

Optimizing the Information Flow on the Construction Site



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Abstract

Productivity in the construction industry is trailing other industries. Architects and engineers are slowly adapting to a more digital way of working. Contractors are, on the other hand, not following this development, although they can see the advantage in using digital information for take-off and tendering. Information on the construction site is mostly paper-based.

The slow implementation of innovative ICT plays a big part in the low productivity faced by the construction industry. The construction industry is a conservative industry and lacks transparency. Managers are reluctant to grant craftsmen access to ICT systems on the construction site.

This thesis addresses these problems, through analysis of the craftsmen's needs, interviews with a project manager and reviews of a survey done for The Danish Construction Association, 2010 (Dansk Byggeri, DB).

To try to solve this problem, the author designed a prototype of a system that can benefit both managers and craftsmen. Three prototypes were made before the final prototype. The thesis also includes a physical prototype of a box that protects the hardware running the software prototype.

The usability tests were successful and showed that this kind of ICT system could benefit both managers and craftsmen. The managers can reduce the time of organizing information, and the craftsmen can be sure that they are executing the work in accordance with the latest information.

Preface

This thesis is the result of a final project of the Cand. Scient. Techn study in Building Informatics, Aalborg University, conducted during the period of September 1, 2011 to January 13, 2012.

The project illustrates how ICT systems can benefit managers and craftsmen on the construction site, and its potential to increase productivity in the Danish construction industry.

The thesis addresses the problem of decreased productivity for the last four decades. Data acquisition included interviewing a project manager on a large construction site and conducting an internet survey aimed at the craftsmen of all trades. The gathered data was then used for developing a software prototype, including a physical infrastructure.

I want to thank my supervisor Kjeld Svidt, Associate Professor at Aalborg University, for his invaluable support and Lasse Brauner Mikkelsen at the AAU workshop for his contribution in making the physical prototype. I am also grateful for all the help received from the people that tested the system and gave constructive feedback to the project. I would also like to thank Lilja Run Bjarnadottir for her contribution proof-reading this thesis. Finally, I want to thank my family for their support and understanding, when working long hours, throughout the writing of this thesis.

Haraldur Arnorsson Aalborg University January 2012

Thesis Structure

Chapter 1 introduces an overall view of this thesis, the problem, the purpose and objectives of the work. Further, the main research questions are presented in this chapter.

Chapter 2 describes what methodology will be used to write this thesis and finally, a discussion of the chosen method.

Chapter 3 provides a theoretical view on the topics studied. It presents a literature review of productivity in the construction industry, along with the new public client demands. Finally, it describes what kind of ICT system is being used on the construction site in Denmark present day.

Chapter 4 describes the field study interview and how the work models were completed.

Chapter 5 this chapter describes the results from an internet survey targeting the craftsmen. The chapter ends by giving an overview of the needs.

Chapter 6 summarizes the problem and the needs in a problem statement and finally, a short description is given of what method is used to solve the problem statement.

Chapter 7 this chapter describes how the work models are redesigned with an ICT system on the construction site.

Chapter 8 describes the ICT and physical prototype that were developed to help solve the problem stated in chapter 6.

Chapter 9 is a short implementation proposal.

Chapter 10 is a discussion of motivation of implementing ICT systems on the construction site and future research.

Chapter 11 describes a solution to the problem statement in chapter 6.

An illustration of the thesis structure can be seen on Figure 1.

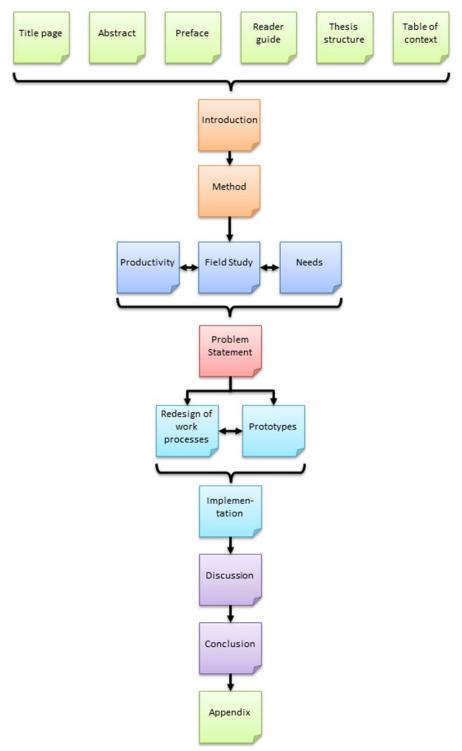


Figure 1 Illustration of the thesis structure

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1 Introduction

This chapter starts with a short description of the problem that the construction site faces today. Then a section describing the need for an information management system follows. Finally, the purpose is described.

1.1. Problem description

Recent studies show that the Danish construction industry is slowly adapting to the digital age, with architects and engineers meeting demands for new standards. Contractors have realized the benefits of using digital information through-out the whole design process, including take-off, tendering and planning (Byggeri & Newinsight, 2011). Although the contractor receives the information in a digital format, the construction site is where the use of digitalization declines dramatically (ARUP, 2000), thus failing to recognize the potential of digital aids for improving workflow efficiency. The construction site still receives information in a paper format. Some contractors make the material accessible on-site in a digital format, but then the workers have to have good IT skills to log onto a PC and to project web to access the information needed (Jakobsen & Øbro, 2010).

The construction industry is known to be an information-intense environment. During the construction phase, a vast amount of revisions are made. It is the Project manager's job to organize the information that arrives on site. It can be difficult to keep track of this information. It often happens that workers are not notified or accidentally use old drawings that lead to larger or smaller mistakes occur (Richter & Koch, 2004).

1.2. The need for Information Management system

There is a need for improving the link between the construction site and designers, and to improve communication between all actors on the construction site. Information Management Systems (IMS) or Enterprise Resource Planning (ERP) is being used on an administration level. A research done for The Danish Construction Association (Dansk Byggeri (DB)), shows that 98% of contractors have some kind of IMS, which is used daily. The research also shows that fewer than 5% of craftsmen have access to IT on the building site (Jakobsen & Øbro, 2010). These numbers indicate that a there is missing link, in the digital information chain, from the contractor to the craftsmen. An IMS, accessible to all actors on the building site could help with the problem stated earlier. An information system would not only save money on printing and organizing information, it would also reduce mistakes and the Request for Information (RFI) during the construction phase. The managers on-site would spend less time organizing information and change orders, and could instead concentrate on administrating activities. The client would also benefit from increased productivity.

1.3. Purpose and objectives of master thesis

The aim of this thesis is to investigate if the use of an Information and Communications Technology (ICT) system on the construction site would reduce errors in the construction phase and increase productivity. Furthermore, to identify the main benefits and barriers of implementing such an ICT system, to a market where the range of users is from IT illiterate to super-users. As well, to explore how Danish construction site managers handle information available on the construction site, and what the procedure is when new information is delivered on-site. This thesis will also

cover what kind of ICT is presently being used, what level of IT-competence on-site workers possess and what the best practice to implement such a system is, in order to increase productivity in the construction industry.

The main objectives are:

- Make consequential improvements on the construction site, in particular, concerning quality, information exchange and document accessibility.
- Achieve maximum efficiency in inter-operability between designers and the construction site.

To gather data the author will use theoretical documents, a field studies and the authors own experience from many years of working on construction sites.

2 Method

This chapter describes what kind of methods suite this master thesis. The methods are then described and finally a short discussion of why the method was chosen.

When choosing a method the author is obligated to think of what is the overall function of the system and who the users are. In this case, the users have very different IT competences. There are a few methods that could be used for designing a user friendly ICT system. Examples of these are Contextual Design developed by Beyer and Holtzblatt (1998) and Universal Design (L. Mace, 1998), which will be described in section 2.1 and 2.2.

2.1. Contextual Design

Contextual Design (CD) gives the software designer great tools to map the needs of the future users, hence meeting their expectations and preventing resistance to implementation of an ICT system in the organization.

Like most projects, lack of time is a big issue. Therefore it is important to analyze what is needed to get the most out of CD, thus limiting work hours needed for designing the system. The first phase of CD is *Contextual Inquiry (CI)*. During this phase, as much information related to the project is gathered as needed. Interviews and observations are the best tools to do this. Qualitative interviews are a good tool for gathering data. Observation is an important part in this step. During observation, unforeseen problems

could arise, which would not have been discovered with traditional interviews. A series of work models are made from the gathered data. The models and the CI are then used to do an affinity diagram. A storyboard sketch is made to visualize how the future user would use the system. Finally, the structure of the system is developed and a prototype is made and tested with users (Beyer & Holtzblatt, 1998).

2.1.1. Contextual Inquiry (CI)

Contextual inquiry is a method that aims to reveal how people actually perform their activities. CI is performed by making interviews and observing people in their work environment. It is important to get the users opinion and feedback on their work and for the interviewer to get as much knowledge about the employees work processes as possible (Beyer & Holtzblatt, 1998).

Interview and observation methods

The most common types of interviews are unstructured, semi-structured and structured. For collecting data from workers on the construction site, a semi-structured interview was chosen, to be able to get a free flow of data gathering. The interviewee can express himself freely, but the interviewer has some guidelines and has to be aware that the interviewee does not go off-course. The author made several questions to help guide him during the interviews.

Quantitative survey

Although semi-structured interviews were chosen to gather data from the user, the author was also interested in knowing what the general status in the construction industry is, regarding the use of ICT and what the general IT competence on-site is. A short internet survey was conducted in the later stage of the thesis writing. A link was posted on BIMbyen.dk and sent to emails extracted from bygdenmark.dk. Together

with the field interviews, this data was analyzed to define the real needs for IT on the construction site.

2.1.2. Work models

The gathered data is used to visualize how the user acts during a normal workday by doing a series of models:

- Flow model showing communication and coordination between actors/roles.
- Physical model showing how the environment affects organizing activity.
- Sequence model that shows business and task processes.
- Artifact model showing things such as computers, time sheets or craftsmen tools and how they are used.

Each work model represents a different aspect of the organization on the construction site. A sketch of these models is used during the interviews to get input from the interviewees to better the models. The models are later used to construct a single coherent diagram called *affinity diagram*. By consolidating all gathered data, the risk of designing from only one point of view, is prevented (Beyer & Holtzblatt, 1998).

Flow Model

The flow model illustrates what people have to do to get work done. The work is divided between people to define their roles and to ensure that the whole work gets done. Persons and groups are shown as bubbles with the role at the top. Underneath the roles, their responsibilities are listed. The actual flow is noted with arrows (fig. 4).

The flow consists of a dialog or the passing of an artifact. Artifacts are shown as boxes on arrows and the dialog is written directly on the arrow without a box surrounding it. If there is a breakdown in the communication it is marked with a lightning bolt (Beyer & Holtzblatt, 1998; K. Holtzblatt, Wendell, & Wood, 2005).

The flow that the author will concentrate on explains how a project manager hands out tasks to craftsmen and what the procedure is, when a change is made to the information that craftsmen use on-site.

Sequence model

A sequence model (fig. 5) is used to map in what order users perform their work tasks, and show their strategies intentions. In order to improve people's routines, it is important that ICT systems build on this knowledge. By understanding the intentions of the user, it is possible to redesign, modify and remove unnecessary steps from the workflow. It is important to understand all the intentions in a workflow, and which intentions must be preserved when making changes to the workflow. To collect the sequences it is necessary to observe people as they work. The hardest part of observing sequences is to know what to pay attention to. That is why, during the observation, the subject must be encouraged to think aloud if the sequence is to be deepened (Beyer & Holtzblatt, 1998).

Artifact Model

People use, make and modify things during their work. Those things are called artifacts. They tell their own story about the work performed. All artifacts have a structure, and this structure shows how work is organized (K. Holtzblatt et al., 2005).

Artifacts are tangible things that people do or use to help them get the job done. Artifacts on the construction site could, for example, be a hammer, a drawing or a time sheet, etc. (fig. 6).

The Physical Model

The work is conducted in physical environments that either support and facilitate the work, or hinder the work from being performed. People reorganize their surroundings

for the work they perform (fig. 7). The construction industry is quite often affected by the changes of physical environment. Every job site has a different setup.

The physical environment is the world they live in: the rooms, cars, buildings, etc. It's about how they move around and work in these environments. Their movements indicate their preferences and social needs (Beyer & Holtzblatt, 1998).

The thing to note is what is important for the overall design. What works well in the current surroundings, and what does not work as well, or even does not work at all? Designing a system for on-site information management could therefore be a difficult task.

2.1.3. Consolidation

The gathered data is consolidated from the models, and the data from the interviews is collected in the affinity diagram.

2.1.4. Storyboarding

Storyboarding is a set of cartoon-like sketches, used to capture how target personas or users currently perform their tasks and how they interact with the new system. Storyboarding is a good way to get an illustrated overview of the consolidated data. Storyboards embody the system requirements and future scenarios (Beyer & Holtzblatt, 1998).

2.1.5. User Environment Design

From the storyboard, a work-oriented model is created, which summarizes the new work process and changed responsibilities. User Environment Design (UED) captures what kind of structure fits the user's tasks best. Design of a user environment can also be used as a checklist of the functions that the system must incorporate.

2.2. Prototype

Prototype can be a paper mock-up or a software with some of the primary functions working (K. Holtzblatt et al., 2005).

The prototype for this thesis consisted of a physical- and an application-prototype. The author chose to use the paper-based prototype to begin with, while switching to a software-prototype at a later stage. The prototype tested also included a box with a computer, touch screen and printer.

2.2.1. Prototype testing method

Early prototypes were tested analytically. Expert evaluators reviewed the design and give feedback on the design.

The final prototype was evaluated with a usability test method. Users tested the prototype in a controlled environment (laboratory test). The prototype usability was tested by handing out two different tasks that the users tried to complete, while being observed by the author. The test-users were encouraged to use the think-aloud method.

2.3. Universal Design

Universal Design (UD) is often used when architects design public buildings. They call it "access to everyone", no matter their disability. UD is also used to design products, such as IT systems. A good example of an ICT system is an Automatic Teller Machine (ATM), which everyone must have equal access to, no matter their disabilities. The author chose to investigate this method further because of the large range of IT competences on construction sites. This method focuses on the design of the user interface, and access to the physical prototype, in order to make the IMS as easy to use as possible.

2.4. Method chosen

CD and UD are both user centered design methods, and fit well to reach out to users with different IT skills. Due to lack of time and resources, the author decided to use a combination of CD and UD. CD was used for gathering user data, making work models and consolidating the data. Meanwhile, the prototype was made using the UD approach, in order to fit the many different levels of IT-skills on the construction site.

2.4.1. Optimization

Performing a full CD is very time- and resource consuming. However, the contextual design may be tailored to the needs and resources of each project. This is done by Rapid Contextual Design (RCD), which is based on a smaller number of tasks. This style of CD was considered the best fit, for the limited time-frame and resources of this thesis.

3

Productivity

The aim of this chapter is to describe the challenges and opportunities that the construction industry in Denmark is facing, obtained from a theoretical study.

3.1. Construction industry

The construction industry is an environment characterized by an overwhelming flow of information, from design offices to construction sites. Because of the intensity and variety of construction information, the efficiency of information management is crucial to the construction industry and has been recognized as an important competitive advantage by construction companies. Construction information management has greatly benefited from the advances in Information, and Communication Technology (ICT), and current ICT support has been extended to construction site offices. However, construction projects typically take place on construction sites, where employees encounter difficulties in gaining access to proper computer systems. The arrival of Information Technology, such as mobile computing and sensors, has great potential to enhance information management on construction sites. Before implementing this new technology, it is necessary to investigate the context in which construction personnel retrieve and transfer information on construction sites (Chen, Kamara, Winterburn, & Mell, 2008). The construction sector is known to be a one-of-a-kind production. Most projects have different partner

setups, which can lead to disputes and mistrust. Clients tend to go for the lowest prize, instead of going for the most economical prize (Bejder & Olsen, 2007).

3.2. Productivity

Productivity in the construction industry has not followed the development of productivity in other industries. A study done by Paul Teicholz from CIFE (Center for Integrated Facility Engineering), shows that productivity has doubled in the production industry during a period of 40 years (fig. 2). In contrast, productivity in the construction industry is 10% less than it was in 1964, but the quality is significantly rising. Products have become more complex, but are produced with less cost. During this period, manual labor has been replaced with automated equipment, and therefore the quality is better but costs less. One reason for this difference between the production and the building industries is the lack of automation in the construction industry. The construction industry is not as willing to implement new innovative technology, and thus use of ICT has not had as big an impact on the construction industry as expected. The paper-based way of working is still the preferred way of communicating information to the construction site (ARUP, 2000). The large variation in worker's IT-skills may explain the slow implementation of digital communication.

Another reason is the fact that the experience from earlier projects is not being documented and passed on to the next project. Experience from earlier projects can easily be relevant, despite the differences between building projects, as the building process is more or less the same.

Yet another reason is building failure. In Denmark, the failure in buildings is a major problem with large economic consequences and productivity reduction. The costs are not just the amount required to repair failures of the finished building, but also all costs associated with the failure. The cost to rectify the building failures is an average of 12 billion Danish Kroner pr. year, representing approximately 10% of the production

value. This expense post is enormous, and although it will never be possible to completely avoid mistakes, it may be viewed as an opportunity for optimization, in order to achieve substantial social savings (Byggeri & Newinsight, 2011).

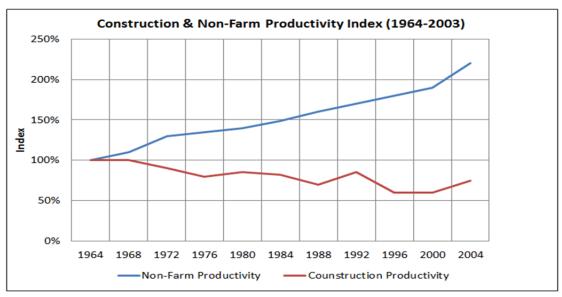


Figure 2 Labor productivity index for U.S. construction industry and all non-farm industries (Source: Paul Teicholz, founding director of the Center for Integrated Facility Engineering at Stanford University)

3.3. Definition of failure

Failure is defined in many ways. The author will use The Danish Enterprise and Construction Authority (*Erhvervs- og Byggestyrelsen (EBST)*) definition of failure:

The failure means that the project material, building materials, constructions or building components in housing, lacks properties to agreements or qualifications by government regulations or good building practice. Failures include all such conditions regardless of their cause and regardless of when they are discovered (Byggestyrelsen, 2004).

This means that failure is associated with both construction and agreements.

 Mistakes are used when the decisions and actions that lead to failure, are associated with the building as actors.

- **Deficiencies** are failures for which there can be financial claims concerning the deficiency.
- Damage is used for unacceptable consequences of failure. For example, a collapse of a building because of under-dimensioned roof beams.

No project is flawless, it is therefore, important to understand what the failure is and the possibility of it leading to project changes (Oracle & Paper, 2009).

Contract deficiency is any mistake or inaccuracy in the agreement documents that can influence the construction of the work. Agreement errors can be small mistakes like simple, numerical or grammatical, but can also include ambiguities and conflicts among different agreement documents (Oracle & Paper, 2009). Some contractors look at these kinds of ambiguities as a bonus. The author talked to one contractor who wished to be anonymous. Here is a quote from him:

My bid was only 60% of the client's total cost. Now the project is halfway, and I have had so much extra work because of an error in the contract. I am up to 80% of the clients total construction cost. The extra cost will definitely reach over 100% and this will delay the project (Anonymous contractor, 2011).

He said that this was a very common way of tendering for projects (fig. 3). If this is the case, it is no wonder that it is hard to increase productivity in the construction industry.

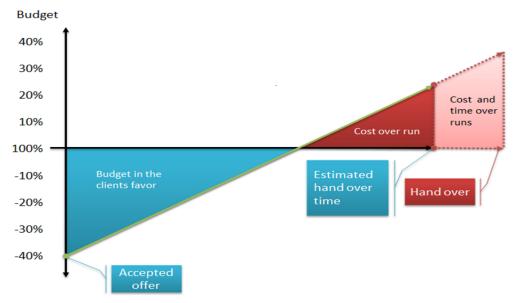


Figure 3 Illustration of how the anonymous contractor turns his low bid into big profit.

3.4. Origin of mistakes

A common misperception is that the majority of building errors are caused by sloppy craftsmanship. However, many of the errors made arise during the design phase, either because of a lack of communication or erroneous information handed out to the construction site. "Over the wall" syndrome is a well-known phenomenon, and describes misinterpretation of information occurring as it is handed from one person to the next, e.g. from an architect to an engineer. When there is little or no communication between two actors, it is called throwing it over the wall. This is also the case when the construction site receives information. Lack of communication between the designers and the construction site is a good example of this phenomenon. Table 1 is from a study by the Danish Construction Institution (*Erhvervsog Byggestyrelsen*). A study shows that 67% of mistakes are made on-site (Byggestyrelsen, 2004). Some of those mistakes have their origin in the design, but are not discovered until the construction has already been carried out on-site. However, it

is not well constrained how large a part of the mistakes is due to poor design or lacking communication from designers to foremen, rather than sloppy craftsmen.

Total cost 2002 All numbers are in billion Danish kroner	Residential buildings, Gov. support	Residential buildings	Commercial buildings	Public buildings	Renovations	Total	Share[%]
Phase							
Design	10	42	52	15	193	312	3
Execution	183	1103	1359	382	5152	8179	67
Warranty Period	25	211	260	73	642	1211	10
Operation	49	422	520	146	1284	2421	20
Total cost	267	1778	2191	616	7271	12123	100

Table 1 Study by the Danish Construction Institution (Erhvervs- og Byggestyrelsen)

3.5. Communication

Communication is a very important part of the construction industry. The current way of communicating leads to a lot of mistakes and frustration between parties. A study by the NCC and DTU that was made in 2004 shows that 61% of errors made were due to lack of communication and cooperation (Table 2).

The construction industry consists of many small groups that still largely depend on old-fashioned, paper-based forms of communication. As mentioned in *chapter 3.3*, errors and omissions in paper-documents often lead to unexpected costs, delays and litigation between the parties in a project. Such problems cause friction, financial costs and delays. It is both costly and time-consuming to generate important information

about a proposed design, including cost estimates, energy analysis, and analysis of structural details, etc., which are usually performed later, when it may already be too late to make important changes, or they become very costly. The industry needs to move the crucial changes, to an earlier time in design phase (Richter & Koch, 2004).

Weaknesses in	%-share
Communication and cooperation	61%
Design activities	45%
Work organization and planning	42%
Project review	36%
Excecution of work on-site	34%
Process and product control	29%
Weather and theft	20%
Access to skilled labor	15%

Table 2 %-share of all tumbling stone in the case study(Richter & Koch, 2004)

3.6. Digital Construction (Det Digitale Byggeri)

The Danish government set a series of demands for public clients that were put into action on 1. January 2007. First, there were 10 demands, which public clients had to fulfill depending on the size of the project. In 2010, those 10 demands were simplified and reduced to five demands. This initiative was intended to improve knowledge-sharing between the parties of the construction sector, from the idea phase, to operation and maintenance.

It would be too much to describe all of those demands here. A summary of the core demands related to the contractor is described in the following section. The text is extracted and translated from The Ministry of Economics and Business Affairs.

Requirement No. 2 – Project web

The client must require that all relevant parties in a construction project have access to and use of a project web, so that all relevant project information can be archived and exchanged digitally.

Public clients must ensure:

- To provide a safe and effective project web system available for all project parties.
- 2. To lay down rules for the efficient use of a project web system. The framework must be documented and communicated to all parties.
- 3. All digital project information, including text documents, drawings and digital building models are archived for all project participants in a readable print-friendly format. If there is no agreement of what kind of format, the documents should be in ODF format, not editable documents to be archived in PDF format.
- 4. The drawing set is made, so it can be printed in A3 format and in scale, and with scale shapes for visual indication of the scale.
- 5. Project web system is available on site, and documents and drawings can be printed on the construction site printer equipment.

Requirement No. 3 - Digital building models

Demand for the use of digital building models in 3D.

The public client must require the use of digital building models in 3D, both of ideas and contests, and during the construction phase.

The public client must use ideas and contests to ensure:

7. Both the combined model and discipline models are available for the contractor in IFC format or other agreed format.

Requirement No. 5 - Digital delivery

Requirements for digital delivery of files, operation, maintenance and management information

The public client must require delivery of applicable digital project information, as assessed relevant to the documentation of the construction case, as built, the future operation, maintenance and management.

The public client shall, in consultation with the operation and maintenance, ensure:

6. To deliver the right basic information about the project to the design and to the contractors.

Public clients must ensure delivery of the following digital project information:

- 7. Process documentation, documenting the proceedings and decisions.
- 8. Product documentation, documenting as built.
- 9. Operating and maintenance information for the finished construction.
- 10. Management Information, which consists of the administrative information related to the finished construction. The client can be in a transitional phase until 31 December 2013, and select one of three delivery methods of operating, maintenance and management information. After the first January 2014, method "I" should always be used:
 - I. The information is to be submitted in a digital building model structured in the DBK standard, open standard (IFC), and based on the design phase, combined building model, subject to claims No. 1 in the case of construction projects that exceed the current thresholds in the EU procurement rules.
 - II. Digital information associated to data objects for transferring to clients and FM system.
- III. Information delivered

This legislation should motivate all actors in the construction industry to implement and use ICT, to be able to tender for public construction projects. It is a matter of debate, how well public clients are ready to receive and use this information. Mette Carstad, Senior Consultant for UBST said, in her presentation on Digital Days at UCN, that the problem for them lay in the lack of technical knowledge that supported the actual requirements and how they were exploited (Carstad, 2010).

3.7. ICT on the construction site

The decreased productivity is being met by implementing innovative ICT on the construction site, both mobile systems and web-based systems. An example of a mobile ICT system is E-Tjek, a mobile quality assurance ICT system (Vogelius, 2005). In appendix 4 is a list of mobile applications in use on Danish construction sites. Project web systems are also starting to be more common on the construction site (Heldgaard, 2005). Byggweb is an example of a project web system that is popular in Denmark.

3.7.1. Mobile and web services

The mobile systems that are being implemented are used to increase quality and enable the managers to get a better overview of ongoing projects. Many of those mobile systems have a direct link to the company's ERP system.

The core functions for these mobile systems are:

- Enterprise Resource Planning (ERP) Integration
- Quality assurance
- Timesheet

Enterprise Resource Planning (ERP) Integration

There are over 300 hundred different ERP systems available to choose from (iWay, 2011). According to Gartner Research Group, the three ERP systems with the biggest market share are SAP, Oracle and Sage. ERP systems are total management systems for companies. Their main functions are:

- Financial management
- Customer Relationship Management
- Human resource management
- Manufacturing Resource planning

Supply-chain management

Several mobile application and web services have been developed to integrate with ERP systems. Many have the ability to send time sheets directly to the ERP system. The administration or project managers can hand out a task to perform via the company's ERP system to the individual craftsmen mobile device.

Quality assurance

Quality assurance is important for the industry and can have an effect on the overall productivity. It is important to register and document all mistakes. With a mobile device, it is easy to go around the construction site and register mistakes, take pictures and mark where the mistakes are. This information is stored on the project web system. The mobile system then automatically generates reports to send to the involved actors.

Timesheet

Each employee can manage his (or her) time spent on their tasks. These time sheets are then uploaded to the company ERP system. This saves a great deal of work for the project manager and for the administration. This also decreases the time that elapses, from task completion until a bill is sent to the client.

3.7.2. Project web systems

The objective of a project web system is to give the participants in a project, the possibility to exchange information across different actors. A project web in the building industry will normally contain drawings, job descriptions and other documents regarding the building project. A project web system ensures that all participants in the project have access to all relevant documents at any time. Many different project web solutions are available, from quite simple solutions to highly complex solutions. It is important to consider the size of the project in question, when choosing a project web

system. Project web is included as a prime element in the future communication strategy of many companies. Project web system is an important element, especially in The Digital Building (DDB), and the state demands that all public building projects should make use of project web from the beginning of 2007 (The Ministry of Economic and Business Affairs, 2010).

Some bigger construction companies have their own project web system. Rambøll, Niras and Grontmij from Carl Bro are some of those companies. Other project web systems that are being used in the Danish construction industry are, ByggeWeb, Project place and projektHOTEL. These systems have the same core functions, access control and information storing. The developers compete in developing extra functions like notifications system and feedback functions. Byggeweb is the only project web provider who can manage authorized digital tenders.



Field study

This chapter provides an overview of the current work process on a building site in Aalborg. To help the author to get an overview of a typical work process and to complete the work models, a project manager on a large construction project in Aalborg was interviewed.

Semi-structured interviewing was chosen to get a free flow of information. The author had questions written down to guide him through the interview. Work models were used to get an overview of the current work process and adapted to the project manager's construction site.

4.1. The field

The company that the project manager worked for was a carpentry sub-contractor. The company had 20 craftsmen, one foreman and a project manager on the construction site. The 20 craftsmen were managed by the foreman, who in turn answered to the project manager.

This was the first time they received digital information during a project. The project manager received emails containing updated information about the project, e.g. if any changes were. The project manager was responsible for printing out the new drawings and replacing the old. The foreman then contacted the relevant craftsmen and notified them of the changes.

4.2. Work models

Work models are made in cooperation with the project manager. These models give a viable overview of the current work processes. These work models are analyzed and redesigned in chapter 7.

4.2.1. Flow model

The flow of tasks and information are summarized in Figure 4. The project manager receives information to his email, and prints the information to review it before handing over to the foreman who contacts the relevant craftsman (fig. 4). If changes are made the project manager has to print and review changes before he hands them on to the foreman. In the interview, the project manager said that he would not stop the craftsmen, even if he knew that such changes meant the work needed to be redone. The reason was that he had to think of the budget and be sure that the changes could be charged to the relevant actor.

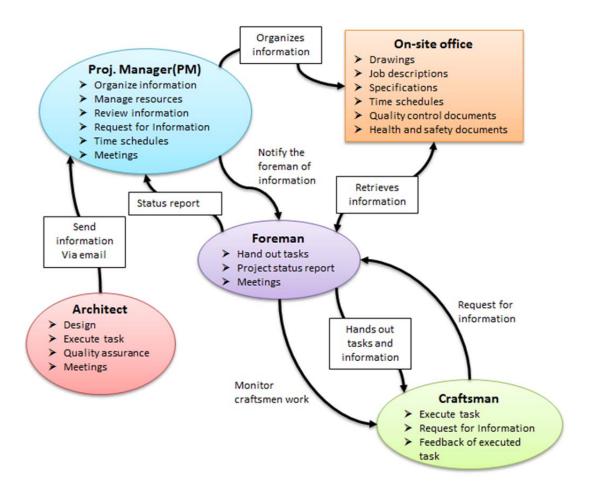


Figure 4 shows the current flow of tasks and information. The bubble indicates persons and their responsibilities. The boxes indicate the physical environment in which the employees retrieve information or perform their tasks. The arrows show the communication, either as one-way or two-way communication. A text box on an arrow indicates that a document is being communicated. Text beside an arrow, indicate communication.

4.2.2. Sequence model

Figure 5 shows the procedure during the trigger, i.e. when the project manager hands out a task to the craftsman. The figure also shows a scenario of, when a drawing used by a craftsman, to perform his task is revised.

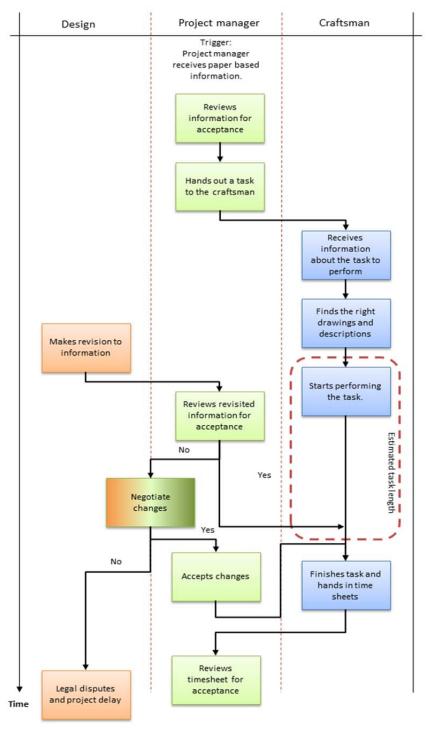


Figure 5 Sequence model showing how project manager hands out tasks and when changes are made. The model is split up into two axes, persons and time. Each step is noted with a box with a description of the activity.

4.2.3. Artifact model

Figure 6 illustrates the artifacts that the sub-contractor uses to communicate information. The artifacts are divided on two locations; project manager's on-site office and the actual job site. Artifact is a thing or an object that the employee uses to communicate and perform his task. It can be a computer, time sheet or even a hammer.



Figure 6 The on-site office (green polygon) is equipped with a computer with internet. The project manager prints information on an A3 printer. He also uses his on-site office to manage resources. The job site (purple polygon) is equipped with relevant craftsmen tools and all information are paper based.

4.2.4. Physical model

All communication with the designer is by phone and information exchange via email (fig. 7). The project manager thought this was very time-consuming and hard to organize information when information arrived on email. This is a quote from him.

It can be time-consuming and quite difficult to keep the overview of information related to the project, and extremely hard to keep track of changes.

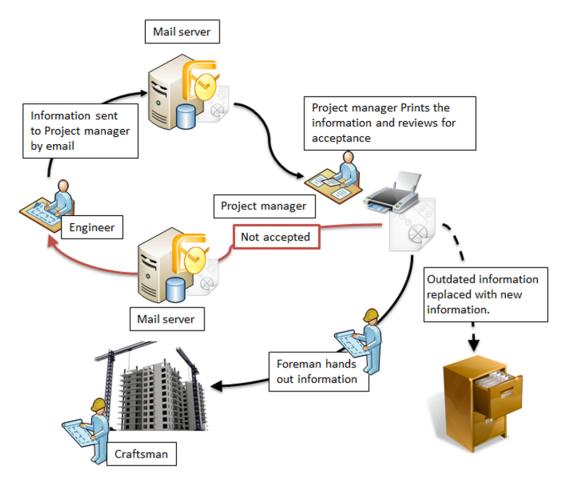


Figure 7 Physical model showing the communication channels. To communicate with the designers the project manager uses email. He has to print and review information he receives by email and archive them. The foreman manages the craftsmen.

4.3. Model Consolidation

The interview and the models gave the author a clear view of what the current work process is. Although this situation cannot be generalized it is a quite common way to communicate today (Wikforss & Löfgren, 2007).

There is a definite possibility to reduce the manual organization of information. E-mail communication does not offer the same ease of information exchange, as a project web system. An ICT system located on the building site, would also allow craftsmen immediate access to updated information.

The data gathered from this interview and completed work models were further analyzed and redesigned. The Field Study and The Need analysis are then used to optimize this work process and described in chapter 7.

5

Needs

This chapter creates an overview of ICT needs for a typical construction site in Denmark. The need analysis is carried out as a quantitative survey aimed to get a response from craftsmen of all trades.

5.1. Quantitative survey

The survey was sent to trade unions that are known to service craftsmen. It was also posted on the web site, bimbyen.dk and on several Facebook sites. The author tried to reach out to as many craftsmen as possible and to all trades. The author expected more responses from the craftsmen, and found it hard to get in contact with them. A likely explanation is that they do not use computers during their normal workday, such as e.g. architects and engineers.

Goal

The goal is to analyze if the craftsmen on-site are capable of fulfilling the demands of the new legislation, implemented by the Danish Enterprise and Construction Authority (Erhvervs- og Byggestyrelsen, EBST) in 2010; Digital Construction (Det Digitale Byggeri). Digital Construction was described in section 3.4.1.

The author's intention with the survey was to investigate the overall IT competence and the use of IT on-site, whether on-site personnel have mobile phones, and if they have used a mobile application in a work-related situation.

The results of the survey were cross-checked with research made for Danish Construction Association in November 2010 (Jakobsen & Øbro, 2010), where the objectives were to identify the contractor's vision on IT, what type of IT system they are currently using and the main barriers of using more IT.

Target group

The target group for this analysis is craftsmen who work with typical building projects. The reason for choosing the craftsmen is because that group has not benefited from new technology, in the same way that other trades have.

Method

A test survey was sent to 25 participants working on a construction site. The survey had the same focus as the final survey. Each question included a comment field, in which the responder could write additional comments. This method proved to be very effective to get good feedback to optimize the survey.

The final survey is a combination of closed and open-ended questionnaires (Dr. Dawson, 2002). A field was included where the responder could write his email address, so he could be asked in detail about his answer. This also allowed the author to establish a connection to some of the responders. The survey consisted of ten mandatory questions. Some of the questions had a comment field, where the responder could freely express his thoughts.

An email was sent out to 700 email addresses extracted from bygdenmark.dk website. More than a third of the emails (250), bounced back, because they were not in use anymore. A link to the survey was also posted on bimbyen.dk and to several Facebook sites belonging to trade unions servicing craftsmen. A total of 72 responses were registered. The reason for this low response rate could be the short time it was valid, and because craftsmen do not normally use computers during their workday.

NOTE: This survey does not represent all the craftsmen in the construction industry. It only represents the 72 who responded. However it provides a hypothetical view of the craftsmen IT skill and IT usage.

5.2. Questions

To get as many responses as possible, only 10 questions were asked. The average time it took the responder to answer was two and half minutes.

1) What is your age?

It is important to know the age range to be able to know if there is a connection with IT usage and age.

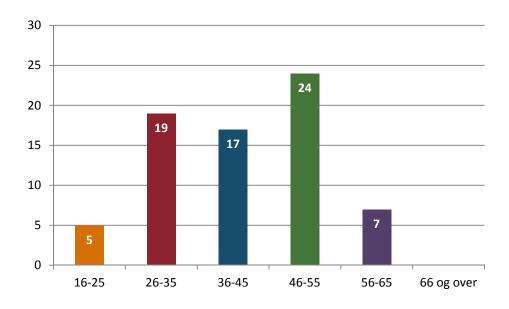


Figure 8: Bar chart showing the age distribution of survey respondents

The age range from 26 to 55 had the most responses (fig. 8). It is interesting that the age range 16 to 25 had only five responses. This could reflect that this age is less motivated to have an opinion on the development of the building industry. There was no response from the age 66 and over, which is not surprising. The construction industry is a hard environment where craftsmen easily wear themselves out and thus

quit at a younger age than in many other trades. Another reason is that many from that age group, have not received basic IT-training during the course of their education, and have not acquired such skills at a later stage.

2) What is your trade?

Some of the craftsmen are more IT-oriented than others. It is therefore, interesting to explore whether IT usage can be linked with trade. Interviewees could choose from a list of the main trades and finally, an "other" option in case something was not listed. For the "other" option, 16 responses were registered, of which 7 of were managers (fig. 9.). Three top trades were carpenters, plumbers and painters.

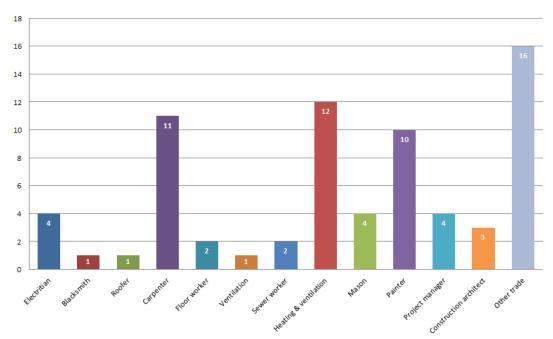


Figure 9 Bar chart of how the responders are distributed by trade

3) How would you describe your IT knowledge?

- My IT skills are... (...none...low...average...high...super user)

This is a key question in the survey. It is crucial for the author to know the level of IT knowledge on-site. The IT knowledge is one of the first things the User Environment

Designer (UED) has to have in mind (Barry & Pitt, 2006). It is also important to know when designing the physical environment (Betty Dion Enterprises, 2006).

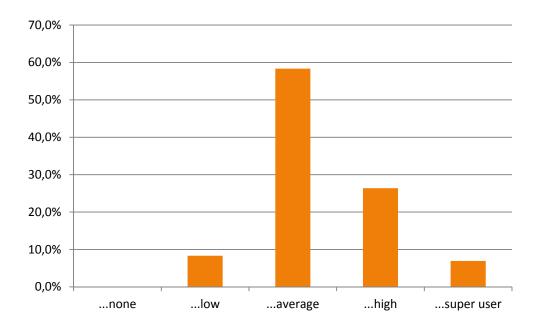


Figure 10: Bar chart showing distribution of self-described IT skills

Figure 10 shows that almost 58% has an average IT knowledge and 26% has high IT knowledge. It is interesting to see that none of the responders have "none" IT knowledge. At first, the author found it strange that many of the responders chose medium or high IT knowledge, but when comparing this survey to a survey made by the THE DANISH CONSTRUCTION ASSOCIATION, it became apparent that, that survey had also got very few responders describing their IT knowledge as low. This could reflect that craftsmen, who do not use computers in their normal workday, may not have the necessary IT knowledge to access an internet survey.

a. Cross check Age vs. IT skills

Before making this survey, one of the things the author expected to find (based on personal experience), was a connection between age and IT skills was expected. If Figure 10 is analyzed, we can see that the author is not entirely wrong.

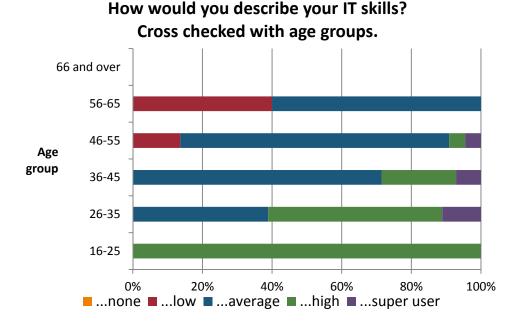


Figure 11: Age groups plotted against the level of IT skills.

The age group from 16 to 45 had average or high IT skills and 4 of the responders even had super user IT skills (fig. 10). The age group from 46 to 65 had an average of 26% low IT skills. There were no responses from the age group 66 and more, and also, no one (at any age) responded that they had no IT skills. This could possibly be a link between higher age (66 and over) and lacking IT skills. Although these findings cannot be generalized other studies have shown the same results (Sørensen, Svidt, & Christiansson, 2007).

4) Do you have access to digital project material on the construction site? -drawings, job descriptions, etc.

The author was interested in knowing if the access to digital material was a common thing on-site. Although roughly one third answered that they have access to digital material (fig. 12), it can be assumed that even if digital information is available on-site, craftsmen do not have easy access to that information. It may be stored on the project

manager's computer, prohibiting access, as was the case with the interviewed project manager.

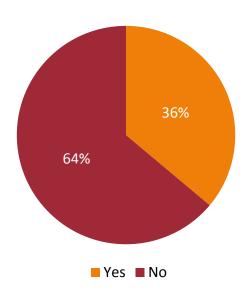


Figure 12: Pie chart describing whether digital information is available on construction sites.

5) What kind of mobile phone do you have?

The aim of asking this question is twofold. Firstly, to explore whether the author's idea of a SMS (Short Message Service) messages when changes are made, could be a possibility. Secondly, to investigate to what degree wide-spread use of smart phones on-site was possible (i.e. how many craftsmen already own smart phones).

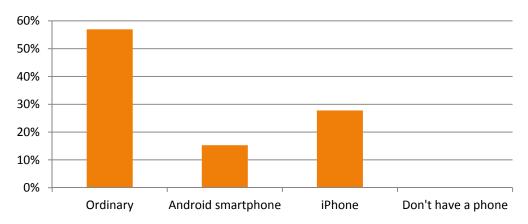


Figure 13 Bar chart showing what type of mobile phone craftsmen own

The result shows that all the respondents have a mobile phone of some sort (fig. 13). Statistics from DST also show that in 2006, 94% of the population has a mobile phone. As seen on Figure 14, the ownership of mobile phones has increased drastically from 1994 to 2006.

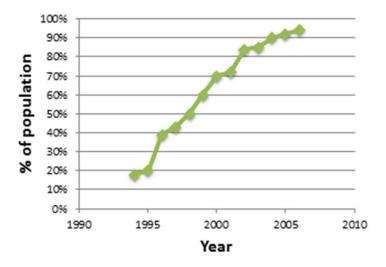


Figure 14 Percentages of the population owning a mobile phone [modified from www.dst.dk]

It is safe to assume that mobile communication is a common thing today and can be implemented in new ICT systems on-site.

Have you used mobile applications on the construction site?

- Mobile applications on your portable phone, for example, to do a quality check and time sheets.

As stated above smart phones are beginning to be a common thing with mobile phone owners. The amount of mobile applications (apps) available for all smart phone brands was 120.000 in Q4 2009. The app market has escalated since then. In Q4 2011, the apps available for all smart phone brands was approximately 1.000.000 (MaximumPC, 2009). The author researched what kind of mobile applications are on the market for the construction industry today, and they are described in appendix 4. Despite this, craftsmen do not appear to be making the most of this technology with only 11% of respondents having used apps as a tool for on-site work (fig. 15).

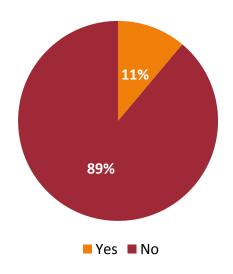


Figure 15: Pie chart showing how many craftsmen have used mobile applications on the construction-site.

6) Have you used a project web on the construction site?

The author's intention with this question is to find out how craftsmen are able to fulfill the public client demand of being able to access a project web system on-site (The Ministry of Economic and Business Affairs, 2010). If compared with the survey made

for DB where the managers were asked how important they thought it was to have access to a project web system. Only 9% answered it was very important. Thus, it is not surprising that only 15% of the respondents of this survey have used an on-site project web (fig. 16).

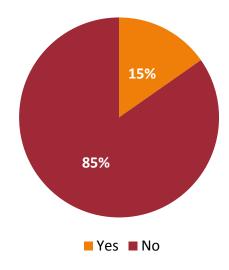


Figure 16: Pie chart showing how many percent of survey respondents have used an on-site project web system.

These findings show that the companies have not yet seen the advantages of having access to a project web system. Around 90% of the companies could find it hard to fulfill the demand §2.5, described in section 2.4.1 of having access to a project web system and be able to print information in A3 (The Ministry of Economic and Business Affairs, 2010).

7) How do you know, that you have the newest information, when you are performing your task?

This question was asked to get an overview of methods used to communicate when changes are made to the information. Furthermore, to see, what the ambition is to know that the craftsmen are actually using the newest information. Five options were given, four options that the author thoughts were relevant and one option that gave

the responders freedom to give their own explanation. This option turned out to be a valuable resource for further analyzes on how the craftsmen communicate information.

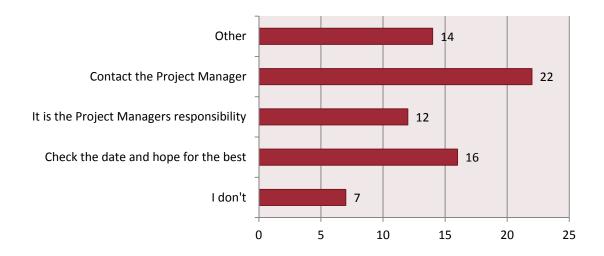


Figure 17: Bar chart showing the most common ways that craftsmen check that they have updated information.

Here are few of the responses that were given to the "other" response option:

"Check out the drawing list from the last project meeting"

"Get manually delivered the newest information."

"The client consultant is responsible for always having the newest updated information on-site."

It can be concluded that there are many ways that craftsmen check that they have the newest information. It appears that some even don't care what information they are working with, but the majority double-checks with the project manager or checks the dates on the information (fig. 17).

There is a need for one standard way for the craftsmen to check if they have the newest information and a system that notifies them if changes are made.

8) If an IT-system would be accessible on the construction site, would you use it?

- A stationary IT-system with a touch screen and an A3 printer, that could ensure you that you would always have the newest updated information.

This question is twofold. Firstly, to find out if the craftsmen were willing to use a stationary ICT system, and secondly if they could benefit from the new legislation that Digital Construction but in action 1. January 2007.

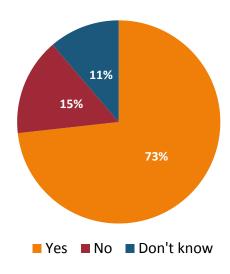


Figure 18: Pie chart showing whether respondents would be willing to use an on-site IT-system.

The author compared his survey with the DB survey where the managers were asked if the craftsmen in their company had easy access to IT on-site (Jakobsen & Øbro, 2010). Of the 110 that answered only one manager said that his craftsmen had access to IT. About half (49%) of the responders said the craftsmen have no access to IT, and they should not have. Compared with the author's survey, there is a very different opinion about IT usage on-site. As seen in Figure 18, the majority of the responders said that they would use an IT system on site if it was available.

9) Do you think that IT could be used to increase the productivity on the construction site?

This question aimed at getting the craftsmen opinion of IT-usage, and whether they thought, it could improve the productivity. The question included comment field, where they could express freely why they thought it would improve the productivity. Some of the feedback can be seen here below.

"It would be among other things to increase communication and make the day more fluid."

"Avoid a number of mistakes, faster corrections, and maximum information after construction meetings, etc. Fantastic!"

"Avoid wasted time and errors because of not having updated drawings and descriptions."

"There is always access to the projects newest information. This applies, however, primarily construction projects of a certain size."

All responders that used the text field gave positive feedback and all agreed that ICT would increase productivity.

5.3. Summarize needs

This survey clearly indicates that there is a need for IT on-site. When the author looks at the survey from beginning to end, he is confident that not only is there need for increased IT use on the construction site, there is also general positivity and acceptance towards increased use of IT. This clearly contradicts the results of the survey made for DB, where managers thought craftsmen should not have access to IT.

There is a need for a change in management style, in order to break down the barriers between managers and craftsmen. The author will describe these needs and try to come up with a possible solution in chapter 9: Implementation.

6

Problem statement

Implementation of innovative ICT systems in the construction industry is trailing other industries. Information that is used on the construction site is still mostly paper-based. According to the need analyzes, craftsmen are willing to use an on-site ICT system that could improve productivity in the construction industry. According to a study made for DB, managers are reluctant to provide access to ICT systems, claiming that it is time consuming. Currently, construction sites do not benefit from the implementation of ICT in the design process, as it is in most cases not able to receive digital information. However, there are indications that easy access to an on-site ICT system could work to increase efficiency and lower costs, e.g. due to fewer construction failures.

This leads to the problem statement:

What is the best way to develop an ICT system that benefits both managers and craftsmen needs, and increases productivity?

ICT system that is...

...User friendly...Robust...Efficient in Communication...Not time-consuming to use

To answer these questions, the work processes described in chapter 4 were redesigned and a prototype of an ICT system made, that could benefit both managers and craftsmen. An implementation method for such a system is also described.

Optimizing the Information flow

This chapter describes what methods could be used to optimize the information flow, on the construction site to increase productivity. Work-models are redesigned to optimize the information flow, and illustrated on a storyboard.

7.1. New process

According to the survey made for this thesis, the majority of the craftsmen are willing and able to use ICT on the construction site. Although the survey was made online and craftsmen with no and low IT skills might not have answered, that is also the case in other industries. IT skills vary from person to person, but as long as they are motivated to use IT, it is merely a matter of teaching and guiding them to learn and use it more efficiently.

ICT is already available on construction sites, either as a handheld device or a computer at the project manager's on-site office. The problem is that it is not being used by the craftsmen. Most of the devices and associated applications being used currently are not very user-friendly and quite time-consuming to use.

A project manager uses a substantial amount of time to organize information when it arrives at the construction site. Changes and revisions have to reach the right

craftsmen as soon as possible, in order to prevent mistakes from being made. Survey results, along with the authors' own experience suggests mistakes are often made because craftsmen are not aware that changes have been made.

Two questions in the survey were aimed at investigating what kind of mobile devices craftsmen have, and whether they have used mobile applications on the construction site. Only ~40% of responders have smart phones, of which only 11% have used mobile applications on the construction site. Possible explanations for this could be the variability of construction sites and rough weather conditions, which may hamper the usage of mobile devices. Imagine a carpenter standing on scaffolding during winter conditions, trying to operate a small mobile device with gloves on. The author has used this scenario when talking to craftsmen. All of them agreed that this would not be possible and a stationary system near the craftsmen resting area would be more suitable.

Only 15% of the responders said that they have used a project web system, and found it hard to access and difficult to use. While a project web system could be a solution to improve the information flow on the construction site, it is useless if it is not being used. On the other hand, 73% of the responders said they would use an ICT system with a touch screen and printer, if stationed at the construction site. This motivated the author to develop a user-friendly Information Management System (IMS), which will be described further in chapter 8.

7.2. Redesigned work models

To describe the optimization of on-site information flow after implementing an ICT system, the models made based on interview results, were redesigned to show the optimized flow of information.

7.2.1. Redesigned Flow model

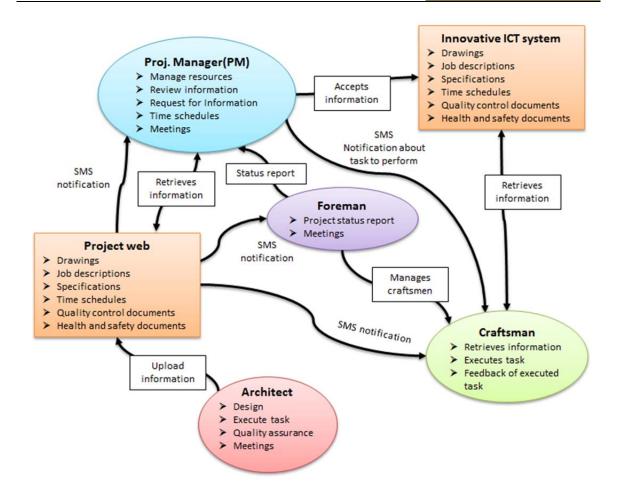


Figure 19 Redesigned Flow model that illustrates how craftsmen receive information.

The flow model seen on Figure 19 illustrates how work is distributed between actors on the building site. In this case, the illustrated workflow shows how craftsmen access information to carry out their task on the building site, and what is the procedure if there is a problem in the information that the craftsmen receive.

Implementation of an IMS would minimize the time passed, from when a change is made, until the craftsmen receive a notification. Although it is the project manager's job to approve changes, craftsmen would receive instant SMS notification when an approved change has been made to the information they are using. An example of such a notification could, for example, be: "Changes have been made to drawing

number 205.23.32.1. Please contact PM before carrying on with your task." One possible scenario where such a system would be useful is if a PM is not present on-site, at the time of receiving information about new changes and thus, unable to notify the craftsmen. As a result, the craftsmen could risk working with outdated information for a considerable amount of time, which could lead to costly errors.

With the use of an IMS, some of those communications could be avoided or made easier. It is very time-consuming to communicate with other actors in the project, especially if the job site is large, with hundreds of workers on-site at the same time. An ICT system automatically notifying individual craftsmen or team leaders of any changes made to the information would greatly aid the project manager and cut costs.

7.2.2. Redesigned Sequence model

After analyzing the options for redesigning the sequence model, the author saw an opportunity for optimizing the communication channels to the craftsmen. The redesigned model can be seen in Figure 20.

According to this model, the time passed from when changes are made until craftsmen receive a notification is just a few seconds. Instead of letting the craftsmen carry on their work, knowing they are working with outdated information. The project manager can assign new tasks to them while information is being reviewed, and negotiations take place. In this way, the productivity loss is minimized.

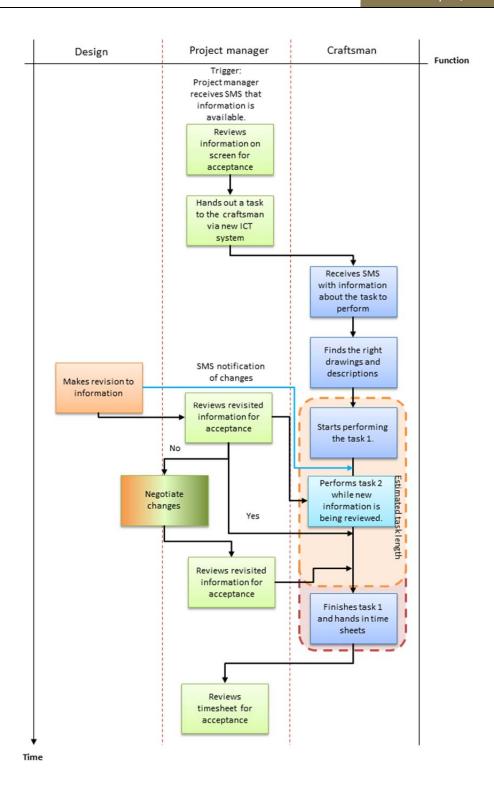


Figure 20 Redesigned sequence model

7.2.3. Redesigned Artifact model

An ICT system is not implemented to cut some of the artifacts away. Its primary purpose is to organize and make it easier for the project manager to manage both information and resources. Therefore, all artifacts from the original design are on the model (fig. 21). However, an ICT system has been added for support that is accessible in a special shed and containing all relevant information to the project.

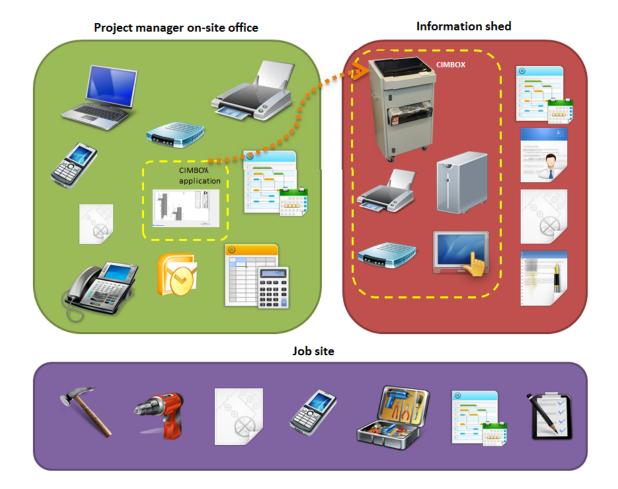


Figure 21 Redesigned artifact model. The dotted lines show what has been added.

The on-site office has administrative access to the ICT system (dotted arrow), and is able to hand out tasks to craftsmen.

The craftsmen are now able to get the latest information from the box, as well as getting notified when changes are made.

7.2.4. Redesigned Physical Model

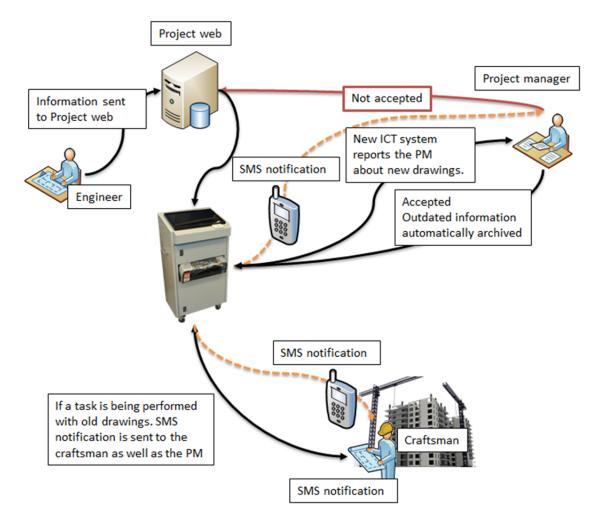


Figure 22 Redesigned physical model

With the use of ICT system, a considerable efficiency can be achieved (fig. 22). The project web server handles all organizing of information. The time that the project manager spent on printing information and updating the drawing list is greatly minimized. The craftsmen can retrieve the relevant information and receive notification if his information is changed.

7.2.5. Storyboard

To illustrate the new work process, a storyboard is made with a scenario were a project manager assigns a task to a carpenter. He gets the relevant information that is changed while performing the task.

1



Project manager goes over the time schedule and hands out a task to a carpenter with filling in a form on the ICT system manager application. The manager application sends the task to the onsite cimbox that sends out an SMS notification to the carpenter.

2



The carpenter receives a text message to his mobile phone, notifying him that he has a new task to perform.

Text message: "You have one new task waiting. Please log onto Cimbox for further information"

3



The carpenter logs into ICT system with his ID card. The system registers that this individual carpenter prints this drawing. That way, the system does only send to him and the project manager if changes are made.

4



The carpenter then prints the information needed to perform the handed out task. The carpenter now has all the necessary information to perform the task.

5



Shortly after he has started. He gets a text message to his mobile phone.

"Changes have been made to the drawing 0789 that you printed, 21-11-11, 08.30. Please logon to cimbox for more instructions."

The ICT system detected that there were changes made to the drawing used by this carpenter. Here is another option.

6



The carpenter logs on to the ICT system. There he finds the drawing that has been changed. If the changes have to be evaluated by the project manager, the carpenter will, then be handed out a different task while the changed drawings are being accepted. That way, an optimal resource management can be achieved.

7



He prints the new drawing.

8



The carpenter can now carry on with his work with updated information, with no or minimum errors.



Prototypes

From the original idea of an ICT system for the construction site, many further have been made to the system proposals. This section describes the prototype process, starting on a paper-based prototype, then a semi-functional prototype made in PowerPoint and finally, a functional prototype developed in the programming language C#.

8.1. Paper-based prototype

As soon as the author came up with the idea of an ICT system for the construction site, he started sketching the system. The main focus was to design a system that could be connected to a project web system and that had a user-friendly interface.

8.1.1. User Environment Model

The primitive user environment was sketched on paper and the overall system design was mocked up. This turned out to be an excellent method, especially in the later stages of the prototype design. The design of all functions were based on the authors own experience and then reviewed by experts. The primitive paper mock-ups were used for analytical testing.

To be able to test this idea on potential users, the author decided to do a digital representation of the system. This will be described in the next section (8.2).

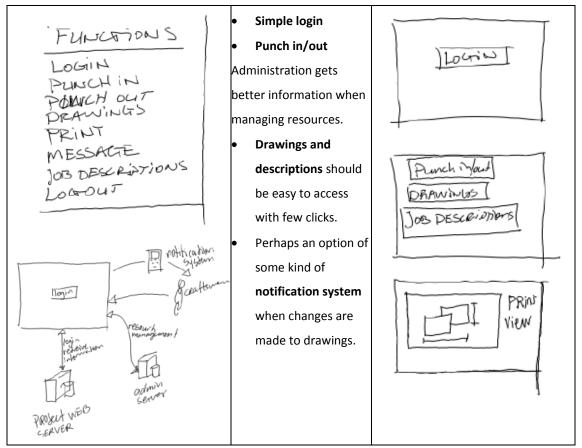


Table 3Early paper mockup of an ICT system for the construction industry

8.2. Semi-functional prototype

The paper-based sketches were used to make a power point layout for presenting to a user test group. The advantage of designing a digital representation of the system is that the users can get a better overview and impression of the system, which makes it easier to give feedback on the design and functions (e.g. colors, icons and overall user experience).

The primary goal was to design a stationary ICT system in a physical box. Although a mobile app was one of the feedbacks from the experts, the author's intentions with the system were primarily to design a system fit for all workers on a construction site, no matter level of IT skills. The ICT system proposed has a slot for an ID card, an A3 printer and a small roll printer used for punching in and out, for printing out drawings

and for printing quantities (that the craftsmen could use as a grocery list at the storage area and pick up what was relevant to their task), respectively.

8.2.1. User Environment Design

Although the author has ten-year experience from the construction site, he could not design the system entirely from his point of view. He decided to use his network of craftsmen to make the user environment model. He gathered three professional acquaintances. A small workshop was set up to discuss the author's idea.



Figure 23 first sketch of the box and accessories.

The User environment model (fig. 25) was drawn to give an overview of the functions and afterwards a description of each function (Table 4).

An explanation for the model is given in Figure 24. Each box indicates a focus area, page or a window. The purpose is described shortly. Functions are listed up, both the ones triggered by the user and by the system. If another focus area is connected, the name of it is listed up under links. Objects that the user is presented by are next listed up. Finally, risks and constraints are given.

Name of page, window or focus area

Purpose: Short description of the purpose.

Functions

Functions to be activated be the user Functions to be activated be the system

Links

>Pages or windows that the system can navigate to

Objects

Objects presented to the user

Risks/constraints

Particular risks/constraints not giving the user the expected experience.

Figure 24 Explanation how the user environment model is built up.

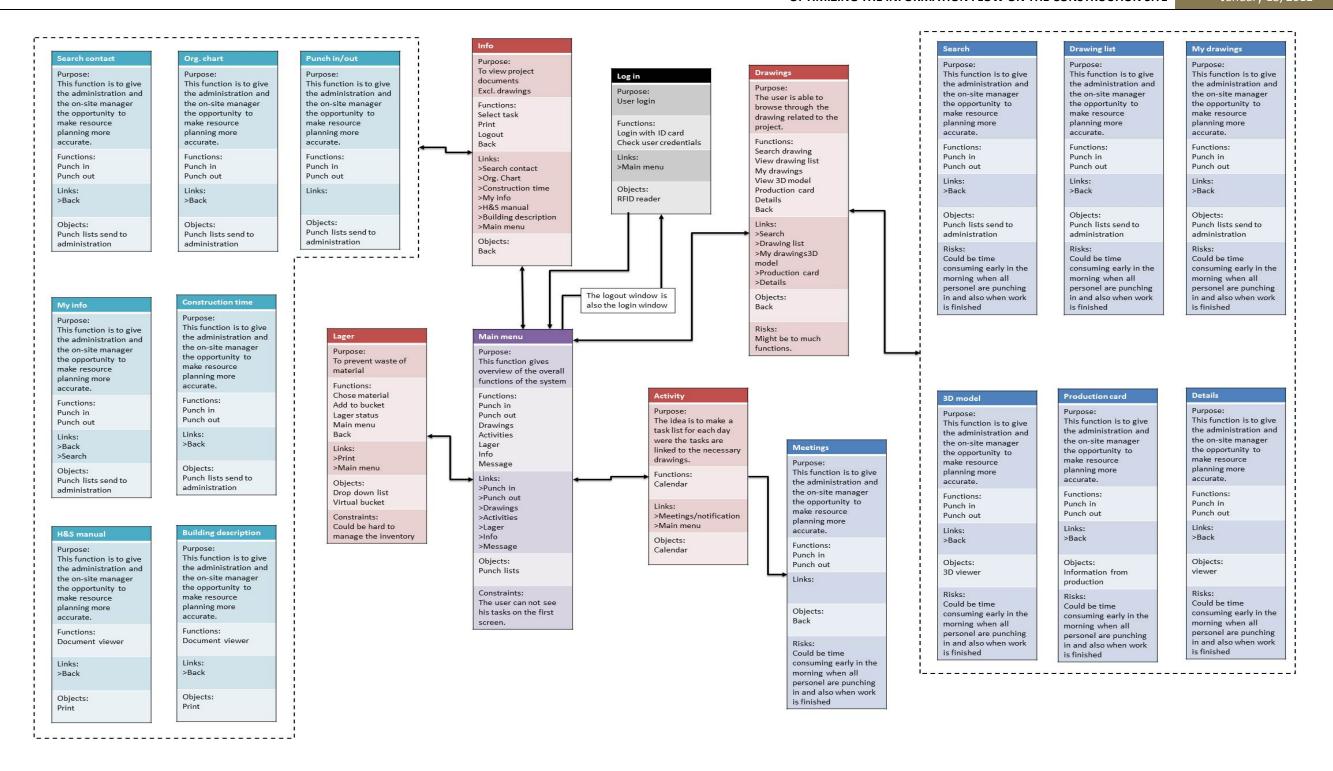


Figure 25 User Environment Model (UED) of the semi functional prototype

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Table 4 Description prototype of functions

Thanks for today Mr. Haroldur Amorison

Use your card to access system

This is what the menu looks like when the user logs on with his ID card. A short password of 4 letters could be an option here. Or if the worker forgets his ID card a function to punch in his personal ID number and then a 4 letter password

2



Punch in and out

This function is to give the administration and the on-site manager the opportunity to make resource-planning more accurate. These two functions could give long queues to punch in and out. Therefore the author will not make these functions a priority.

Message - Description in row 18.

The system keeps track of who prints what drawings and notifies the user if some of the information has changed after his last printout.

Activities – Description in row 18.

Activities linked to the individual user.

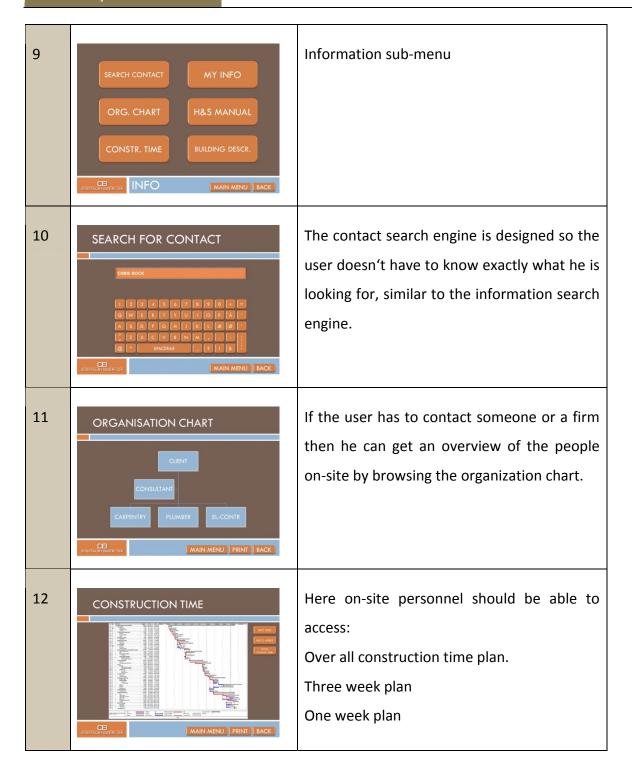
Activities can be handed out by the on-site manager and the administration.

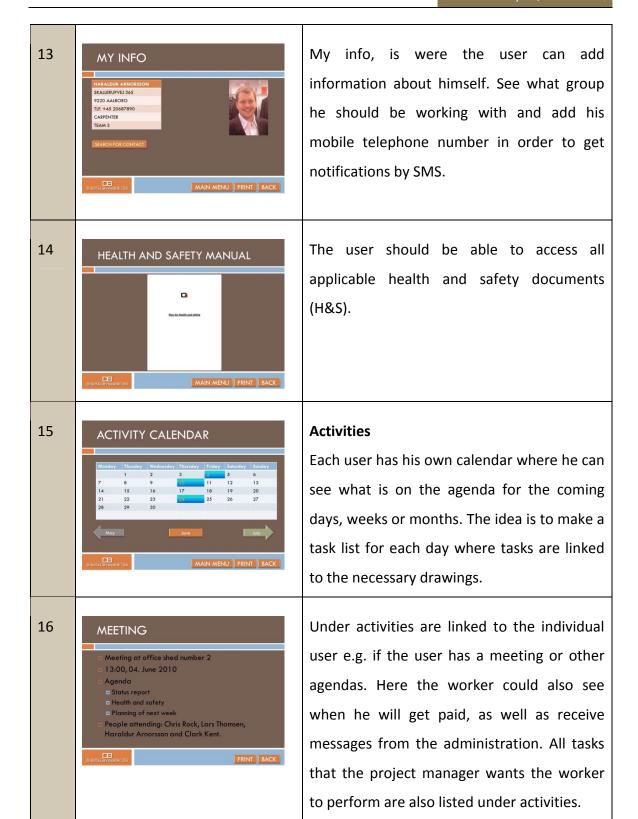
Drawings – Description in row 18.

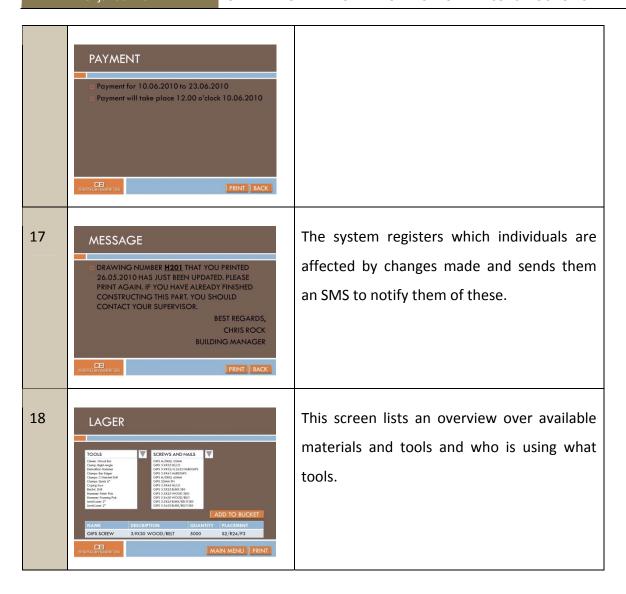
Here the user can access all drawings that are linked to the project.

Lager – Description in row 18. Function that keeps track of all materials used on the site and what craftsmen tools are being used by whom. Info – Description in row 18. General information such as job descriptions and contact list. 3 This menu is where users would have access to all drawing material. DRAWING LIST 4 The search engine is designed so the user SEARCH FOR DRAWING doesn't have to know exactly what he is looking for. A search like "3. floor" would give the user all drawings linked to the 3rd floor. 5 This menu gives the user access to all DRAWING LIST drawing material linked to the individual project. Here the user can use two functions: View or Add to my drawings. The system does not register the drawing to the user if he only views it. But if he uses Add to my

drawings then the system will register it and is therefore able to send the user a message if there are changes made, in the form of a message next time he logs on or as an SMS. When the user is in view mode he is able to 6 PLANS AND SECTIONS zoom in and out. The circles on the drawings indicate that there is a drawing linked to the one being viewed. 7 The drawing material should include a 3D 3D VIEW model of the construction where the user can zoom in and out, pan and do a walkthrough to get a better picture of what his task is. The usual details can be printed in A3 8 DETAIL format. This should include detailed information, such as what material to use and a job description.







8.2.2. Prototype evaluation

To evaluate the prototype a number of experts (professors, students and three craftsmen), were introduced to the system, given an introduction of how the system would work and what problems it would solve. This turned out to be really useful and a aided greatly in the design of the system. The first version that was tested was far too complicated. The reason for this was that the author has an IT education and is

comfortable to operate complex systems. His network, on the other hand, has different IT skills.

Figure 26 shows an ideal construction site that has implemented the box. Building design is connected to a project web server and the project server is connected to the box. The administration server is also connected to the project server, so they can do resource planning and manage budgets. Material inventory is also accessible through the box. Craftsmen have access to relevant project information via the box. Project managers use personal digital assistant (PDA) for quality assurance.

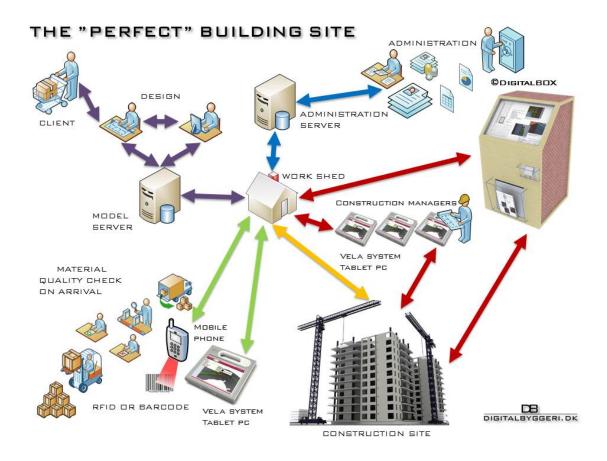


Figure 26 Rich picture of the construction site with the system implemented

8.3. Functional prototypes

The User Environment Design provides a structural thinking that responds to the storyboards.

To develop the UED as seen on Figure 27, the redesigned work models, consolidation, and storyboards were used to fulfill the user requirements.

It is important that the user environment is made as simple as possible. The login window has a fairly simple login function. The user has the possibility to login manually or by using radio-frequency identification (RFID) card. The login is linked to the "Main window" which acts as a home screen for the user. The user can see all his tasks and printed drawings. The main window links to all windows in the system. A message object appears if the user has a new message. To give the user freedom to browse through information, other than that assigned to him, links are created to "drawings" and "Information." Both "Drawings" and "Information" has a viewer object to browse through the information and print function.

The final step of the User Environment Design is the walkthrough. This step should not be skipped (Beyer & Holtzblatt, 1998). It should been taken before User Interface design starts.

The walkthrough for this UED was made with three craftsmen from two different trades, one plumber and two carpenters. Their main job was to see if the design could fulfill the requirements and if some focus areas could be merged or split up. The UED model seen on Figure 27, fulfilled their expectation and was thus used for the next step of User Interface design.

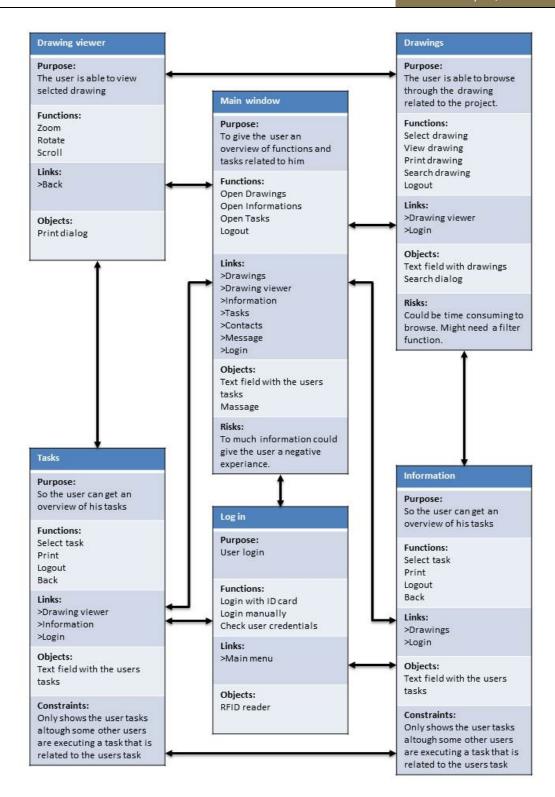


Figure 27 User Environment Model of the final prototype

8.4. Physical prototype

The box mentioned in 8.2 was designed further and a prototype was constructed. The physical prototype consists of a 22" touch monitor, RFID scanner, A3 printer and a laptop computer, running windows 7 Home with internet access as seen on (fig. 28).

8.5. Web-based prototype

The easiest way, for the author, to make a functional prototype was to develop a website. An open-source Content Management System (CMS) by the name JOOMLA was used to design both the back-end and the front-end.



Figure 28 Physical prototype

8.5.1. JOOMLA

Joomla is a free and open source content management system (CMS) for publishing content on the World Wide Web and intranets Web application framework. Joomla is written in PHP and uses object-oriented programming (OOP) techniques. JOOMLA stores data in a MySQL database (Burge, 2011).

JOOMLA 1.6 was installed on a web server, http://digitalbyggeri.dk/digibox and a simple login window was designed as the start page. JOOMLA offers thousands of extensions that can be installed. To manage information such as drawings and job descriptions an extension called DocMAN was purchased and installed. DocMAN is a very simple information management extension that can upload multiple files to the database. The front-end of DocMAN can be seen on Figure 32. DocMAN is the backbone of the system. It serves as a project web system for the prototype.

8.5.2. Login

As mentioned earlier the login has to be simple. There are many reasons for that. To mention a few, different IT skills, users could have some disabilities like poor eye-sight or the time of year could also make a difference. In cold weather craftsmen wear gloves and might want to keep them on when operating the ICT system.



Figure 29 Touchatag RFID scanner.



Figure 30 Touchatag configuration window

Touchatag server.

Figure 30 shows how the login system is designed. When the user sweeps his ID card through the scanner, the scanner sends the RFID hash number to the Touchatag server. The server finds the application associated with the RFID tag and executes, as seen on Figure 31. Reprogramming the scanner, to send the hash code directly to the JOOMLA MySQL database, turned out to be a complicated task. A workaround was made by executing a command file that included a path to a Hotkey file. A hotkey file records screen actions which can then be executed by the RFID tag.

The idea of an ID card equipped with a RFID chip was tested. RFID scanner from Touchatag was chosen. The RFID scanner can be seen on Figure 29. The setup was quite complex. When the ID card is swept through the scanner it contacts the Touchatag server. That means the ICT system has a demand of a steady internet connection to the

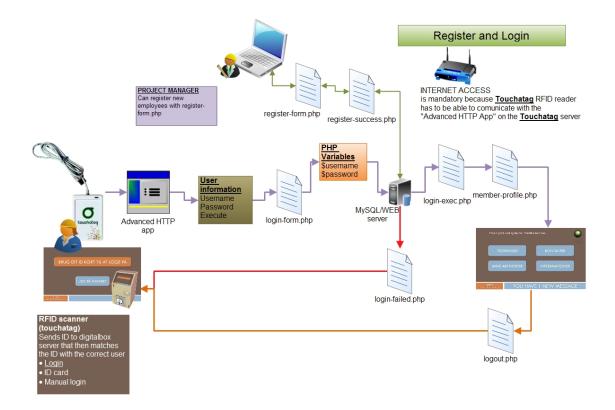


Figure 31 Overview of the login system

The user interface was also made simple. The craftsmen need to have quick access to relevant information and they have to be able to do so, with just a few clicks. The user interface, as seen on Figure 32, has only four buttons, Login/logout, drawings, time schedule and descriptions. This makes it easy to navigate and the buttons are always visible so the user can easily jump between functions.

8.5.3. Prototype evaluation

Being a web-based prototype gave it flexible evaluation opportunity. An expert evaluation method was used to evaluate the prototype. Five users were registered on the system. These were expert users with good IT skills. Two had craftsman background. Users gave good feedback for the usability and were overall positive towards the design. One user tested the system on an iPad. That test was not on the schedule but it gave the system a new dimension in usability.

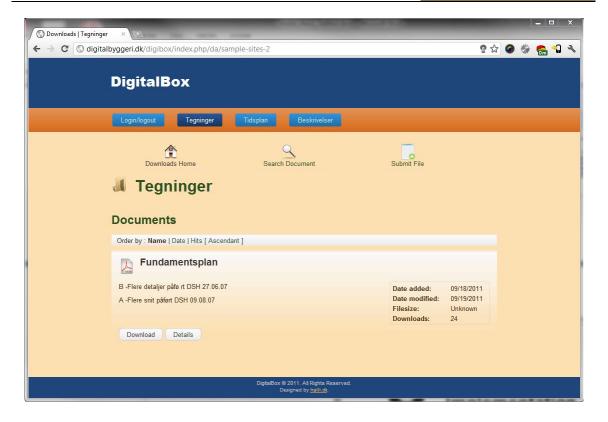


Figure 32 Screen shot of a web based prototype

8.6. Functional prototype

An Innovation network supported by Aalborg University, hosted a kick-start weekend for students in week 44, with 70 participants pitching 28 innovative ideas. Out of these, 10 were chosen by the participants to be developed further over the weekend. The idea of an on-site digital information system caught the eyes of the participants and it was one of the chosen ideas. The owners of the ideas then put together a team that they wanted to help develop the idea. The author gathered three programmers, one graphic designer, a global business engineer and a technical integrator (a diary from the weekend is included in appendix 2).

The website prototype was used to introduce the idea to the team, along with the user environment design (see fig. 27). The power Point prototype was also used to show

what the idea first looked like and to demonstrate that the early prototypes were too complex.

It was agreed to design the user interface in C SHARP (C#). C# is an Object Oriented Programming language (OOP). For storing data a MySQL database server was developed. The author sketched an E-R diagram to give the developers a rough idea of what the structure of the database should look like. The final structure can be seen on Figure 33.

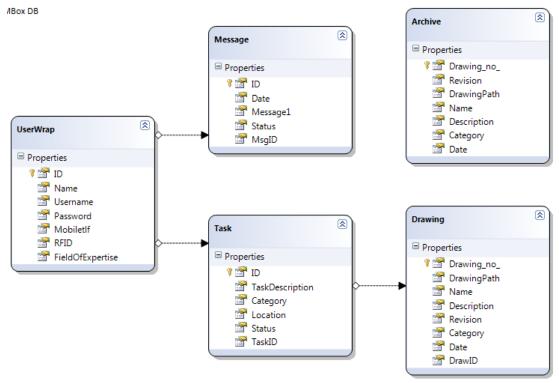


Figure 33 Database diagram

8.6.1. The User Interface design

The interface needed to be as user-friendly as possible, with simple layout, few buttons and not too crowded with information. The main focus was on the first screen after the user logs on to the system. The user should be able to see all his current tasks and links to relevant information, without navigating to a different screen. However, in the case of missing information he can browse through information with the buttons on the right site of the screen. A logout button is placed on the four main windows to make it easy for the user to logout. It is important for users to logout so the next user doesn't use prior users account. The system has to recognize the users to be able to send out notification to the right users.



The login is made easy with an RFID scanner. Each craftsman is equipped with an ID card. So with one sweep he can access the system without striking any key.

2.

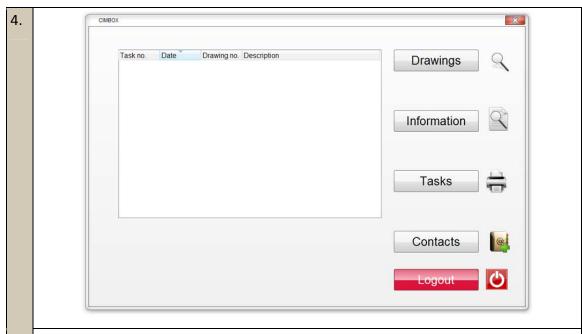


In the case of a forgotten ID card, the craftsman has the opportunity to login manually.

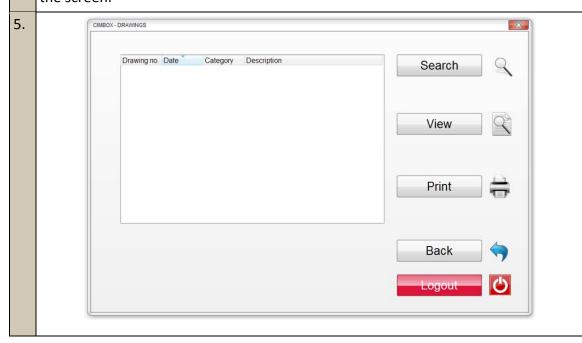
3.



With manual login this dialog pops up. The craftsman enters his user name and password.



To make the interface simple and easy to navigate, all information relevant to the user appears on the first screen after logging in i.e. tasks that the Project manager assigns to him and links to relevant information such as drawings and descriptions. With this function the user does not have to search for drawings self. If he needs additional information he has the possibility to use the buttons on the right side of the screen.



When the drawing button is used this window appears. Here the user can select a drawing, which he can either view or print. He is also able to search for drawings by name, number, description or date.

6.

Search

View

Print

The view dialog window. The user can move, scroll or zoom with two fingers.

8.6.2. Prototype evaluation

A usability test method was used for testing the prototype. The author invited four craftsmen to test the system in a controlled environment. The test persons were first introduced to the project. Then a short semi-structured pre-interview was conducted (see appendix 3), to evaluate their level of IT skills and their first impression of the system. To test the usability each user was given two tasks. The first task was to login with the ID card and print a specific drawing and logout. The second task was to search for a specific drawing and then print it and finally logout. The test persons had never seen the box or tested the system before the actual test day. The author did not give any introduction on how to operate the system. The idea was to check whether the system was so user-friendly that users could intuitively use it without an introduction.

Table 5 Results from the usability test

	Time to complete Task 1, in		Time to complete Task2, in	
Participant	seconds	Completion	seconds	Completion
Α	44	Successful	62	Successful
В	81	Successful	80	Successful
С	48	Successful	65	Successful
D	60	Successful	70	Successful
E	52	Successful	80	Successful
F	63	Successful	64	Successful
Average	58	Seconds	70	Seconds

The usability test was a great success. All testers finished both their tasks. The average time to complete task 1 was 58 seconds and the average time for task 2 was 70 seconds.

As part of a survey made by Danish Construction Industry (Dansk Byggeri) a workshop was held. Some of the participants believed ICT systems are time-consuming and hard to operate (Jakobsen & Øbro, 2010). The definition of time- consuming is, "using or taking up a great deal of time." The authors opinion is that a system with the average of 70 seconds to get the information needed could hardly be called time-consuming. During this test the tester reported that the system was very easy to operate and gave positive feedback for the simple user interface. Even if task 2 was more difficult, the testers thought it was much easier, because performing task 1 was enough to get a good overall knowledge of the system. The prototype testers had IT skills from low to super users. With the IT skill range from low to super users the author is quite convinced that this system could be used by craftsmen on the construction site. A detailed report can be seen in appendix 3.

9

Implementation

This chapter describes what organizational changes take place when implementing new ICT systems and analyzes what implementation methods could be used to make the transition as smooth as possible. Kotter's 8-step change model is used to analyze the changes that occur when implementing an ICT system.

9.1. Implementation of an ICT system in a construction company

It is a complex procedure to implement new ICT system in companies and many things to keep in mind. The objective is to analyze the changes that arise, both internal and external, when implementing an ICT system that all actors, no matter their trade, can access to and retrieve information.

Figure 34 shows Kotter's 8-step model. The model describes the phases that the implementation must include, to ensure minimal resistance towards the new system. Kotter's model can be used for both small and large organizations. Kotter emphasizes that each step has to be finished before moving on to the next step. Small wins are crucial to keep the implementation team motivated. Kotter's model has proven to be effective and is being used for many implementation projects.

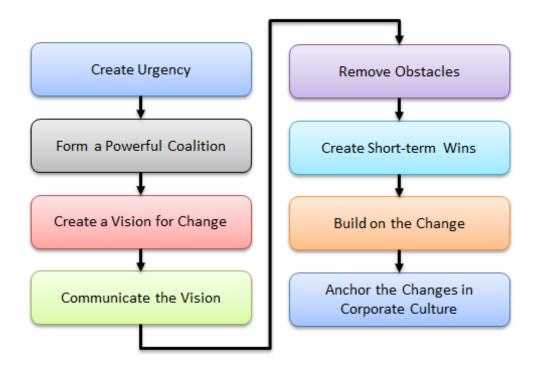


Figure 34 Kotter's 8-step change (Kotter, 1995).

Create Urgency

When creating urgency it is important to look both internally and externally. Both the Porters 5 forces and the Leavitt model are good tools for creating an overview of internal and

external environment. The Leavitt model suits better for this project.

It is important that the whole company is aware of the changes and to have the support from the managers. A big motivation for changes is the new legislation acts, described in chapter 3. It is not all about showing bad numbers and productivity, although it could be a motivation to show the profit of increased productivity. It could also be a concurrence parameter to introduce the company as a fully digital company all the way to the craftsmen. An open and honest discussion is important. A good tool to get a free flow in discussion is to make a group, for example, on Facebook. That way is it possible to reach to all parties involved in the project, both internal and external users. People that do not feel comfortable by expressing themselves on big meetings

can write comments and questions in the safety of their home. Kotter states that it is important to spend good time in establishing urgency before moving on to the next step.



Figure 35 Leavitt's diamond, used to analyze effect changes have on the organization, authors view.

The Leavitt Diamond can give the senior managers an overview of what effect the changes could have on the organization. The Leavitt Diamond is made of five elements (Figure 35). The idea of the diamond is that, a change made to one element, affects the whole organization. Like in this case, when applying a new technology, the other three are affected. Employees need to learn how to use the system and in some cases change their daily routines. The task element is affected in the way that the organization can tender for different projects. The organization could be affected in more drastic ways. People could be moved up or down the hierarchy depending on what work processes are changed. This could potentially lead to resistance on the manager's side.

Form a Powerful Coalition

To start with, find few but motivated people to form a change team. It is important to have a Senior Manager on board. They form the core of the team.

A good idea is to get a representative from key customers and/or a member from the local authorities to join the team. This could be fruitful in the case of implementing an ICT system to fulfill the new public client legislation act.

The team should have a good mix of managers and members lower in the hierarchy. The team should work together without thinking of hierarchy. This could be hard for the managers but it is necessary to get the most out of the team. A good idea would be to have a team building workshop outside the office.

It is important to choose members with care when forming a change team. Figure 36 shows four types of people. The company wants to choose the people with the highest

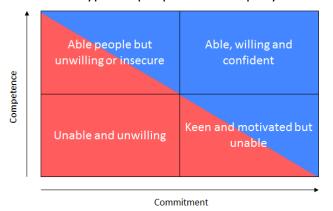


Figure 36 The change competence/commitment matrix, authors view (Cadle & Yeates, 2004).

competences and commitment (blue area). Those people can then motivate and teach the people that are less compatible and committed (red area).

The survey made for this thesis shows that there is a link between age and IT skills. The older

craftsmen are not as keen to use new ICT systems as the younger generation (Sørensen et al., 2007). It would be a good idea to have some of the younger carpenters on the team and introduce them to system. They could teach and motivate the craftsmen that are unable or unwilling to use the system.

Create a Vision for Change

Make a vision statement that motivates the employees to give the team the enthusiasm these kinds of changes need, in order to be successful. It is

important to constantly promote the vision, in a way so no team member will forget why the changes are being made.

An Example of a mission and vision statement:

Mission

 To be the most productive construction company in the building industry.

Vision

 We make sure that our clients get the best quality construction and on time.

Make sure that the values for the change are clear. That will motivate both senior managers and other employees. Before the team can move on to the next step, this rule of thumb is useful to think about.

"If you can't communicate the vision to someone in five minutes or less and get a reaction that signifies both understanding and interest, you are not yet done with this phase of the transformation process (Kotter, 1995)."

Communicate the Vision

Some short-term sacrifices are inevitable during the transformation. Sacrifices that could be in the form of moving employees up or down the hierarchy or

changes in the employee's daily routine. It can be hard to communicate the vision if the employees are afraid of losing their jobs. This could increase resistance to the transformation. It is important for the executives to use all means of communication channels to broadcast their vision and be ready to get negative and positive feedback. The executive could use social media platforms or team building workshops to reach out to the employees.

Remove Obstacles

It can be hard to get rid of obstacles, especially if the obstacles are people. It is crucial that people are treated in a fair manner. It could be hard to get rid of all obstacles so it is

necessary to evaluate what are the big obstacles and get rid of them. Managers are often an obstacle. They are afraid that changes do not produce the same profit and could try to slow down the change or terminate it completely.

M. Lynne Markus writes about three theories of resistance:

- People Determined
- System-Determined
- Interaction Theory

People Determined is when people show resistance to technology

System Determined is when the new technology is not user-friendly which leads to people showing resistance.

Interaction theory is when people show resistance to the new technology. Markus emphasizes that it is not a combination of the two earlier mentioned, but rather when resistance comes due to shifting of power within the company (Markus, 1983).

After interviewing a project manager from a medium sized contractor it was clear, that he was an obstacle for implementing an ICT system that craftsmen could have access to, and would improve productivity on the construction site. He considered it his job to receive new information on email, print and file them. Possibly this resistance rose from a fear of losing his importance and power.

Create Short-term Wins

Short term wins are important to keep the momentum in the team. Most people want recognition for their work. There are no short-term wins then there is risk of

the team members joining the resistance.

In the case of implementation of an ICT system on the construction site, it could be considered a short-term win, when all craftsmen have learned and started to use the system.

Build on the Change

It can be fatal to celebrate to soon. Changes take time and it could take years for changes to sink in and become an established part of the daily routine. It is often a

combination of change initiators and change resistors that create the premature victory celebration (Kotter, 1995).

After implementation is it important not to dissolve the change team. Over time there are always some new demands that arise and new changes to tackle.

The construction site is still a low tech environment. (Azimi, Lee, AbouRizk, & Alvanchi, 2011). Therefore, it is crucial to have a good service contract with the system developers.

Anchor the Changes in Corporate Culture

Successful transformation is when a change becomes a norm. That is, it is part of the job or just like turning on

the computer. But it is necessary to constantly show people how the new change has improved the work process. When people are on their own they tend to use the systems as they think is best, working around how the systems are intended to be used. This behavior has to be confronted and a solution to the problem implemented. Another risk is when the people that led the transformation quit and there is no one

left to talk in favor of the changes made. In some cases companies think that changes cannot be undone. That is not the case. It takes just one skeptic manager to rewind the company to the old ways of doing things.

10

Discussion

This chapter sums up the main inspiration for completing this thesis, the results obtained from the need's analysis, the problem statement and the proposed solution in order to improve access to digital information for craftsmen on a construction site.

The motivation for making this project, is the authors own experience from construction sites, combined with the fact that the ICT development in the construction industry is trailing other industries (Jakobsen & Øbro, 2010). To support this, a survey and interview with experts in the building industry was conducted and the results from the need analyses in chapter 5 show clearly that there is a need for on-site ICT systems.

Analyzing the building industry as a whole, showed that the construction industry is slowly adapting to the digital age (Byggeri & Newinsight, 2011). The majority of actors in the industry are using one or more ICT tools to organize their activities (Jakobsen & Øbro, 2010). The problem is that when contractors receive digital information they do not pass them on to the construction site in digital format. Instead they print the information which makes it difficult for the construction management to have a complete overview of the newest information. Currently, the effort of implementing ICT tools on-site, are mainly targeted the administration level, and not the craftsmen.

According to the results of the authors survey and a survey made for the Danish Construction, Project managers and craftsmen's did not agree on whether ICT should

be accessible for the craftsmen on-site. The survey results presented in 5.2, show that 73% of the responders would be willing to use an ICT system if it was available but in the other survey only 1 of 110 managers that answered, said that the craftsmen should have access to ICT. This could be one of many reasons why the ICT development is trailing other industries.

Architects and engineers are in most cases using CAD tools and project web systems to organize their information. Clients and suppliers are slowly seeing the advantages of ICT. The contractors are, on the one hand using ICT for take offs and tendering, but on the other hand sending the received digital information to the building site. Instead they in most cases print the information and send the paper-based information to the construction site (Figure 37).

One very important function was left out due to lack of time. This function is the feedback option, where craftsmen can write comments about how the work was performed and if there were any complications. This function could give the client and the operation and maintenance viable information about how the building was constructed. Doing this from day one gives a much accurate "as build" model instead of throwing some useless documents into a folder after the building has been handed over to the client.

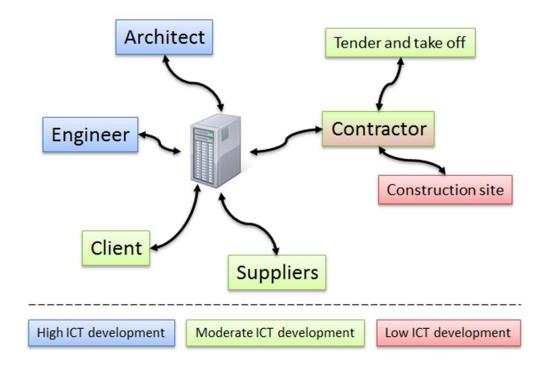


Figure 37 the author's opinion on the ICT development in the construction industry.

11 Conclusion

Although new client demands put forth by The Ministry of Economic and Business Affairs only apply to government-supported construction, it was concluded that private clients are also starting to demand digital work. That should motivate actors in the construction industry, to increase the use of innovative ICT systems on the construction site.

The results of the needs analyses (chapter 5), reveal that craftsmen are willing to use ICT systems on the construction site, and consider them an asset. When comparing these results with a survey made for DB, it became apparent that craftsmen and managers have opposing views when it comes to the matter of on-site access to digital information. The majority of managers think ICT systems are too time-consuming and do wish to incorporate their use more on-site for craftsmen.

These contradicting views were the main motivation for designing an ICT system that could benefit both managers and craftsmen.

A stationary ICT system was chosen due to the difficulty for the craftsmen to operate mobile devices in the harsh environment as a construction site can be. This also provided the opportunity to develop a user-friendly ICT system that craftsmen and managers, with different IT skills can use.

It was recognized that doing a paper-based prototype was very helpful, due to the short time it takes to sketch up a prototype in accordance to needs. It was concluded that a paper-based prototype was not the easiest to test with users. Therefore a semi-functional prototype was made with the application, Power Point, to be able to test and get feedback for further development. The power point prototype was used to introduce both the idea and the main functions.

Although the PowerPoint prototype turned out to be too complex, it gave valuable input for further development.

Two functional prototypes were made, a web-based and a desktop application. It was concluded that the web-based prototype was quite easy to make and rather easy to add functions to. However, when it came to making more specialized functions (not downloadable from the CMS website), it was harder and required writing complex programming code, which was impossible to do in such a short time. The desktop application was developed with the help of three IT students. This prototype was tested, focusing on the user interface (how easy it was for the user to intuitively navigate the system), and the test persons overall impression, regarding system use and potential. Test persons gave valuable feed-back which was used to better the system further.

As seen on the redesigned flow model in 7.2.1 the project manager does not longer have to receive emails with information and print them for reviewing. As the system is connected to a project web server, he can review them on the screen and when approved they are automatically available on the ICT system to other actors in the project. He can also assign tasks to craftsmen and supply a link to the relevant information. The craftsmen then get a notification via SMS that there is a task waiting for him on the ICT system or changes have been made to the information he is using.

The results from the usability test showed that it only took testers an average of 70 seconds to find and print a selected drawing without receiving introduction to the system before performing the test. The reason for managers thinking that ICT systems are time consuming is probably because of their lack of IT skills or bad experience operating an ICT system on the construction site.

After redesigning the work process, some opportunities were recognized to increase productivity. If both the manager and the craftsmen receive information about changes as soon as they are made, the manager can assign new tasks to the craftsmen while the updated information is being processed. That way, the manager can manage his resources better and fewer mistakes are made.

This thesis concludes that the building industry can be a conservative environment, in which it is hard to show the managers the true value of ICT on the construction site. However, with a user-friendly ICT system and a good implementation strategy, the barriers between the designers and the construction site are minimized and increased productivity is achieved.

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Appendixes

Appendix 1: Internet survey

Appendix 2: Diary from Kick-start weekend

Appendix 3: Usability testing

Appendix 4: Overview of web and mobile applications

Appendix 1

Quantitative survey

Din alder?

It is important to know the age range to be able to know if there is a connection with IT usage and age.

Hvad er dit fagområde?

Some of the craftsmen tend to be more IT orienteered than others. It is there for interesting to know if there IT usage can be linked with trade

Hvordan vil du beskrive dine IT komptencer? - Mine IT kompetenser er...(...non,...low...average,...high,...super user)

This is a key question in the survey. It is crucial for the author to know, what is the IT knowledge to be able to focus on the right places when designing the box.

Har du adgang til digitalt projektmateriale på byggepladsen? - Tegninger, beskrivelser m.v.

The author was interested I knowing if the access to digital material was a common thing on-site

Hvilken slags mobiltelefon har du?

This question is twofold one was to know if the authors idea of sms message when changes are made. The other reason was to investigate how much craftsmen could be ready to use smartphones.

Har du anvendt mobilapplikationer på byggepladsen? - Med mobilapplikationer menes programmer til mobiltelefonen, hvor du f.eks. kan lave kvalitetssikring eller udfylde timesedler.

The author did some research of what kind of mobile applications are available today therefor was he interested in knowing if craftsmen are using some of them.

Har du brugt projektweb på byggepladsen?

This is another key question. Mainly to investigate how many are using a project web system. This was also to give the author little inspiration to try to improve the usage of a project web systems.

Hvordan ved du, at du har de nyeste informationer i hånden, når du skal udføre en opgave?

This question was asked to get overview of methods used to communicate if there are changes made to the information. Also to see what is the ambition to know that the craftsmen are actually using the newest information.

Hvis et IT-system var tilgængeligt på byggepladsen, ville du så bruge det? - Et stationært IT-system med touch skærm og A3 printer, som kunne sikre, at du altid har de nyeste opdaterede informationer i hånden.

This question is twofold. One thing was to find out if the construction site could fulfill the new legislation. Second was to prove for the author that his idea for a information management system could work and be used on the construction site.

Tror du, at IT kan være med til at øge produktiviteten på byggepladsen?

This question was to get the craftsmen opinion of the usage of IT and if they thought it could improve the productivity. They had also a text filed were they could express freely why they thought it would improve the productivity.

Appendix 2

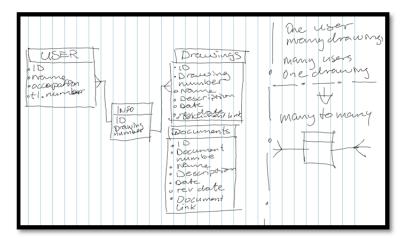
Diary from Kick-start weekend

AAU has a great network for entrepreneurs. One of them is Kickstart. Kickstart is for students who have an idea but don't know how to go further with it. That is exactly the authors ease. To optimize the information flow on the Building site the author came up with the idea of a stationary box. This box includes a computer, a printer and a touch screen. As mentioned the range of IT Knowledge is big. And conditions are also very different between building projects. Just to name one reason why a stationary system would work better on the building site. Imagine a carpenter standing on a scaffolding, in high winter when it is snowing and ÷ degrees outside. Could he have an iPad hanging in his belt or even could he operate a smartphone in these conditions? I think the answer to this question is pretty clear.

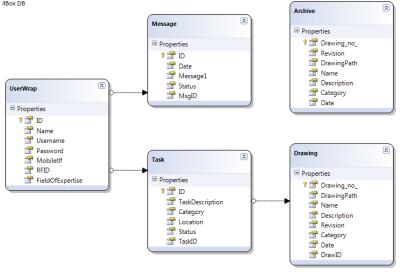
The Kickstart weekend started 17.00 on a Friday with networking and then 19:00 people with pitched their ideas. One minute was given to each pitch. In all 28 ideas were pitched. Afterwards the students attending this Kickstart weekend choose their favorite. Top ten ideas were found and their leader tried to sell the ideas to the people he needed to work on his idea. The author's idea was one of those ten lucky ideas and the author was able to gather a fantastic team. The team was build up with 3 software developers, a graphic designer, a global business engineer and a technical Integrator. The authors roll was then to lead this group. This scenario was exactly like it would be out in the real world. The courses CSTBI have been taking had been a tremendous help. Courses like "ICT knowledge", Contextual Design, strategy, project management, and Implementing IT in organizations, just to mention a few. Of 70 participants the only one with a construction background was the author himself. This made it even more challenging. To gather data to see what functions should be included a

Contextual Design methodology was used and Universal Design method to design the interface. At first the author had the role of a craftsman because of his prior experience from the construction site. The team had a session of open interview to the author which became more of an discussion of the building industry in Denmark and how an information management system could help the construction industry. The

rest of the team was quite interested in hearing about the construction industry. They had never imagined that it was in the position as it is today. The team had only this weekend to finish a working prototype and to



present it for 5 minutes on Sunday night. Saturday morning brought the box with him that had been mounted with a touchscreen. The author had also found a name for the box. It got the name Cimbox, which stands for Construction Information Management Box. A website was developed to introduce the cimbox to the world the link is /Box DB



www.cimbox.com.

The 3 software developers are currently on their 3rd semester in computer science study. C# was chosen as a platform for the box. The reason for choosing C# was

very simple. The software developers had the most experience in that programming

language. Some other platforms were discussed. Like Java and a web based system. SD started by receiving a simple sketch of how the database should look like which can be seen on figure x. It was obvious that they had done their homework. It took them under an hour to make a database ready with some additional tables and connections. The author could see that what he had been studying in the course "ICT and Knowledge Representations" was of great help. Not only too understand what the developers were doing but also to get a better overview of the software development and to be able to manage the resources in the whole team.

The moment of truth was Sunday night. A 5 minute presentation was prepared. I got help from one team member to make a little play. He got the roll of a engineer implementing the ICT system on my construction site. That way we could introduce the system and have some humor along the way. Needless to say we got a lot of laughter but the crowd thought it did not lose the professionalism so the presentation was a success although it did not get us the first prize.



Figure 38 Finished physical prototype

It was priceless for me to get a glimpse into to the business side of making a system like this. A business model canvas was made that can be seen on the next page.



Figure 39 the author introducing the overall functions of the system

The Business Model Canvas	Model Canvas	Designed for: cimbox cimbox com	Designed By: Haraldur Amorsson Iteration	On: 08-11-2011
Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Hardware suppliers Universities	Managment consulting Analyse induvitual solutions and implementation Design software and hardware Design Software development Sales/marketing Laywer Administration Facilities Transport Service and support Consultants	errors ces nformation flow sss to the	Feephone Email Meetings Hjerrimeside Subscription Solgt/rented with all hardware included Service cars Company account Pay per project	Building owners Contractors Engineer consultant companies
Cost Structure		Revenue Streams		
Fixed cost Facilities Transport Salleries Variable cost Hardware		3 months in advance a; a insurance Choose what kind og functions, servi Monthly or anual payments	3 months in advance as: a insurance Choose what kind og t _u nctions, service and support. Monthly or anual payments	

Figure 40 Business Model Canvas for the CIMBOX



Figure 41 the team that I managed to gather. f.l. Me, Kenneth, Michael, Morten, Jakob and Natasha



Figure 42 Picture from our presentation.

Appendix 3

Pre-interview for prototype testing

Test	ter:	

Tester age				
☐ 16-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ over 66	The age range of the testers was from 16-45.			
How would you describe your IT knowledge?				
□ None□ Low□ Medium□ High□ Super user	The IT skills 1 Low 1 Medium 1 High 2 Super users			
What is your trade?				
Four of the testers had experience from the construction industry. The one that didn't				
is studying to become a teacher.				
What is your first impression of the box?				
After a short introduction the author asked what the first impression of the system				
was. All the participants thought it was very professional. One tester asked where the				
laminating machine was. That is a good idea to have such a machine bud it is not				
relevant to the system itself.				

Task to perform

Task 1:

1. Login with the ID card

Did you find the ICT system easy to operate?

- 2. View drawing number 0003/Floor plan
- 3. print the drawing
- 4. Logout

Task 2:

- 1. Login with the ID card
- 2. Search for drawing that has the name "Floor and Ceiling plan"
- 3. View the drawing and then print it
- 4. Logout

Participant	Time to complete Task 1, in seconds	Completion	Time to complete Task2, in seconds	Completion
Α	44	Successful	62	Successful
В	81	Successful	80	Successful
С	48	Successful	65	Successful
D	60	Successful	70	Successful
E	52	Successful	80	Successful
F	63	Successful	64	Successful
Average	58	Seconds	70	Seconds

There were no errors that were registered during the actual test. The only downside to the test was the slow response from the Touchatag RFID server. This problem could be solved with a RFID system that connects direct to the same database as the system is running on, rather of having to connect to an internet server.

The general opinion was that the system is easy to operate. No tester had problems to navigate to the right place. The buttons were easy to read. The only problem was with the RFID login due to slow connection to the internet server that hosts the usernames.

Is there something that you think is missing?

One participant mentioned that it could be good to have icons on the buttons. The author agreed to that point. He had that also in mind when the interface was designed. But time and resources did not make it possible to implement. But that will be done in the final release.

If a system like this box was on the construction site, would you use it?

Participants could easily see this kind of system on the construction site. Participant C is an electrician; he said it would be fantastic to have the newest information in one system that would also notify of changes.

What actor in the building industry, do you think would benefit the most from such a system?

All participants were unanimous that all actors in the construction industry could benefit from such a system. One mentioned that maybe the client could gain the most from it. Because of the it would minimize errors and therefor increase productivity

Wrap-up interview after prototype testing

Appendix 4

In Table 6 is a list over popular ERP integration applications that are being used in the construction industry.

Table 6 Overview of web and mobile applications in use on the construction site (bips, 2011).

	Document management	ERP-integration	Job management	Quality assurance	Materials management	Planning	Barcode scanning	Time sheets
BC Pro		х						х
Caddie		Х			х			х
EasyTime		Х			х			х
EVA 2000		х	х	Х	х		х	х
LMe-mobil		Х	х		х	Х	х	х
NetMill		х	х		х	х	х	х
Qmanager	х	х	х			х		
REEFT mobile		х	х	Х	х	х	х	х
StarTime		х					х	х
Timesed- ler.dk		х						х
WPA		х	х	Х	Х	х	х	х

The above table is taken from bips U102, Overview of mobile for contractors. The table has been modified so it fits the purpose of this thesis. Only solutions that can integrate with ERP system as shown.