually contains 3D models) that connects you get these fringe Denmark or outside the Greater Copenhagen. It is a competition problem, since they do not have the capacity to run these models and therefore it must not be given too much importance. I believe that the tender list shall consist of individual systems (and sanitation, radiators), which can provide a price. There must then be a set list that shows what each system contains. The volumes are contained in the tender list gives a fuck. This makes the offer list is incredibly long and what to take with you where. If you want a price with every single point of volumes, well, how many pieces of 3 meters is it? It is hard to put a computer system up to hit volumes when the same tube has 6 different plumbing numbers depending on the plumbing wholesaler you buy from. One reads 514 and the other called the 114 and the same with the valves. It is excellent plumbing number system, it's not the same from wholesaler to wholesaler

Interview with Niels Treldal, Rambøll

1. Has there been any clarification with the owner regarding which detail level of quantities

No. We just keep the ICT and have the connection of DBK. They (BYGST) specifiec that the did not want procurement based on operational needs. Besides you cannot after the DBK - only classify

2. Why pricing per each main system

It is not what the contractor want. Besides it gives advantages in relation to all the joint pieces. And it is easier to find out what is included. But at the DTU project we did not structure per main system

3. Paradigme in Rambøll

Not yet. But we are starting up now.

4. Classification problems for designer

Prepare the ground for problems as the designer now should know the number of sub and main system when modeling

5. Level of detailing

We have reached the bar at the Mærsk Bygningen project. It is simply not possible to detail more than that due to contractor depend quantities

6. Quantities

The question is also. Who is going the verify the quantities as-built as the contractor claims. In Germany and England they are using the Quantity Surveyors

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