UNIVERSITY OF AGDER

Improving Construction Site Documentation Based on Cell Phone and Web Technology

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Thesis submitted in Partial Fulfillment of the Requirements for the Degree Master of Science in Information and Communication Technology

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University of Agder

Grimstad
May 2010

CONFIDENTIAL

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May 20th, 2010

Abstract

In many construction companies it is a policy that all the work done on construction sites must be documented. By studying how the pilot customer documents their construction work, we found that their documentation methods were inconvenient, and therefore, on some occasions, not done correctly. Currently, the documentation is based on capturing construction images with a digital camera and writing checklists on paper. When the documentation is done, it is manually archived.

The intention of this project was to create an alternative to the manual documentation process, which is currently in use, by creating a prototype cell phone and web application that can do the construction site documentation work digitally.

By working in collaboration with Oras Agder, the project group was allowed to carry out onsite observations of the current documentation work done on construction sites. The functional requirements described in this document are based on the onsite observations and the information provided by Oras Agder. The prototype was developed by following a user-driven, iterative process to be able to meet the end user's expectations.

The implementation resulted in a web application and a cell phone application. The web application can be used both in the planning and the building phase of a construction site. It is used by the project managers to split the construction site blueprint into areas, and attach checklist templates to these areas. They are also able to check the progress of the construction site directly from the prototype.

The cell phone application is used by the construction site workers onsite. The cell phone application can be used to document the work that has been done by capturing images or creating checklists, and then attach them to a location on the construction site blueprint.

The project requirements were fulfilled during a total of approximately 3000 man hours. The feedback from the end users, during the project and at the end of the project, has been positive. The project managers are able to easily keep track of the documentation progress, while the workers easily can document their work.

Executive Summary

The executive summary provides an overview of the work done and the prototype developed with the preliminary name ByggDoc. The executive summary is meant as an information source for the customer by presenting the usage and benefits gained from using ByggDoc as a documentation system on construction sites.

0.1 Introduction

ByggDoc was developed because of the poor and labor intensive documentation procedures that is often found on construction sites today. The application will improve the existing procedures for documenting the different tasks performed on construction sites. This involves taking photographs and filling in checklist by using web and cell phone technology.

This report documents the work done both for the prototype development of ByggDoc and the research done on how to best document building projects.

The project owner is Red Rock AS which is a company founded in 2009 that focuses on developing quality software for web and mobile platforms.

The work is done in cooperation with Oras Agder AS. They are the pilot customer for the ByggDoc product that is built as a prototype product.

0.2 Project Approach

For this project, Agile development was used. Agile is a development method that includes breaking the tasks down into user stories. This method was successfully utilized in cooperation with the pilot customer

Oras Agder AS.

The first step of the project was to examine the current documentation process at a construction site. A qualitative research method was used to collect and analyze the data. Several concepts were created and compared to match user needs and expectations. Based on these analyzes, a design for the application was made. The main goals were to improve the quality of the construction documentation, make the process more convenient and reduce errors.

The tasks were then broken down into user stories and the various sprints were planned. There were deliveries every 2nd week to the customer. After all the sprints were done, final testing and validation commenced. All the features were implemented and all the test cases were successfully completed.

0.3 Construction Site Documentation

Construction site documentation is done in different ways in a variety of companies, but many of them still use paper based solutions. Typically, it includes checklists for various parts of a building and also image documentation for the work completed. This approach has several disadvantages; some of the disadvantages are listed below.

- **Slow updates** - It takes some time from the documentation is made to the project leader can viw it and check the progress.
- **Easy to lose** - Paper documentation can get easily lost or destroyed.
- **Time consuming** - Documentation is time consuming when it is done in a way that clearly describes what is documented in the images.

0.4 Implementation

The implementation of the prototype product ByggDoc uses three major components, a cell phone application, a web application and a web service. The cell phone application is intended for use in the field, both to make and view documentation. The web application is intended for use in the office by the project leader to view documentation and add documentation requirements to a project. The web service is used for communication between server and cell phone.

The main task for this project is to improve the documentation procedures mentioned in the previous section. The following list represents the basic objectives for each part of the implementation:

- **Cell Phone Application** - View construction blueprints, select rooms and documents by either taking pictures, writing comments or filling in checklists.
- **Web Application** - View construction blueprints from a web browser. Either select, edit or create rooms, checklists, pictures or comments.
- **Web Service** - Handle communication to both the web application and the cell phone application.

0.5 Product Usage and Benefits

There are several key customer benefits in ByggDoc; some of them are major improvements to the current way building documentation is created, accessed and managed. The key customer benefits are presented in this section.

For both the cell phone and web client, the prototype makes it easy to store data. There is no longer a need for the company to categorize the data; everything is handled by the system, which significantly reduces the required manual tasks. The customer only has to provide the raw data, and the system handles the rest. As a result, the prototype helps the company save time, resources and money.

The product performs consistently over time and has no unscheduled downtimes. Because of the low maintenance, repair costs and attention, it allows the customer to focus more on tasks related to the core business and increases overall productivity for the company.

A further improvement is that documentation done on construction sites with the prototype is more likely to be free of errors than with previous procedures. Incorrect project numbers or locations is a thing of the past, as the system provides routines to validate all entries. The system also ensures that information is never lost, with a digital backup of all the data provided.

The product can be used by both cell phones and web browsers, but the customer can choose from a wide selection of clients. Any of the most popular browsers that exist today can be used. This includes Internet Explorer, Mozilla Firefox, Google Chrome, Opera and Safari. Since the heavy calculations are handled server side, the hardware requirement is very low, and almost any kind of web client can be used. The cell phone prototype is developed for Windows Mobile 6.5, which gives a wide selection of phones to choose from. The product is still in development, but when the product is officially released, all types of operating systems for smart phones will be supported.

0.6 Conclusion

As it is today, documentation is often skipped because of the time consuming procedure that often leads to more confusion rather than results. It is expected that the introduction of ByggDoc to the market will lead to increased quality in documentation procedures and a general increase in documentation usage.

The prototype is fully implemented and all the test cases are successfully completed. Oras Agder AS give positive feedback on the prototype and think it will significantly improve the quality of their construction documentation. One of the feedback given was:

"I wish we had this application earlier. The documentation procedures is now more complete, accurate, timely, in electronic instead of paper form, and thereby more reliable and more easily accessible throughout the process, and a very valuable contribution to a future facility management system."

Even though the prototype is a good product to have for any kind of company working with construction blueprints today, future versions will be even more interesting. Support for 3D blueprints, facility management features and indoor positioning is only some of the features that are under consideration.

Preface

This project was performed for our own software development company, Red Rock AS. Red Rock AS is an innovative software development company that specializes in web and cell phone applications. We founded the company in 2009, and our office is located in Grimstad, Norway.

Both Grimstad Næringsråd and Innovasjon Norge have shown great interest in the product. Red Rock have already received helpful support from Grimstad Næringsråd, and an even larger support from Innovasjon Norge looks very promising at the moment. The product development has been the primary focus for Red Rock AS these past few months, and will hopefully get an even larger focus as the scope of the project increases in the near future.

While writing this report, a pilot has been developed for the new Agder Energi office building construction site in Kristiansand. The pilot has been developed for Red Rock AS, in collaboration with the construction firm, Oras Agder AS. The preliminary title for the product is ByggDoc.

We would like to thank Oras Agder AS and our supervisor, Stein Bergsmark, for suggestions and inspiration.

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Grimstad

May 2010

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Chapter 1

Introduction

This chapter will present the background, objectives and some of the contributions for this master thesis. The background is important, because it represents a basic need that several construction firms currently have in regard to documentation procedures. These needs will be even more clear when customer benefits are presented later in this chapter. Literature review is also an essential part of this chapter, where the relevant research areas within mobile technology and document managing will be mentioned.

1.1 Background

Nowadays documentation on building sites is usually a demanding process. Several construction firms have strict policies on how documentation should be executed. In most cases these policies include check lists, capturing images and a tedious categorical sorting of data. Some companies have existing systems for the data sorting, whereas others sort the data manually. Nevertheless, an alternative system for the mentioned procedures would be a welcomed contribution to the construction trade.

As background for this master thesis, a thorough investigation of current practice in the field has been carried out. Oras Agder AS was chosen as the pilot customer for the new system and was of great help in the background research. On-site observation of workers performing the documentation procedures has played a central role in the study. A more detailed investigation has also been carried out, where interviews and meetings with workers from both construction sites and office administration has resulted in the goals and objectives presented in this report.

1.2 Problem Definition

On most construction sites today, every wall, ceiling and floor must be documented throughout the entire building process. In the plumber or carpenter profession for instance, the paperwork required for these procedures is both expensive and time-consuming.

Because of this, a digital solution for documentation in construction sites could prove to be an alternative for companies with a high production rate. There are many challenges in regard to this domain, and before any sort of development can be started, extensive research on how the documentation is done today must be undertaken.

The new solution must be familiar, easy to use and work on multiple platforms. To complete a thorough and meaningful background research, an agreement with a relevant construction firm is essential. With a connection to a construction firm, several important steps can be done before the development starts. The project sponsor for this master thesis is Red Rock AS, and they have provided the necessary connection to a construction firm. The project group will follow a user-driven, iterative development process to be able to meet the end users expectations.

1.2.1 Main Goal

The project has one main goal and several objectives. The main goal is as follows:

- Greatly improve the documentation process on construction sites by making use of mobile clients, web technology, and supporting back-end systems.

1.2.2 Objectives

The objectives are meant as a more detailed description of the main goal. The following objectives are essential for the success of this project.

- Carry out a study on how the existing documentation procedures on construction sites are done today.
- Convert the raw construction site designs to a format suitable for both cell phones and for a web interface.
- Easy and user-friendly methods for navigating within the construction design for both the cell phone and a web interface.

- Make use of positioning technology to suggest the nearest building sites with construction designs available and show the results on a cell phone.
- Capture images with a cell phone and link them to the building designs at the current position.
- View the documentation overlay by navigating within the building deisgns and selecting the room, wall or ceiling that is of interest.
- Set up a server that handles all the communication and storage operations.
- Integrating the pilot in Red Rock's existing user and customer service.
- Add administrator functionality to the web interface that controls both new and existing users/-customers.

If Time Allows

If time allows, additional objectives will be considered. These objectives are not essential for the project to be a success, but will improve the functionality of the final product.

- Add points on the construction designs that describe the corresponding features on the drawing.
- Orientate the construction design based on a cell phone's built-in compass.

1.2.3 Key Assumptions

To get the work done some important parts need to be in place.

- **Cell phone technology**

  A requirement for the pilot to succeed is the built-in hardware in the cell phone. There must at least be a compass, accelerometer, camera and preferably a GPS. Without these components, several functional requirements will be hard, if not impossible to complete.

- **The company testing the product will be available**

  It would be difficult to know how to improve the documentation of a construction site with new hardware and software if there was no communication with the people that utilize it. A natural assumption is that the company testing the product will be regularly available to test the application and to inform what the documentation needs to contain.

- **Construction plans will be available**

  The solution needs to contain a way to view construction plans on a cell phone. Plans from a relevant construction site must be available.

1.2.4 Limitations

The scope of this project is quite large. Therefore some limitations are needed:

- **Not all devices will be supported**

  There exists a large number of different cell phone models and platforms. This application will only be customized for one or more cell phone models. It would be natural to expand it to work on more models when it progresses from a prototype to a fully functional product. Due to the time limits of this project, this will not be attempted.

- **Indoor positioning**

  No automatic indoor positioning will be attempted. If an indoor position is needed, the user needs to supply it.

- **The pilot is the first prototype release, R1**

  The pilot developed will be the first prototype, release 1. Because of the project size, it is not intended that the pilot will be released as a complete product.

- **Depending on the information provided by the construction company, changes in the specifications might happen during this project**

  The initial functional requirements described in this document are based on the information provided by the construction company, and our onsite observations. The specifications might need updates during the project, but due to time constraints it might not be possible to update the implementation accordingly.

1.3 Literature Review

There are several different research areas that are relevant for the this project, these include research on mobile technology, electronic document management and building information modeling.

1.3.1 Electronic Document Management

Electronic document management (EDM) are often web based solutions, that are designed to manage and distribute project documents. This work focuses on the process of documenting the work done on a construction site, which is an important part of EDM. Typical documents that will be stored are check lists and photos of various parts of the building or building components.

EDM systems in construction are discussed in the paper 'Use of document management systems - a case study of the Finnish construction industry' [39]. This paper is based on interviews of key personnel on 100 construction projects in Finland. The research has several interesting findings that can be of use in this project.

One result showed that the necessary technical infrastructure (Internet connection) was sufficient most places, even for large files like ".CAD" blueprints. These is results are from Finland and might not be comparable other places in the world, but there should be similar results in Scandinavia. The result does not say anything about the availability of wireless bandwidth, which is an an important factor in the work done in this project. The results also found that the usage of EDM system differs considerably from user to user[14]. It is important to consider this when designing a new system that handles building documents.

The main obstacle for the use of EDM systems was found to be that key persons in the project would consider it too much work to use and adopt the system. Easy setup and use is an important factor when designing this kind of system and has to be taken in to account to make a successful application.

One of the key benefits of using an EDM system in a construction project is that it can add value later on when the building is done and goes into a maintenance phase. This can even affect the selling price of the property.

1.3.2 Building Information Modelling

Building Information Modelling (BIM) is a new way of handling data for the designing, building and management phase of a building. The purpose of BIM is to increase productivity by real employing time modelling of the building data[7].

Some of the benefits of using BIM include reduction of errors and that data need only be stored in one location [5].

In a study about the impact of the implementation of BIM on construction project, positive results were found for quality, on-time completion and units per man hour [13].

The application built will, in its first stages, mainly target contractors. Market surveys conducted about BIM concludes that the primary drivers of BIM are architects (40%), contractors are only considered to be the primary driver in 1% of the cases[6]. This might change in the future, but a full BIM implementation might not be useful before the application is developed farther to include more than contractors.

The pilot customer for ByggDoc, Oras Agder AS, is seeing more projects being planned using BIM software. It is important to build this application with the goal of making it BIM compatible in the future.

1.3.3 Cell Phone and Network

The company comScore is a resource for mobile industry metrics, where they study everything form market sizing and megatrends to specifics on device usage and applications adoption. Their February 2010 report from the US mobile market share, points out that the Smartphone platform market share is increasing rapidly. At the end of February 2010, 234 million Americans above the age of 13, were mobile subscribers. 45,4 million of the subscribers owned a smartphone. The study also points out that the number of people owning a smartphone has increased by 21%, from a period of September - November 2009, to a period of December 2009 to the end of February 2010. The comScore study is backed up by the study by Gartner Research, which shows that the worldwide smartphone sales in the second quarter of 2009 were strong. 40,9 million smartphone devices were sold, and it was said that smartphones is the fastest growing market segment. This shows that there is an increasing trend of purchasing smartphones amongst consumers worldwide, which gives a pointer that developing software for smartphones could reach a high amount of people. [8, 15]

Cell phone trend reports is AdMob's speciality. Their reports are based on the ad requests they receive from their network of more than 15000 mobile web site and cell phone applications. An interesting result that was found in their February 2010 report, shows that worldwide handset network traffic is increasing fast. Smartphone traffic has increased from 35% to 48% within a year. Featured phones declined from 58% of traffic to 35%, while mobile internet devices, like the iPod touch, experienced a growth which increased their account to 17% of the traffic in AdMob's network. [27]

Long term Evolution mobile network, is one of the most important happenings within mobile network technology. The Global mobile Suppliers Association has released a paper that points out that LTE is the next step for a superior mobile broadband experience and is an evolution of the GSM/WCDMA-HSDPA system. The LTE mobile network will give enhancements to capacity and data rate, to support new services and features. It is believed that the need of performance will be vital, regarding the new services and features that will come.[17] The ByggDoc is one of these applications that will require a cell phone network with a higher bandwith than EDGE to work as expected. This is in context to the the image

tile loading and communication via the webservice.

1.3.4 Web

Cloud Computing is increasing in popularity, which centers on software as a service (or SaaS) such as Google Apps. With the SaaS-model, the customer or enterprise does not own either the software or the infrastructure. They only pay a subscription fee to the SaaS provider to use the application.

The paper "Getting It Right with SaaS" [35], published by Infosys in 2010, goes through the benefits with SaaS for enterprises and finishes with an interesting conclusion.:

"SaaS can give organizations give the best of both worlds - a best-fit, state-of-the-art technology platform that is cost-effective."

This is one of the main reasons why SaaS was chosen as an important business case for this project. SaaS enables business users to be more agile, and decreases the total cost of ownership, which is probably the most important factor for organizations investing in new systems today.

1.3.5 Qualitative Research

Qualitative research methods enable researchers to study social and cultural phenomena. The book, Qualitative Research in Business and Management by Myers M. D.[29], discusses the use of qualitative research in all of the business disciplines. This book goes through various research methods including observation methods, documents and texts, interviews and questionnaires and the researcher's impressions and reactions. It has been an important resource when developing the methods presented in chapter 2.

When selecting the data analysis method, a detailed investigation of existing methods was performed. Perhaps the most interesting read came from Donald Ratcliff, which has collected 15 methods of data analysis in a well structured document [33]. Among other things, the document mentioned the Constant Comparison/Grounded Theory, mainly developed by the American sociologist Anselm Strauss[2]. It went through several steps that was well suited for the upcoming data collection, and was chosen as the data analysis method.

1.4 Approach

The ByggDoc background research and prototype development will require a large amount of study and development hours. An involvement from a company that has experience with this kind of documentation

may also be a key factor to success. Red Rock AS has already found a company named Oras Agder as an involved partner. One of the first stages after making contact with Oras Agder will be to find out if there exists any solutions for doing this kind of electronic documentation already. The study will give Red Rock AS an idea of who the competitors are, and what they have produced. IEEE research papers will be a useful source for collecting relevant data.

Background Research

The product is going to be used by a different set of customers. Some of them are going to be on the construction site using a cell phone, while others will be following a construction site project from their office, using a web browser. The project group have to come up with several concepts, which can be shown and evaluated by the end users. By doing this the project group can find out whether the proposed concept met the end users expectations or not. This process may give new requirements that will improve the product.

It will probably be three types of users for ByggDoc, project managers, construction site workers and administrators. Project managers will use both the cell phone and web browser version of ByggDoc, and construction site workers will mostly use the cell phone version. Administrators is typically the developers or company that sell the product, which can add or edit customers. To do proper documentation, an understanding of what is needed by the application is vital. By visiting a construction site and taking interest in the work that is done there, the project group can get a better understanding of how the construction site workers and managers need to document. A visit will also increase the knowledge of what is needed of hardware to make the application as good as possible.

Project Structure and Design

The project group should by now have many ideas of how the application should look and feel for the users, and it is of great importance to create a well-structured application and database. The project group therefore has to meet with some of the responsible people within Oras Agder to write the specifications. This will include the making of work packages that should describe application features, and what is expected when the various work packages are done. A later stage of the project process will include the making of test cases, since it is important to deliver an application that is thoroughly tested.

Designing a database will also be done in cooperation with Oras Agder, where a discussion between the project group and Oras Agder will bring forward an idea of how the database should be structured and designed. A class design should also be created for both the cell phone application and the web application, so that the developers involved have a structure to refer to when starting the development process.

Algorithms and Routines

A cellphone has a very restricted screenspace which makes it difficult to use for interaction and to browse

large amounts of data, like a construction site blueprint. It is therefore important that the project group studies algorithms that can ease the work of converting these types of files to a proper format for a cellphone.

When the study of how craftsmen document their work, and the project has been structured and designed, a study of how to convert the large ".CAD" files to a proper format for both cell phones and web should be carried out. It is assumed that the ".CAD" file will be a fairly large sized file, and that the best way to be able to show the converted image file on web and a cell phone, should be to split the image tile into a large amount of tiles, so that the application can choose what segment of the construction design it wants to show on screen. By assuming this, it is important that the project group studies different algorithms and routines that can split the converted image file into a large amount of tiles. If any algorithms or routines are found, it will save the project a considerable amount of work.

The study of converting and splitting an image should lead the project group to an idea of how the tiles should be visualized, both in a web browser and on a cell phone. One of the requirements for the cell phone application will be that there should not be a large amount of image tiles shown on the cell phone at the same time, since it has a larger restriction on memory than a desktop computer has. The image tiles will be stored on a server, and therefore it is even more important that the cell phone does not show any more image tiles than necessary. There must be written an algorithm that only shows the image tiles that are necessary to show, or an already existing algorithm that does this must be found. A projection method should also be worked out, so that both the web application and the cell phone application should be able to show points of interest and documentation points, at the correct coordinate on the construction design.

Product Development
Most of the studies should be done by now, and the development process should be started. The project group prefers to use Agile development. A schedule of work tasks will be created and followed by delivering work each week. The developers will test code segments, and use test cases to ensure that the code segments works as they should. The developers will document their work by commenting the functions or code segments they have created. Some of the more challenging code segments or functions, will also be written to a document that Red Rock AS may have use for later.

During the development stage, Oras Agder will get some showcases of both the web application and cell phone application, so that they can give feedback on what needs to be done differently or added to the applications. This will ensure that Oras Agder get the features they want in the product, and that the product is well qualified for use in other companies that may have use of this kind of application.

Validation by customer and potential users The project is following a user-driven, iterative development process, where the developers works in cooperation with the end-users to get user feedback at

development time. This process can help improve the prototype before release one(R1) of the prototype. Before R1, the customer will validate that the prototype has met their requirements and expectations, so that the prototype can be released as a beta version of the product.

Product Release
The final procedure will be to build and deploy a beta version of the product, which Oras Agder will test for several months in a production environment. This procedure will be handled by Red Rock AS, and will not be included in this project.

1.5 Contribution

There are several types of contributions, especially for a software product like the prototype developed for this thesis.

1.5.1 Contributions to Knowledge

Some of the techniques used on the cell phone prototype can be related to map services like Google Maps, but in reality, most of the techniques for the cell phone prototype have been developed from scratch. As for the web interface, Google Maps has again been a source of inspiration, but there are several significant contributions to knowledge that should be pointed out.

- **Displaying ".CAD" files on Windows Mobile 6.5 cell phones and web browsers**

  Since windows mobile 6.5 and web browsers does not support ".CAD" files directly, a method of converting these files to a more suitable format has been developed.

- **Navigating the construction drawings on Windows Mobile 6.5 cell phones and web browsers**

  Since Windows Mobile 6.5 does not have the Google Maps API integrated, a method of navigating the construction blueprints has been developed from concept to finished product. On web browsers more advanced navigation tools have been developed.

- **Selecting, editing and creating areas, rooms or points of interests from a construction blueprint**

  Areas, rooms or points of interest can be selected, edited or created directly when navigating the construction drawings. There is no separation from the viewing- and editing-mode when using the product from a web browser.

1.5.2 Contributions to Trends

As the prototype will be used as a new form of documentation on construction sites, there are several exciting new trends that might occur over time.

- **View and edit digital check lists from Windows Mobile 6.5 cell phone devices and web browsers**

  Up to now, check lists has been viewed and edited on a sheet of paper, where a tedious categorizing procedure followed to categorize the different check lists. Now, with the developed prototype, the check lists are digitalized and can be edited directly on a Windows Mobile 6.5 device or from a web browser.

- **Gather the procedures and tasks that follow both the construction and management of a building**

  So far, the construction and management of a building has been clearly separated. One of the concepts behind this project is to merge them together so that both can utilize the others data if required.

1.5.3 Customer Benefits

User benefits are a key factor in how the prototype will be received by the users. The end user benefits have been in mind during the entire development process, and will probably be the most important factor for a company that want to change their documentation procedures to the results presented in this master thesis.

- **Economically Efficient**
  - Less Manual Work - For both the cell phone and the PC client, the prototype makes it easy to store data. There is no longer a need for the user to categorize data; everything is handled by the system.
  - Less Maintenance - Compared to other systems, the prototype developed requires significantly less maintenance. The user only has to provide the raw data collected, and the system handles the rest.
- **Productivity Increase**

  - Allow Resources to Focus on Core Business - Since the solution requires little maintenance, repairs or attention, the end user is able to focus on more important things related to the core business.
  - Consistent Product Performance - The developed prototype performs consistently over time, and has no unscheduled downtimes.

- **Ensure Consistency**
  - Less faulty entries - the prototype is made so that entries is consistent and error checked.

- **Higher Resell Value**
  - Resell Value Increases Significantly - When the building is well documented, it increase both the buyer's trust and the building's value.

- **Freedom of Client Choice**
  - Browser - Any of the most popular browsers that exist today can be used. This includes Internet Explorer (Version 6.0 - 8.0), Mozilla Firefox, Google Chrome, Opera and Safari.
  - PC Client - Since most of the calculations are handled server side, the hardware required for the web-based prototype is very low.
  - Cell Phone - The prototype is developed for Windows Mobile 6.5, but when the prototype is officially released, all types of smart phones will be supported. This gives a wide selection of cell phones to choose from for a potential customer.

- **Any Place, Any Machine or Cell Phone**
  - PC Client - As long as the client has an internet connection, the web-based prototype can be used at any place.
  - Cell Phone - The cell phone prototype can be used anywhere there is a connection to the user's carrier provider. This gives the user more freedom and is essential for the end user.

1.6 Report Outline

The first chapter of this report introduces the reader to the project's problem definition, goals and objectives, limitations, and key assumptions. The resources used for the survey and the problem definition, is described in the section "Literature review". The section "Approach" explains in detail how the project group proceeded to plan and work out how to create a solution that will fit the requirements. The project

will contribute to both knowledge and trends by making a well thought-out prototype that may ease other people's and developer's work. This will be described in chapter 1, and also includes the user benefits of using this prototype.

The second chapter introduces the reader to the various methods used to research and develop the prototype. One of the most important research topics is the field research that has been done by conducting a survey. The engineering paradigm describes how the project group as developers, solved the tasks that were given. Quality assurance will describe the methods used to assure that the quality of the prototype is acceptable for the project sponsor. The quality of the prototype will also be ensured by using a test program which is described as a last part in chapter two.

The third chapter introduces the reader to the survey of construction site documentation which describes how the documentation of a construction site is currently done. Chapter three provides details about how the blueprints of the construction site is presented to a project manager. The whole chapter gives the reader an idea of how the construction site workers and project managers work at present time, regarding documentation of a construction site. The chapter also shows how the check lists are designed and structured, as well as how the image documentation is carried out. The last section will introduce the different platforms that the project depends on, and what their use is in this context.

The fourth chapter will concern the requirements of the project and how the prototype was implemented and developed. Further on the chapter gives an idea of how the implementation was structured by creating work packages and test cases. The chapter will show how both the web application and the cell phone application were designed and implemented, what development tools were used, and how the prototype were tested. The database design and structure is shown in a section that will give an impression of the complexity of the database structure.

The fifth chapter reveals the results acquired from the construction site survey and the results from the implementation, tests, and user experiences.

The sixth chapter discusses the results acquired in chapter five. The chapter include discussions about the construction site survey that has been conducted, what has been improved by the new electronic document management, and what can be done differently regarding future work.

The seventh chapter gives a conclusion to whether the prototype is better to use than the present construction site documentation, by comparing the construction site survey with the prototype. The chapter includes a section on what features need to be added to the prototype in the future to make improve it.

Chapter 2

Methods

This chapter describes the methods used in this project, both for the background research and the product development. For this reason, this chapter has been divided into two main sections, one for the background research and one for product development. The first part is about the research methods for the data collection and analyzing, and the last part is about the methods used for developing the product prototype. Quality Assurance is also a major focus for this project, and the test program will be presented at the end of this chapter.

2.1 Research Methods

The current knowledge in the field is essential for the success of this project. A specific set of research methods have been chosen to help with the survey of existing construction site documentation procedures. The results from the survey will be used in the development of the prototype, and help improve the final product.

2.1.1 Qualitative Research

Before any suggestions on how to improve the existing documentation procedures can be proposed, an insight in how the current procedures are carried out should be acquired. A qualitative approach was chosen as the best method in the background research and data collection process. Denzin and Lincoln (1994) define qualitative research as follows:

"Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials case study, personal experience, introspective, life story interview, observational, historical, interactional, and visual texts-that describe routine and problematic moments and meaning in individuals' lives."[32]

Qualitative research is normally done in the following sequence:

- Collect data.
- Analyze the data.
- Present the recommendations.

Data Collection

In a qualitative approach, a field observation is a popular method for collecting data. The researcher does field work to observes the natural state of the current domain. Extensive field notes is normally taken during the entire research period which are analyzed in a variety of ways. The approach for the field observation will be presented in this subsection.

Langley, P. (1988) - "Observation involves looking and listening very carefully. We all watch other pople sometimes, but we don't usually watch them in order to discover particular information about their behaviour. This is what observation in social science involves."

To gather qualitative data, there are two common types of observation methods used.

- **Participant Observation** - A demanding qualitative data collection method, but also very common. This method requires that the observer becomes a part of the observed culture itself. The participant observation method often requires months or years of intensive work, because the researcher must become a natural part of the cultur in order to assure that the observations are natural.
- **Direct Observation** - Direct observation is distinguished from participant observation in several ways. The observer is as modest as possible and does not try to become a a participant in the culture itself. Secondly, direct observation is focused on a more detached perspective. The observer is watching rather then taking part. Next, direct observation is focused on certain sampled situations, rather than focused on the entire context. Finally, direct observation is usually not as time consuming as participant observation.

Data Analysis

There are several methods used when modelling and transforming the data collected with the goal of highlighting useful information and suggestions. Some of these methods are well suited for this master thesis, and the most relevant are briefly presented below.

- **Constant Comparison and Grounded Theory** - A widely used analysis method that was developed in the late 60's by Anselm Strauss. It follows a strict set of procedures that focus on note and code comparison.
- **Domain Analysis** - Another widely used method developed by professor James Bradley. Often describes social situations and the cultural patters within it. It focus on semantic relationships.
- **Analytic Induction** - One of the oldest methods that is still used today, developed by F. Znaniecki, Howard Becker and Jack Katz. It focuses on an event and developing hypothetical statements of what happened in that event. Further on, it looks at a similar event and sees if it fits the hypothesis. If it does not, the hypothesis is revised.
- **Content Analysis** - A common analysis method developed by R. P. Weber. It is a theory driven method, where theory determines what to look for.

2.1.2 Qualitative Procedures

Because of the short time frame of this master thesis and the complexity of the existing systems discovered in the field survey, direct observation was chosen as an observation method. Constant Comparison and Grounded Theory is used to analyze the data collected.

Direct Observation Procedure

To acquire good results in a direct observation, a specific observation procedure was chosen:

- Decide on what observations that might be useful for the context.
- Make the necessary arrangements for the observation to take place.
- Ask for permission in advance to arrange the observation.
- Plan on which day or days the observation will take place. Also decide on how long it will last.

- Decide on what groups or situations that will be relevant.
- Plan the headings for the field notes.
- Individually collect data in field notes.

The results and field notes from the observation will be presented in chapter 5, results.

Constant Comparison/Grounded Theory Procedure

In a qualitative approach, the data collected should be analyzed before any suggestions to improvements can be presented. There are several methods to choose from when analyzing the data, but Constant Comparison and Grounded Theory was chosen for this work. The following procedures were worked out during the data analysis and is, as mentioned in the previous subsection, based on the work done by Anselm Strauss[2]:

- Study the field notes from the data collection.
- Look for indicators of categories in events and behavior. Name them, and list them on the data analysis document.
- Compare field notes to find consistencies and differences.
- Consistencies between codes reveal categories. List the categories on the data analysis document.
- Eventually certain categories become an important focus. Separate into focus axial categories and perhaps even core categories.

2.2 Prototype Development Methods

The prototype is developed by following the principles of agile development. The engineering paradigm is an engineer's method for solving a task and is presented in the section below.

2.2.1 The Engineering Paradigm

The usage of the engineering paradigm is important when creating a new system. The engineering paradigm is an engineer's method to solving a task and has four stages that need to be taken into consideration. The four stages that are listed below are the stages used to solve one of this project's tasks: creating a prototype of ByggDoc.

State Requirements

The requirements are divided into functional requirements and non-functional requirements. Non-functional requirements include topics like runtime, extensibility, etc. The functional requirements will include more of the actual project modules that have to be included to make the prototype functional.

State Specifications

State what specifications the prototype should have to make it work as intended. The prototype will be specified by using UML models.

Design and Implement the System

When the specifications and the requirements are done, the design process can start. This includes making a overwiev of what is going to be created, by e.g making UML diagrams. The UML diagrams will give every developer in this project a understanding of what needs to be done and how the whole system should cohere. By creating UML diagrams first, the prototype will be easier to implement, since the developer have the class structure ready. The development process for this process was done by using agile methods.

Test the System

Testing the system is important to find bugs and knowing that the release is a near fault free working solution. Most of the testing was done by using the already created use cases, and of course by testing each block of code by running it. Use cases help the developer see if fragments of the code are working as they should.

2.2.2 Code and Software Design

One coding standard is used throughout the whole project, for all platforms, to increase the efficiency of a new project developer that has to read and learn how a specific code segments works. To make the project code structured and well designed, model-view-controller is used to divide the code into various modules. This is done to separate the business module, user interface, and database models.

2.3 Quality Assurance

It is important that the quality of the product is satisfying since this prototype is going to be commercialized. The quality requirements are set by the product sponsor, and is characterised by two key principles: The product should be suitable for the intended purpose and mistakes on site should be eliminated. Red Rock AS also focuses on module-based software development. Building high-quality software parts that can be reused by third parties long term is therefore essential.

In past decades, many test methods, strategies, and criteria have been developed to support testing of software modules at the unit level. These test methods can be classified into the following two categories[23]:

- **Black-box testing**Focus on validating required functional features and behaviors of software modules from an external view. Based on the given module specifications, test methods are developed to generate unit tests.
- **White-box testing**Focus on validating program behaviors, structures, and logic of software modules from an internal view. These test methods are designed to make unit tests based on the given source code of the module.

The primary objectives in unit testing for a module are to[23]:

- Uncover as many errors as possible by designing high-quality unit tests.
- based on a predefined unit test model and criteria, achieve adequate test coverage.
- By matching the given requirements and design, conduct cost-effective unit tests to demonstrate its functions and behaviors.

There are four major tasks in unit testing for a module. The first is to design and perform white-box testing to validate its internal logic, data, and program structure based on the given design and source code. The second is to design and perform black-box testing to validate its external accessible functions, behaviors, and interfaces based on the given requirements. The third is to validate and measure its performance (such as reliability and processing speed) based on the given requirements. The final task is to report testing results, program errors, and test coverage.

The major focuses in unit testing are[23]:

- Checking incorrect internal module structure and functional logic.
- Checking incorrect internal data types, object classes, and data values.

- Checking incorrect functions, interfaces, and behaviors, as well as performance in a software module.

Engineers need the following means to conduct effective unit testing:

- Adequate test models to provide a fundamental basis for engineers to come out with test criteria and strategies.
- White-box testing of modules refers to the unit testing that is performed using program-based tests to uncover the program errors in internal logic, data, and structures.
- Black-box testing of modules refers to the unit testing that is performed using requirement-based tests to uncover the program errors in external functions, behaviors, and interfaces.
- Well-defined test criteria to support a quality control process.
- Efficient test methods to support test case design.
- Cost-effective test strategies to support a test process.

2.3.1 Test Program

The IEEE 829 standard for software test documentation has been used as a basis for the test program. Not all the stages are taken into account, but each stage was evaluated and the following stages where chosen as topics for the test cases.

- Test plan identifier
- Introduction
- Environmental needs
- Features to be tested
- Item pass/fail criteria
- Risks and contingencies
- Approvals

2.3.2 Configuration Management

Today, there are several standards for configuration management (CM). According to Leon (2000), the most comprehensive international standard is ANSI/IEEE standard 1042[9]. It defines CM with the following quotation:

"Software CM is a discipline for managing the evolution of computer program products, both during the initial stages of development and during all stages of maintenance."[9]

The three main goals for using CM in this project are as follows:

- Avoid chaos when software changes occur.
- Assist the reviser of both CM and software process.
- Provide helpful information about the current state of development.

Configuration Management Plan

A successful CM implementation often requires careful planning and management. What, Who, When and How are essential questions to ask when developing such a plan and the following steps were taken to assure a successful CM implementation:

- **Identify all activities to be performed in the project** - Separate each task into a work package. Create test cases based on the work packages and to ensure that the work packages will be completed.
- **Identify responsibilities for performing the planned activities** - Each member of the project group must be given specific tasks.
- **Identify the time frames for each activity in the project** - Give each work package a set time frame to be completed based on the difficulty of the work package.
- **Identify the tools required for executing the plan** - Go through each work package and work out what tools are required to complete this plan. Also, a CM system is required to assure that the three main goals for CM mentioned earlier in this section are fulfilled.

Chapter 3

Background Theory

The background research on construction sites proved to be a great aid when developing the specifications for the prototype. Platform and network is also an important part of this chapter, where the technologies related to this project is presented.

3.1 Construction Site Documentation

On construction sites today, for instance a construction site managed by Oras Agder, there is usually a high demand for documentation of tasks executed. There are numerous reasons for documenting tasks at construction sites, and several different procedures of documentation, each of them meant for specific tasks.

In this section, the different reasons and procedures will be presented, beginning with the systems used in present documentation procedures.

3.1.1 Existing Systems

As described in section 1.3, Literature Review, there are several Electronic Document Management(EDM) systems in use today. A more comprehensive system, with the use of cell phones to do the documentation, has not been discovered during the background research.

For the process of documenting the work done on a construction site, Oras Agder owns and uses a self manufactured EDM system. The system helps the employees categorizing the different checklists. If the

checklists are changed or modified in any way, they are stored as new files in an existing project folder structure. These new files are not accessed by the EDM system, only the templates are available here.

As for the systems used in the remaining procedures, a normal digital camera is used to capture images, while checklists are made and categorized manually. This checklist procedure is poorly implemented today, and the documentation is often skipped by the workers because of the tedious procedures.

3.1.2 Checklists

There are several types of checklists, each of them containing unique kind of information. Two different types are presented in figure 3.1 and 3.2 below.

KVALITETSSYSTEM FOR ORAS - KONSERNET
12.0 HELSE, MILJØ OG SIKKERHETSHÅNDBOK
5.6.1.1 SKJEMA FOR UTARBEIDELSE AV SIKKER JOBB ANALYSE (SJA)

Utarbeidet av:	Godkjent av:	Rev. dato:	Side 1 av 1
K. Wasskog	O.F. Hanevold	28.11.2001	
		Rev. nr.: 01	

KUNDE: NORSK VVS-MERKING A/S KUNDENR. <num >
ANLEGG: Oras Agder AS - HMS ANLEGGSNR INT0007

Trinn	Arbeidsoppgave	Farer	Konsekvenser	Sikkerhetstiltak	Utført
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

SJA utarbeidet av: _____ (Signatur Bas / Prosjektleder)

Arbeid utføres av : _____ (Signatur operatør)

Dato: _____

\\app03\SuperOffice\SO_ARC\BYRLIN\2010.1\NORSK _5.6.1.doc

Figure 3.1: Check list example 1

This is a special type of checklist with optional fields. In this type of checklist, the manager can input information about all kinds of tasks or events to focus on. There are several important fields here that make this checklist stand out, for instance potential risks, consequences and safety measures for the specific task.

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7.1.2 NS311 SJEKKLISTE FOR INNVENDIGE BUNNLEDNINGER

Utarbeidet av:	Godkjent av:	Rev. dato: 11.11.2009 Rev. nr.: 07	Side 1 av 1
A. Skredderstuen	K. Wasskog		

Tiltakshaver: NORSK VVS-MERKING A/S	Kundenr.: 1130093
Prosjektnavn: Oras Agder AS - HMS	Prosjektnr.: INT0007
Sted/anleggsdel:	Tegning nr./Rev. nr.:

OK - I orden NEI - Ikke godkjent IA - Ikke aktuelt

Sjekket	Dato	Sjekket av	OK	Avvik nr.	Rettet dato	Rettet sign.	Utførelse kontrolleres mot *
Vann Rørtype Dim.							
Spillvann Rørtype Dim.							
Overvann Rørtype Dim.							
Grøftebunn og fundament (visuell kontroll) Komprimert (hvis mulig får entreprenøren til å signere på at grøftebunn er ok). Hvis ikke skriv avvik							
Gjennomføringer i grunnmur/såler							
Omfylling og overdekking av rør (min. 10 cm pukk under/30 cm over)							
Rør til fettutskiller							
Fall sjekkes							
Utmåling av oppstikk ..... antall oppstikk							
Utmåling av sluk.....- antall sluk							
Stakekum/stakepunkt							
Jordingsmuffe (230V)							
Avløp til sluk							
Levert slukrister og kjellerkumlokk							
Tersing/plugging av oppstikk							
Vanntilførsel, type og dimensjon							
Frostsikring							
Innvendig hovedstoppeventil							
Vann påsatt							
Fordelings- og koplingsledninger i gulv							
TV-kontroll							
Rydding og fjerning av overflødig materiell?							

* RHB = Rørhåndbok PB =Prosjektbeskrivelse M = Monteringsanvisning T = Tegning B = Bilde Annet = Beskriv hva

Kommentarer:

Sjekkliste kontrollert av:_____ Melding mottatt:: _____ Dato: _____

Signatur (Bas evt. prosjektleder) Signatur (Oppdragsgiver)

\\app03\SuperOffice\SO_ARC\BYRLIN\2010.1\NORSK _7.1.2_test.doc

Figure 3.2: Check list example 2

This is a more normal type of checklist, where the fields are already set and containing specific tasks to be performed. This checklist comes from a template-checklist, and usually not all of the fields are relevant for the room that is going to be inspected.

3.1.3 Image documentation

Image documentation today is usually executed by a digital camera and stored internally on the cameras storage space. When the documentation is completed at the construction site, the images are forwarded either manually or digitally to the central office where the images will be categorized manually by an employee at the company. Project managers can then on look at the images by requesting them from the central office. The system works, but in many occasions it is skipped because of time related issues.

Below are a couple of image examples taken during the observation procedure performed by the project group.

Figure 3.3: An example of work done correctly at a construction site

Figure 3.3 above show an example on how the work is done. It also illustrates the fact that many areas on a construction site suffer from low light conditions. This proved to be a subject when choosing the cell phone for the application. A camera with flash or another form of light source would be recommended.

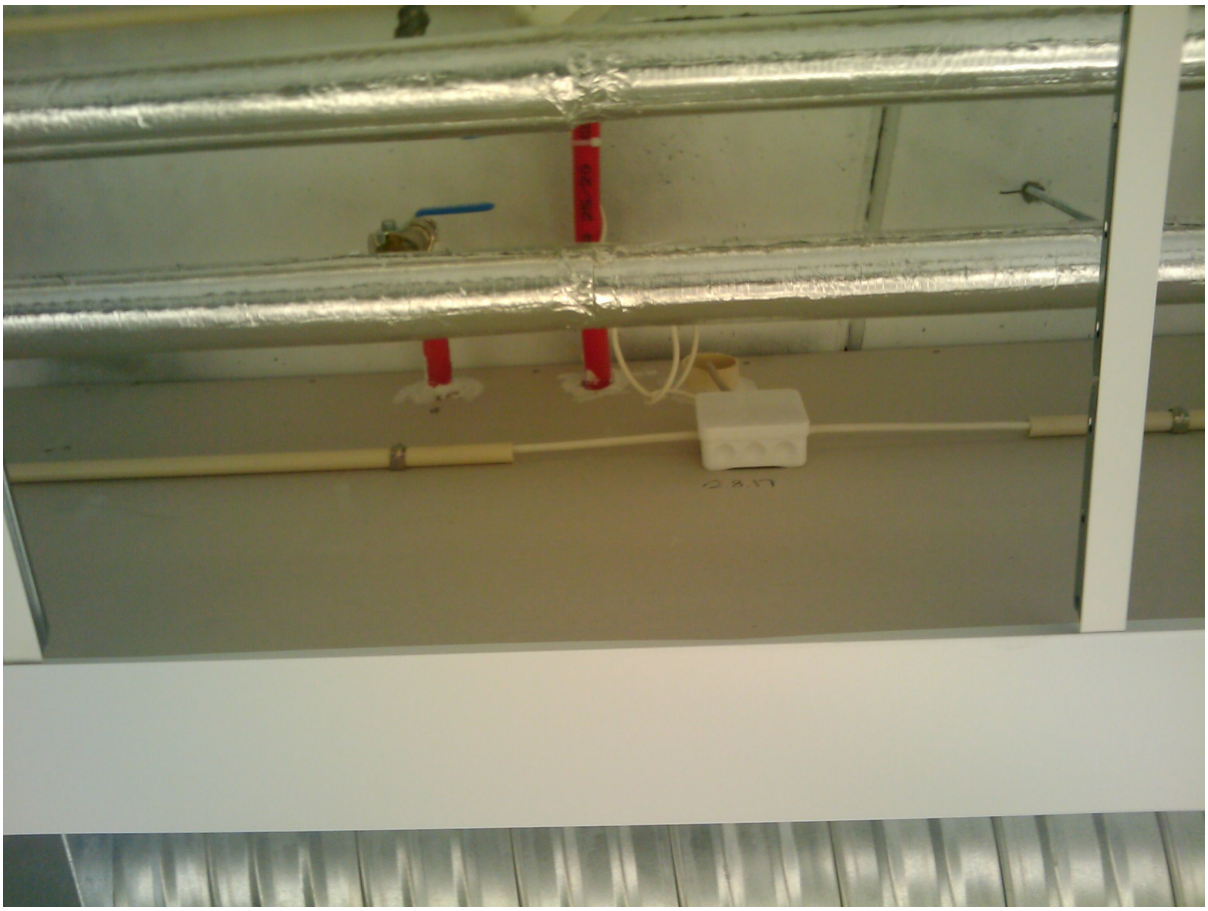


Figure 3.4: An example of work done incorrectly at a construction site

This image presented in figure 3.4 documents the work that has been done, and illustrates how this kind of image can show work that is not done correctly. In this case the fire proofing is not done properly as seen on the red pipe to the right.

3.2 Map Projections

Choosing a map projection algorithm was a central issue in the background research, with several algorithms and methods to choose from. By using a map projection algorithm to display the custom blueprint maps, the distance and measurements made based upon the custom maps would be correct related to the real world, and already existing maps.

A map projection is a way to represent the curved surface of the Earth on the flat surface of a map. To create a map, map projections are required. The map projection will project the surface of any form on to a plane. The form of the surface that is going to be mapped can be of many shapes, and can still be mapped as a plane. This depends on what kind of projection that is used to project the map. When projecting a map, distortions may occur. The cartographer will try to eliminate distortion in one or several aspects of the map, but may also choose to allow a little distortion in all four of the listed aspects below, to produce the right type of map.

- Conformity - the shapes of places are accurate
- Distance - measured distances are accurate
- Area/Equivalence - the areas represented on the map are proportional to their area on the earth
- Direction - angles of direction are portrayed accurately

[30, 31]

There are many map projections, but this report will only consider two of them. The first projection is the Mercator projection, which is one of the most popular projection that exists, and Google Maps makes use of it to project the world map on a plane. The second projection is the Euclidean projection, which projects a flat map to a plane with the correct geographical coordinates.

Figure 3.5 shows approximately how the projection of the construction site blueprint would look like, by using the Mercator projection. The red segments illustrate rooms that have been set by a project manager. The Mercator projection is usually used when a map is wrapped around a sphere, like the Earth. Since the construction site blueprint is a flat map, the Mercator projection is a wrong projection to use within this, as seen below on figure 3.5.

Figure 3.5: Construction site blueprint, using Mercator projection

The Euclidean projection gives a correct projection of the construction site blueprint, as seen below on

figure 3.6. The red segments present rooms that have been set by a project manager. The construction site blueprint is mapped on a plane, and every platform that will make use of this map, will get the correct coordinates by using the Euclidean projection.

Figure 3.6: Construction site blueprint, using Euclidean projection

3.2.1 Mercator Projection

The Mercator projection is a cylindrical map projection presented by the cartographer Gerardus Mercator, in 1569. The description of the Mercator map, given by Gerardus Mercator, "new and augmented description of Earth corrected for the use of navigation", shows that the purpose of the map projection was for the use of marine navigation. The map projection was useful for nautical reasons, and it became the standard map because of its ability to represent lines of constant course, known as rhumb lines or loxodromes, which represented straight segments.

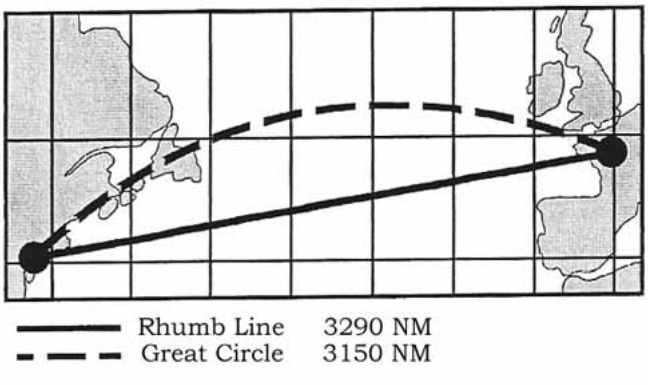


Figure 3.7: Example of a Rhumb line[34]

The linear scale is constant in all directions around any point and the Mercator projection preserves the angles and the shapes of small objects, while it distorts the size and shapes of large objects as the scale increases from the Equator to the poles, where it becomes infinite. All lines of constant bearing (rhumb lines) are represented by straight segments on a Mercator map. This represents the exact route used by ships at sea.

$$\begin{aligned} x &= \lambda - \lambda_0 \\ y &= \ln\left(\tan\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)\right) \end{aligned}$$

The equation which determines the x and y coordinates of a point on a Mercator map from its latitude φ and longitude λ. [26]

3.2.2 Euclidean Projection

Google Maps uses Mercator projection to be able to show relative coordinates in relation to the cylindrical shape that the world map is wrapped around. A construction site blueprint would not wrap itself around a sphere, but will be on a plane and use the Euclidean projection to get and set relative coordinates to that specific construction site map.

The Euclidean algorithm is used to find the larges number that divides two other numbers(GCD). The greatest common divisor of two numbers does not change if the smaller number is subtracted from the large number. The largest of the two numbers is reduced, and repeating this process gives successively smaller numbers until one of them is zero. When that happens, the GCD is the remaining nonzero number. This can be put in context by using it with Google Custom maps, where the developer can choose what kind of projection he wants to use. By using the Euclidean projection, which makes use of the Euclidean algorithm, the custom map tiles will be placed in the correct sequence in a square. [12]

$$\begin{aligned} gcd(a,0) &= a \\ gcd(a,b) &= gcd(b, a - b\left[\frac{a}{b}\right]) \end{aligned}$$

Euclidean algorithm which finds the greatest common divisor.[16]

The relation between the Euclidean projection and screen coordinates, was found and extracted from the Google Maps API as an algorithm, as shown below.

$$\begin{aligned} TileSize &= 256 \\ TileBounds &= 2^{ZoomLevel} \\ TotalTileSize &= TileSize * TileBounds \\ CenterOfTiles &= (TotalTileSize/2) \\ PixelsPerLonDegree &= (TotalTileSize/360) \\ Origo &= Coordinate(CenterOfTiles, CenterOfTiles) \end{aligned}$$

From Euclid coordinates to pixels:

$$\begin{aligned} (int)x &= Round(Origo.x + (EuclidCoord.LON * PixelsPerLonDegree)) \\ (int)y &= Round(Origi.y + ((-2 * EuclidCoord.LAT) * PixelsPerLonDegree)) \end{aligned}$$

From pixels to Euclid coordinates:

$$\begin{aligned}(double)lng &= (PixelCoord.x - Origo.x)/PixelsPerLonDegree \\ (double)lat &= -0,5 * (PixelCoord.y - Origo.y)/PixelsPerLonDegree\end{aligned}$$

3.3 Platforms and Networks

When developing software for the currente cell phone market, there are several platforms and networks to take into consideration. The following section will present a brief look at the current state of the art subjects within this domain.

3.3.1 Cell Phone Platforms

When developing on cell phone platforms, extra consideration is necessary in regard to the limited computing power and data storage, battery life and smaller screen than normal computers. To get the best possible performance, it is therefore very important to write efficient code. There are many important factors to consider:

- Allocation of memory is perhaps the most important factor to consider, therefore object creation should be avoided if possible. If for instance objects are created inside a loop, it will force a periodic garbage collection, and slows down the application or algorithm significantly.
- On cell phone platforms, virtual methods (e.g. i = getSize()) are a lot more expensive than field lookups (e.g. i = iSize). Especially if it is inside a class, fields should always be accessed directly.
- Embedded processors on mobile phones do not have hardware floating point support, so all operations on "float" and "double" are performed in software. For instance, some basic floating point operations can take over a millisecond to complete. Therefore, avoiding floats is important when possible.

Android

Google describes Android as:

> The first truly open and comprehensive platform for mobile devices, all of the software to

> run a mobile phone but without the proprietary obstacles that have hindered mobile innovation. - Andy Rubin, Director of Mobile Platforms

More in detail, Android is a software stack, an operating system and a software platform, for mobile devices. It was released in October 2008 by Google, it is now maintained by Open Handset Alliance.

The Android operating system is based on the Linux kernel and is open source. Android application developers have access to most of the hardware and a lot of other functionalities through a programming language with a Java like syntax. The programming language includes the basic classes that are available in Java. The code is compiled to byte code and Dalvik Virtual Machine runs the code, Dalvik is described in more detail later in this chapter. It is also possible to write code in other languages than Java and compile it to ARM native code but this is not officially supported [1]. The structure of Android is shown in the following illustration.

iPhone and iPad

The iPhone OS was released June 2007 together with the iPhone, and has advanced to be one of the most popular cell phone platforms in the world. Direct manipulation and multi-touch gestures is the focus of iPhone OS user interface. The user interface control elements consists of sliders, switches, and buttons. The iPhone's CPU is an ARM-based (32-bit reduced instruction set computer developed by ARM Holdings [4]) processor and uses OpenGL ES 1.1 rendering by the PowerVR 3d graphis hardware accelerator co-processor. [22]

Symbian

The Symbian platform is an operating system designed for smartphones, made available as open source code in February 2010. The Symbian platform is maintained by the "Symbian Foundation". EPOC, was an operating system developed by Psion in the late 1980s, and was later on renamed to Symbian OS in 1998. The Operative System was originally made for ARM processors and was a pre-emptive multitasking, single user operative system with memory protection. This encourages the developer to separate their program into an engine and an interface. The first Symbian OS phone was released in June 2001, with the version Symbian 6.0. [36]

Windows Mobile

The Windows Mobile OS is made for pocket pc's without mobile phone capabilities and devices with cell phone capabilities. The official name of Windows Mobile OS intended for Pocket PCs is "Windows Mobile 6 Classic", while the Windows Mobile OS for devices with cell phone capabilities is refered to as "Windows Mobile 6 Professional". Windows Mobile debuted in 2002 with the release of Pocket PC 2002. The current version of Windows Mobile is based on the windows CE 5.2 kernel, and makes use of the Microsoft Windows API. [40]

Other platforms

In the future tablet computers might be an important platform for the application. The popularity and user friendliness of Apples new iPad might be an indication that tablets might be widely available in the coming years. A documentation application like ByggDoc would be a good match for a tablet computer with its large touch screen, provided it has a built in camera.

3.3.2 Web Platform

Developing for web platforms or "web as a platform" separates itself from developing for specific platforms like Windows, Linux and Mac OS in several ways, where the most important difference might be that web-based applications are completely independent of the operating system run by the user.

Web based platforms are commonly associated with the term "Web 2.0", which focuses on collaboration, information sharing, user-centered design and interoperability[10]. Interaction is also an important aspect of "Web 2.0", and is often a key factor in developing good applications for the web platform.

3.3.3 Networks

GSM (Global System for Mobile Communications) is a cellular network. The GSM networks operates in different carrier frequency ranges. These ranges are separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G. Most of the 2G GSM networks operates in the 900MHz or 1800 MHz bands, while most of the 3G GSM networks in Europe operates in the 2100MHz frequency band. [19] Some of the various network bands are described below:

GPRS (2G)

GPRS (Genereal Packet Radio Service) is a packet oriented mobile data service which provides data rates of 56-114 kbit/s abroad the GSM cellular network. [18]

EDGE (2,75G)

EDGE (Enhanced Data rates for GSM Evolution) is a backward-compatible digital mobile phone technology extension on top of standard GSM. The EDGE band was deployed in 2003 by AT&T in the United States. It is possible to use EDGE for any packet switched application, such as an Internet connection, and it delivers a higher bit-rate per radio channel, than the GPRS band. [11]

UMTS (3G)

UMTS (Universal Mobile Telecommunications System) is a third-generation mobile telecommunications technology which is being developed into a 4G technology. The first commercial UMTS network was deployed in Norway December 1, 2001. The UMTS requires new base stations and new frequency allocations (Europe - 2100 MHz band), as shown in the start of this subsection. Users in 3G deployed networks can expect a transfer rate of up to 3.6 Mbps, but many countries have upgraded to the 3.5G network, also known as HSDPA.[38, 37]

HSDPA (3,5G)

HSDPA (High-Speed Downlink Packet Access) is an enhancement of the UMTS network. It is also known as the 3.5G or turbo 3G. The enhancement has resolved in a higher data transfer speed and capacity than the UMTS network band. HSDPA supports download speeds up to 14 Mbps. The first HSDPA network was deployed in 2006. [21, 20]

LTE (4G)

LTE (Long Term Evolution) is the project name of a high performance air interface for cellular mobile telephony. The LTE is a 3.9G technology, which does not fully comply with the IMT Advanced 4G requirements. Several carriers around the world has started the process of converting their network to LTE. The world's first public LTE-service was opened by TeliaSonera in Stockholm and Oslo on the 14th of December 2009. The LTE service has been proved to reach 173 Mbps in a test done by "Nokia Siemens Networks", which outperformed their previous test that had a result of 100 Mbps. [24, 25]

Figure 3.8 shows that the smartphone usage of mobile internet is increasing. With the increasing mobile internet usage, people will demand faster mobile networks.

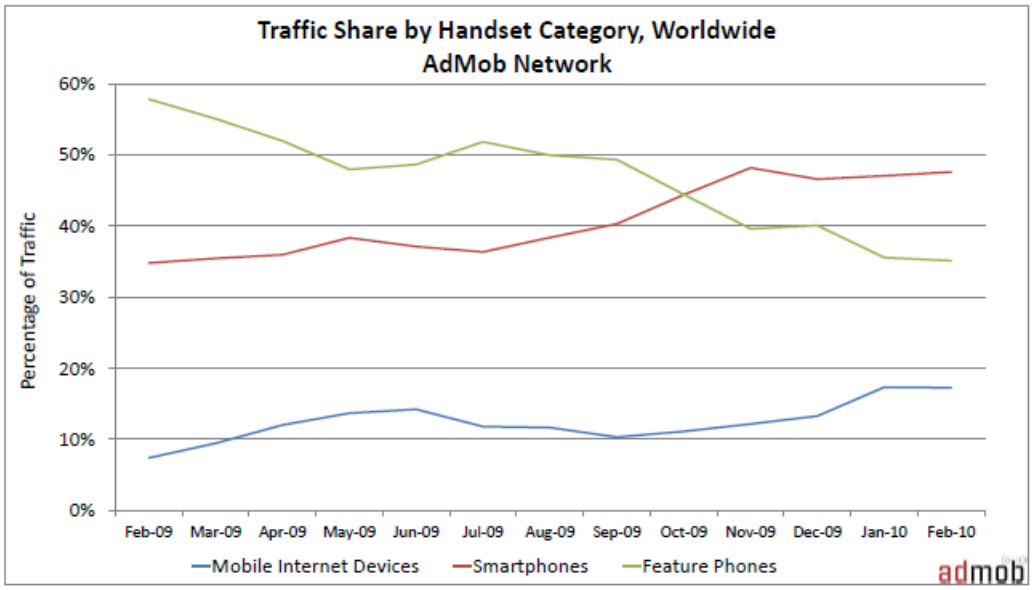


Figure 3.8: AdMob's Worldwide mobile traffic: Feb-09 - Feb-10, showing network traffic by various devices.[27]

Chapter 4

Solution

This chapter describes the solution including the requirements, system design, system documentation and the development platform. The solution is described in terms of both functional and non-functional requirements, like power consumption, memory usage etc. How the project is implemented, documented and tested will also be outlined in this chapter.

4.1 Requirements

The following subsections will contain the functional and non-functional requirements of the project. They will be defined as FR1-FR15 and NFR1-NFR7 because of easier reference to them in later chapters. Some of the functional requirements will only be completed if time allows it, and is specified appropriately.

4.1.1 Functional requirements

The functional requirements are divided into three different sections, one for each major part of the system. Not all of the functional requirements are essential for the project's success, but each requirement will improve the pilot‘s functionality. The requirements that is not essential is classified under the “if time allows” subsection.

End user cellphone application

The pilot developed for the application will be a time consuming task. There are many advanced features that require an imposing amount of hours to complete.

FR1: Convert the raw construction designs to a format suitable for cell phones The exact format depends on what cell phone platform that will be used for the development.

FR2: Easy and user-friendly methods for navigating through the designs on a cell phone Make it easy to navigate through buildings with multiple floors.

FR3: Capture images with a cell phone and attach them to the building designs at the current position Use compass, accelerometer or GPS to pinpoint the exact position and angle when capturing an image.

FR4: View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest This includes images, product instructions and digital checklists to make sure that the current work for that area is ongoing or completed.

FR5: Make use of positioning technology to suggest the nearest building sites with designs available Use triangulation or GPS to find the approximate position, and based on that position, suggest the closest building sites.

End user mobile application: If Time Allows

FR6: Orientate the construction design based on a cell phone's built in compass When turning around in the building, the construction designs should keep their correct orientation, even if the person holding the cell phone moves or turns.

FR7: Add points on the construction designs that describe the corresponding features on the drawing The features will usually be some installation on the construction site that needs to be documented. Images and checklists can also be added to the points.

End user web application

The web interface will have much of the same functionality as what is available for the cell phone pilot, but some differences can be pointed out.

FR8: Convert the raw construction designs to a format suitable for a web interface There is usually a lot more computational power available when developing for a computer than when developing for mobile devices. Because of this, alternative methods for displaying the construction designs for a web interface must be considered.

FR9: Easy and user-friendly methods for navigating through the designs on a web interface There are more options available for a web interface then on a cell phone. For instance, there is normally a keyboard and mouse available as input devices. In addition, as in FR10, there is usually more computational power available, so alternative methods for navigation must be considered.

FR10: View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest As described in FR8 and FR9, there are more options available when developing for computers, and as in the previous requirements for the web interface alternative methods for displaying the documentation on a design overlay must be considered.

FR11: Integrating the web service in Red Rock's existing user and customer service Red Rock AS has an advanced user and customer service, where all its services are integrated as a single user experience. Integrating the solution that will be presented in this master thesis, with Red Rock's service, will be an essential part of Red Rock's business idea, and must be done at some point in the future.

FR12: Adding or editing users for both the web interface and the cell phone pilot There must be an administrator possibility somewhere in the web interface, where the administrator can add or edit users/customers. There must be at least two kinds of administrators, each with their own rights. One of them controls the rights for users within a specific company, and the other controls the rights of adding or editing the companies themselves.

End user web application: If Time Allows

FR13: Add points on the construction designs that describe the corresponding features on the drawing The features will usually be some installation on the construction site that needs to be

documented. Images and checklists can be added to the points.

Servers

The server will handle all of the communication between the cell phones and the web based interface described below.

FR14: Images, instructions and digital checklist must be stored on the server for further usage Since the server language will be PHP, MySQL will be used as a database system. It is a relational database management system and well suited for web development.

FR15: Handle communication to both the cell phone pilot and the web interface The communication will be done using the JSON format over a HTTP connection. The incoming requests are decoded and processed by the server. The next step will be to either store or send back the proper information depending on the request.

4.1.2 Non-functional Requirements

NFR 1 Documentation

The primary goal of the documentation for the pilot, is to get programmers up to speed on how to use it as soon as possible. The secondary goal is to make it easy for programmers who want to modify or expand the code. This is done by not writing a lot of pages of documentation, but by documenting the functions and classes with Java doc and PHP doc. The code is also supposed to be self documented to some extent, by clear structure and logical names for classes, functions and variables. All the code written follows the same coding style to make it easy to read. If there are places in the code that might be unclear there should be comments there explaining what it does. The code should also be documented by using some class diagrams, as explained in more detail later. All the classes and class functions in this project are documented. The documentation is done while writing the code so that the programmer remembers what the function does while documenting that piece of code. The way classes and functions are documented is by Java doc and PHP doc. All the classes and class functions will also be documented by a UML diagram to show the structure and how the classes and functions work together. A high level diagram for how the different parts of the prototype work together will also be produced. The use of classes in the two mobile parts of this pilot is somewhat limited as it is a mobile platform and system resources are scarce, this will be clearly visible from the class diagrams.

NFR 2 Extensibility

One of the important requirements for this project is that the pilot can be easily expanded. Other programmers must be able to use the code and extend it as they please. It must be easy to add new modules in the future to the existing code so that it can go from a pilot to a fully functional and tested application.

NFR 3 Platform Compatibility

The server part of the prototype will be written in PHP and should support both Windows and Linux servers. To ensure platform compatibility the code for the mobile part is written in C sharp with a modular design, this should at least ensure that it is easy to use parts of the code on new platforms.

NFR 4 Runtime

If the prototype is slow, it will be of no use to the end user, so it is important to make the code as fast as possible. This is done by using a small data structure. It is important to use few classes, as classes tend to be a bit slow on mobile platforms.

NFR 5 Mobile Platform Power Consumption

As mobile platforms are intended for mobile devices, the memory consumption of the code is really important as the device is often not plugged into the power grid. The pilot must be designed with power consumption in mind. When resources are no longer needed they are cleared from the application, like for instance the camera which will be used a lot. The code must also be designed to use a minimum of CPU cycles, something which is beneficial to the power usage.

NFR 6 Bandwidth Consumption

In the mobile version of the prototype, it is important that the bandwidth consumption is as low as possible so the customer does not get a larger phone bill and to ensure that even under bad reception conditions the program runs smoothly. The downloadable files should therefore be limited, scripts should run efficiently and the web pages should be kept clean and rich web content limited.

NFR 7 Security

One important factor in all web and mobile related projects is security. The system needs to be designed so the system is secure. This is an extensive topic but some of the most important security issues will be briefly described here.

- **Validate input** - This includes input from other web sites. Validate that that input is possible and that it does not contain any type of script or code.
- **Authentication** - It is important that the user is properly authenticated so that he has access to the right resources.
- **Malicious file execution** - Care must be taken when the user can upload files so it is not possible to upload script or applications that later can be executed on the server. The user should not be able to set whole file paths in the input.

4.1.3 Platform Requirements

The system has some requirements for both the server and the workstation that is a minimum for the system to run.

Server

- At least two double core 2GHz x86 or x64 processor.
- At least 4 GB of system memory.
- At least 4 GB of storage.
- Microsoft Windows Server 2008 or Debian.
- PHP 5.2.x.
- Apache 2.0 or above.
- MySQL Server 5.1 or above.

Workstations

- At least a single core 2 GHz x86 or x64 processor.
- At least 1 GB of system memory.
- At least 2 GB of storage.
- Broadband connection.

Cell Phone

- At least 500 MHz processor.
- At least 2 GB of storage.
- At least 3 Megapixel camera with either flash or LED.
- Windows Mobile 6.0 Operative System.
- Touch screen.
- Stylus (touch pen).

4.2 Work Packages

Work packages are used to define subsets of the project derived from the specifications. Each work package is then assigned to a specific group or role for execution. The entire set of work packages can be found in Appendix B, but the following sections contain an overview and example of the work packages prepared for this project.

4.2.1 Work Packages Overview

This subsection includes an overview of the work packages. As presented in table 4.1 below, there are a total of 16 work packages. They cover everything that has been implemented for the cell phone application, web application and server. Each work package has been clearly defined and can be found in Appendix B.

Work package	Description
Work package 01[Cell phone application]	Convert the raw construction designs to a format suitable for cell phones
Work package 02 [Cell phone application]	Easy and user-friendly methods for navigating through the construction designs on a cell phone
Work package 03 [Cell phone application]	Capture images with a cell phone and attach them to the building designs at the current position
Work package 04 [Cell phone application]	View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest
Work package 05 [Cell phone application]	Make use of positioning technology to suggest the nearest construction sites with designs available
Work package 06 [Cell phone application] (If time allows)	Orientate the construction design based on a cell phones inbuilt compass
Work package 07 [Cell phone application] (If time allows)	Add points on the construction designs that describe the corresponding features on the drawing
Work package 08 [Web application]	Convert the raw construction designs to a format suitable for a web interface
Work package 09 [Web application]	Easy and user-friendly methods for navigating through the designs on a web inter-face
Work package 10 [Web application]	View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest
Work package 11 [Web application]	Integrating the web service in Red Rock's existing user and customer service
Work package 12 [Web application]	Adding or editing users, using the web interface
Work package 13 [Cell phone application]	Adding or editing users using the cell phone
Work package 14 [Web application] (If time allows)	Add points on the construction designs that describe the corresponding features on the drawing
Work package 15 [Servers]	Images, instructions and digital checklist must be stored on the server for further usage
Work package 16 [Servers]	Images, instructions and digital checklist must be stored on the server for further usage

Table 4.1: Work package overview

As seen in Appendix B and the work packages seen in table 4.1, the scale of this project is huge. A total of approximately 3000 man-hours have been spent to complete every work package. Time spent on test cases and writing this report is also included in this calculation, since each work package has a set of test cases that need to be completed in order for the work package to be done. The work has been shared equally between three people, but still, for a project spanning over five months, 3000 man-hours is a lot of work.

4.2.2 Work Packages Example

The following figure shows an example of how work packages are made for this project.

Work Package 04: [Cell phone application]

View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest

User story

What: - As a user I want to navigate the building designs and be able to get points of interest on a wall, ceiling or in a room/place. The points of interest (POI) can be images, product information or digital checklists.

Why: - So that I can see the documentation of the work that has been performed in the chosen position.

Purpose of Work package

This work package will make the user able to see all the points of interests in the construction design.

Man hours estimate: 130 hours

Work Package Description

Use JSON to communicate with a webservice, where the points of interests can be downloaded from.

The points of interests should include coordinates.

Map the points of interests to the construction design.

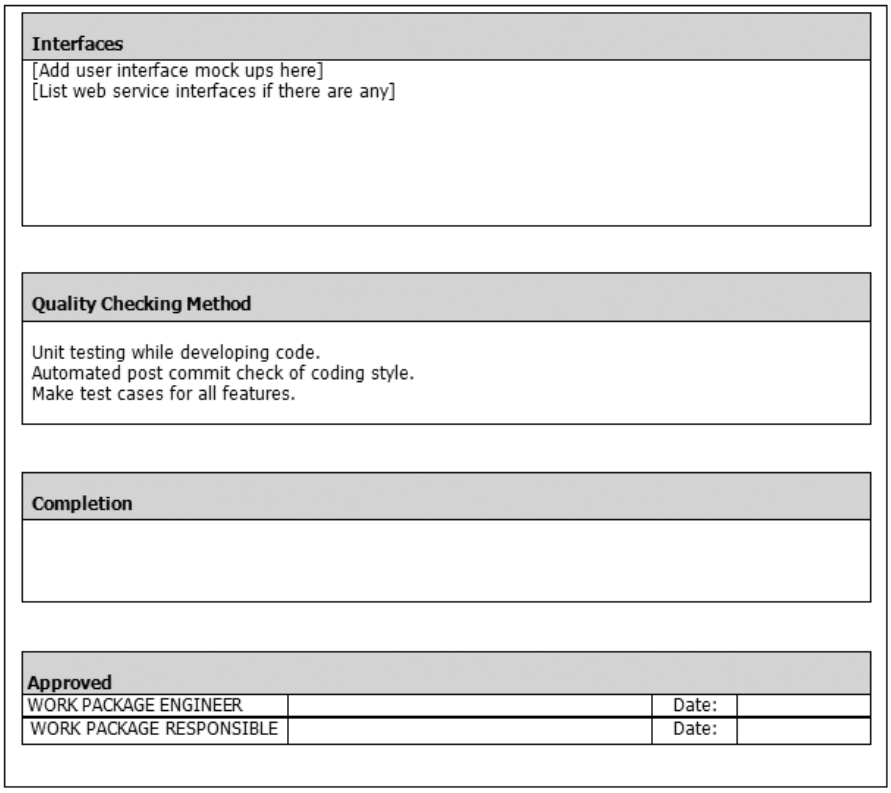
List of deliverables:

- The construction site design should show points of interest at the coordinates that they have been set.
- The points of interest should be clickable and bring up a menu of actions that the user can perform on the current point of interest.

Product Description(s)

The user can see points of interests on the construction design, click them and get information about them. The POI's can be images, product information, or digital checklists that have been created for this construction design.

Figure 4.1: Work package example part 1



Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Figure 4.2: Work package example part 2

As seen on figure 4.1 and figure 4.2, each section in the table defines a specific need for the work package.

- **User Story** - Tells the reader what and why the work package is defined.
- **Purpose of Work Package** - in addition to telling the user the purpose of the work package, it also states the estimated man hours required to complete the task.
- **Work Package Description** - Describes the work package and provides a list of deliverables.
- **Product Description** - Describes the result of the work package and how the user will interact with the current feature.
- **Interfaces** - Provides mock-ups and interface details for the work package.
- **Quality Checking Method** - Information about testing and test cases required to complete the current work package.

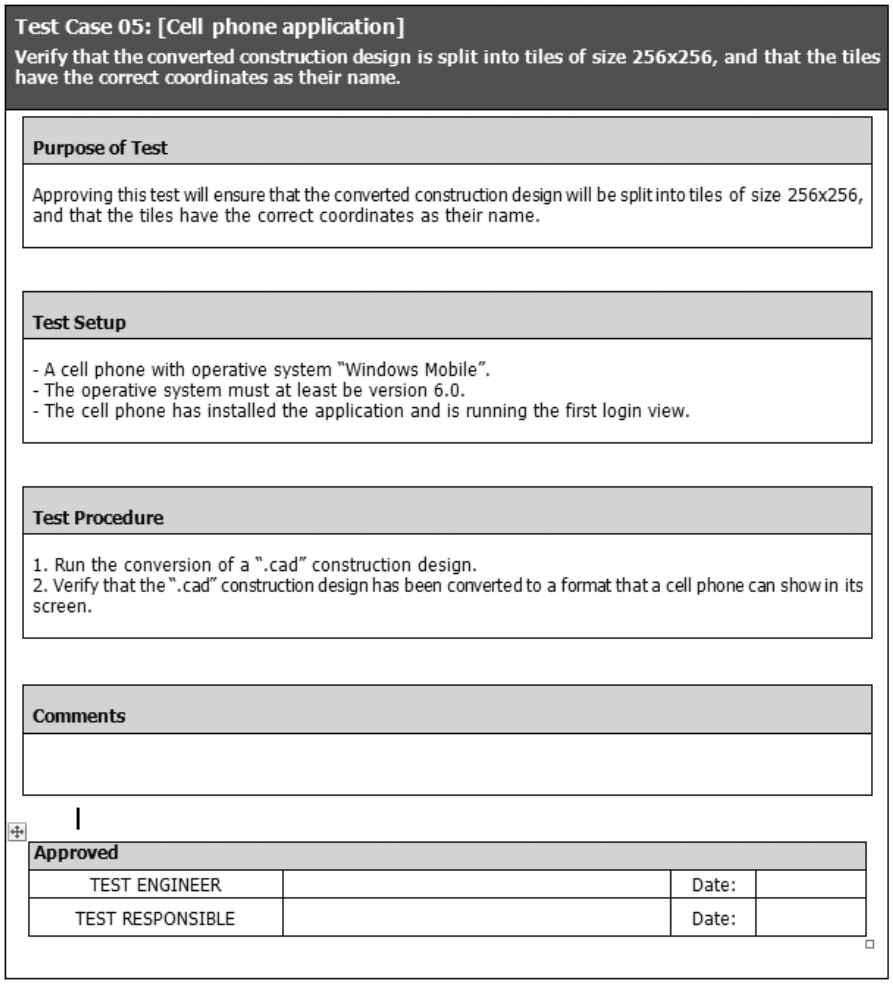
- **Completion and Approval** - Tells if the work package is complete, and in that case, by who and when it was completed.

4.3 Test Cases

Test cases are a standard part of software development today, and for this project; essential in the completion of the work packages defined in the previous section. A series of test cases have been made that exercise various important functions or features of the software. For a full list of test cases, see Appendix B.

4.3.1 Test Cases Example

The following figure shows an example of how test cases are made for this project. The specific fields in each test case have been derived according to the test program found in sub section 2.3.1. Each field is described in more detail below the test case example, but for a full overview, go to Appendix B.



Test Case 05: [Cell phone application]

Verify that the converted construction design is split into tiles of size 256x256, and that the tiles have the correct coordinates as their name.

Purpose of Test

Approving this test will ensure that the converted construction design will be split into tiles of size 256x256, and that the tiles have the correct coordinates as their name.

Test Setup

- A cell phone with operative system "Windows Mobile".
- The operative system must at least be version 6.0.
- The cell phone has installed the application and is running the first login view.

Test Procedure

1. Run the conversion of a ".cad" construction design.
2. Verify that the ".cad" construction design has been converted to a format that a cell phone can show in its screen.

Comments

Approved			
TEST ENGINEER		Date:	
TEST RESPONSIBLE		Date:	

Figure 4.3: Test case example

As seen in figure 4.3, each section in the table defines a specific need for the test case.

- **Purpose of Test** - Explains briefly what the test is about and why the test is important.
- **Test Setup** - Gives a list of what is required for the test to start.
- **Test Procedure** - Goes through each step of the test in detail.
- **Comments and Approved** - Approved by and comments for the tester with date field.

4.4 System Design

By defining the architecture, modules and components of a system before development, an abstract representation of the system can be presented. Working on system design on a project often leads to both better and more efficient code. Because of this, system design has been a primary focus in this project, and UML models, use cases and sequence diagrams have been created for the most important features in the project. The next subsections will present some of the system design created, but more will be found in the appendix.

4.4.1 Database Design

The database design has been one of the primary goals during the development. The tables and modules developed for this project are integrated into Red Rock's existing customer system. The database design for Red Rock's customer system was also developed during the project period, but only the relevant tables are included in this section. A more detailed look at Red Rock's customer system database design can be found in Appendix C.

The following figures and descriptions present the modules in the database design developed for this master thesis.

Red Rock Customer

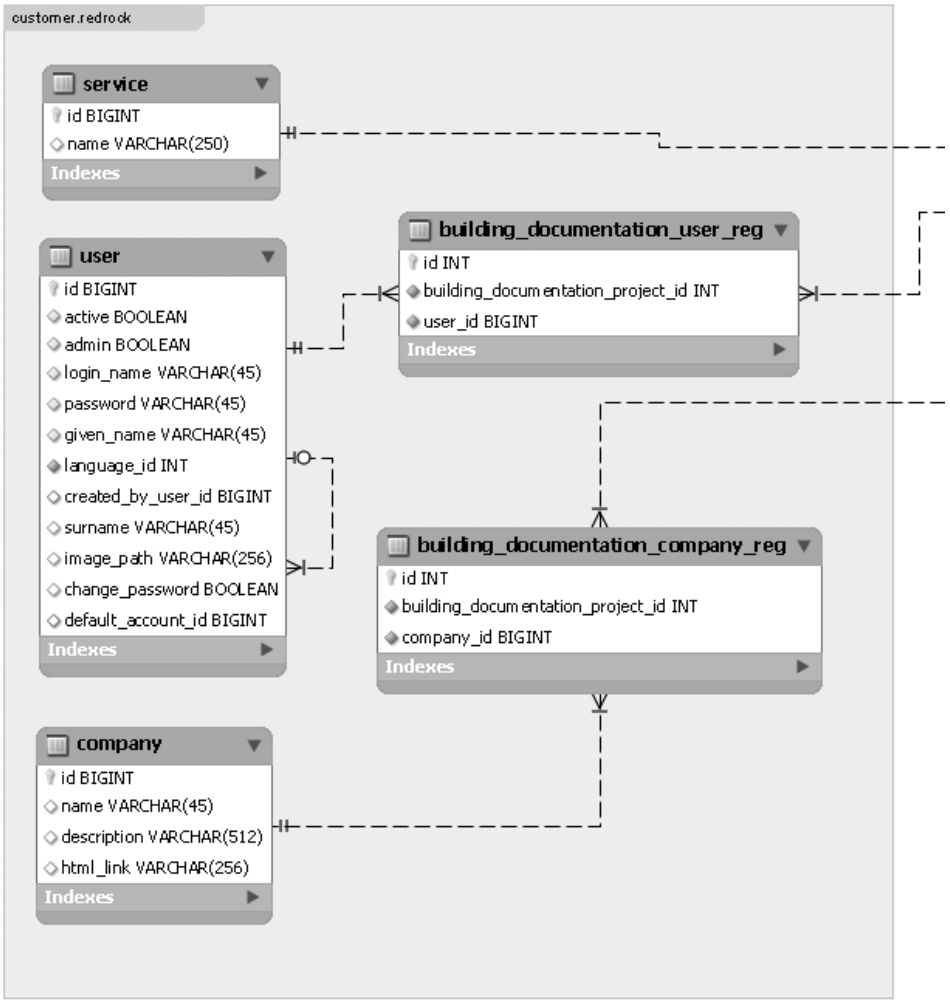


Figure 4.4: Database Design, integration with Red Rock's customer system

As seen in figure 4.4 there are several connections to Red Rock's customer system. Two linking tables have been created to match the records from the relevant project and user/company. The Service table is also linked to the building documentation project. As mentioned before, the Red Rock customer system has also been developed as part of this project. The tables seen in figure 4.4 are only a small part of this database design, and a more detailed overview can be seen in Appendix C.

Building Documentation Project

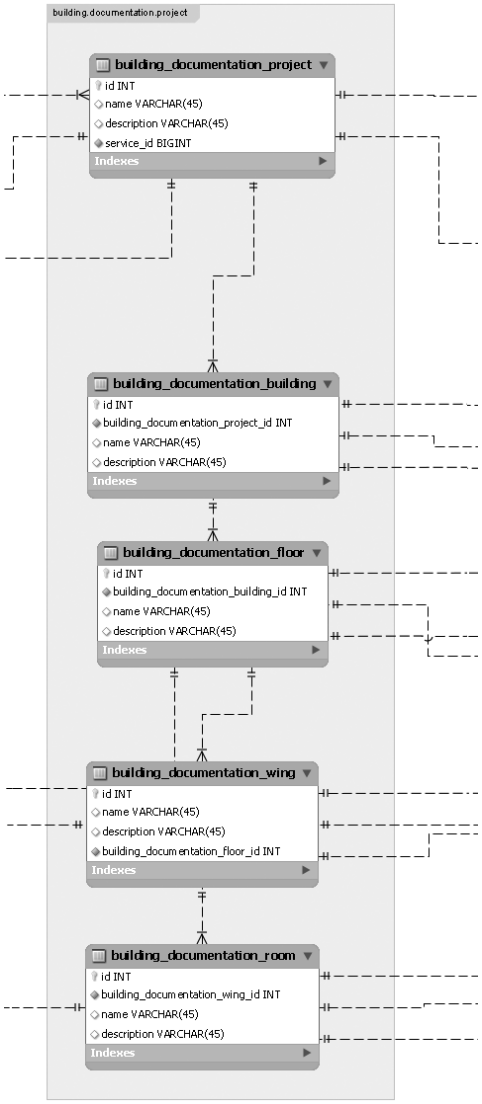


Figure 4.5: Database Design, building documentation project

Figure 4.5 presents the tables that holds the most basic information for each project. As seen on the figure, each project can contain buildings, floors, wings and rooms. Each of these specific objects can then again contain other objects which will be presented in the next modules.

Building Documentation Vertex

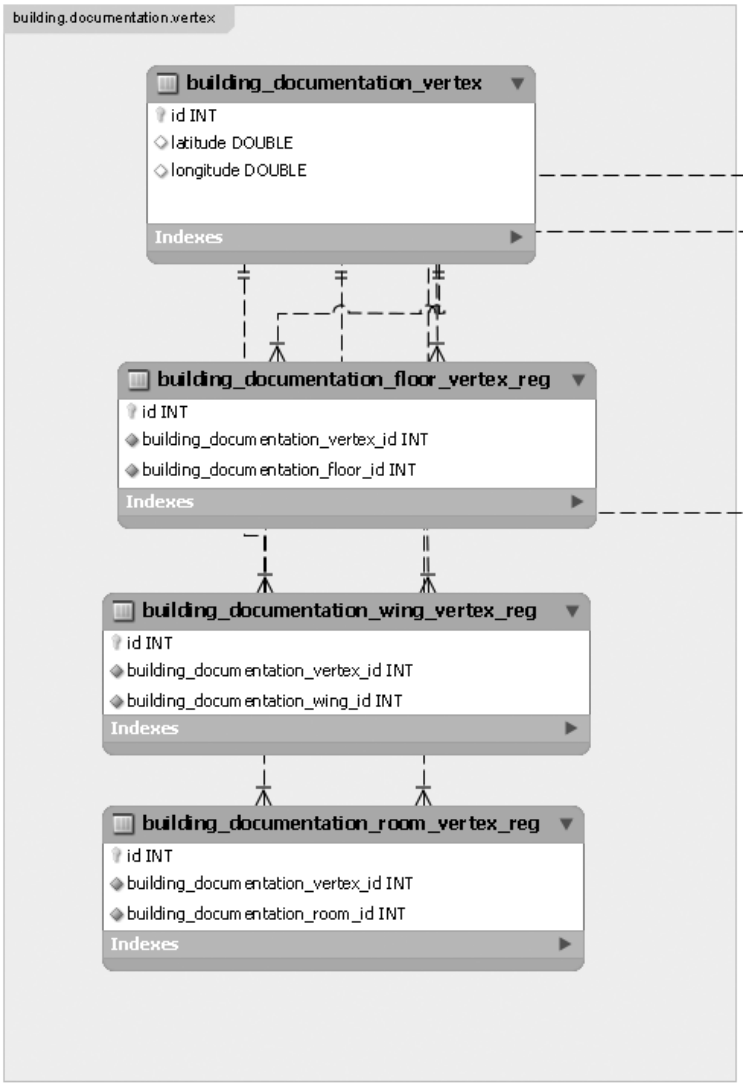


Figure 4.6: Database Design, building documentation vertex tables

The model presented in figure 4.6 holds the latitude and longitude coordinates for either a building, floor, wing or room. As seen in the figure, only the primary table in the module holds the latitude and longitude values, and the remaining are linking tables.

Building Documentation Checklists

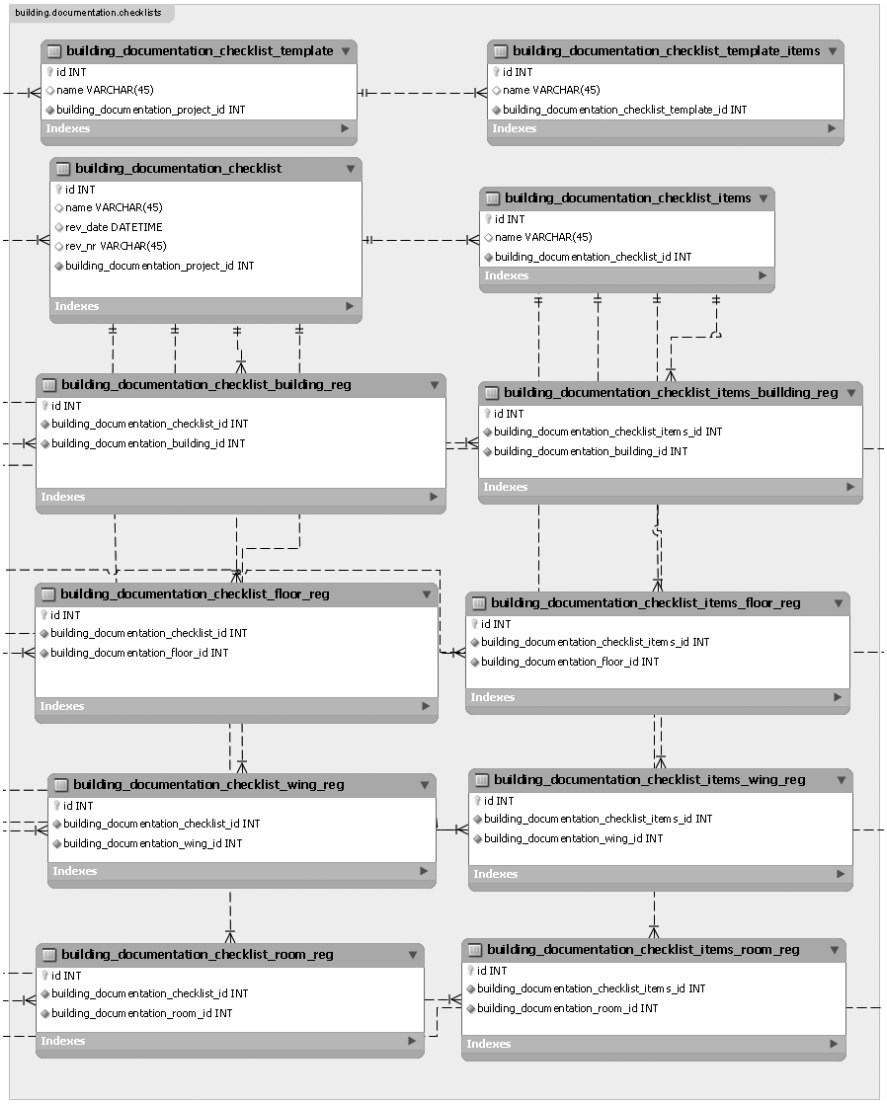


Figure 4.7: Database, building documentation checklists

The checklists are a central part of this project and are presented as seen in figure 4.7. There are two main tables for this module that contain the data specific for that checklist or checklist item. The remaining tables are linking tables from either the checklist or checklist item to the relevant object (building, floor, wing or room).

Building Documentation Pictures

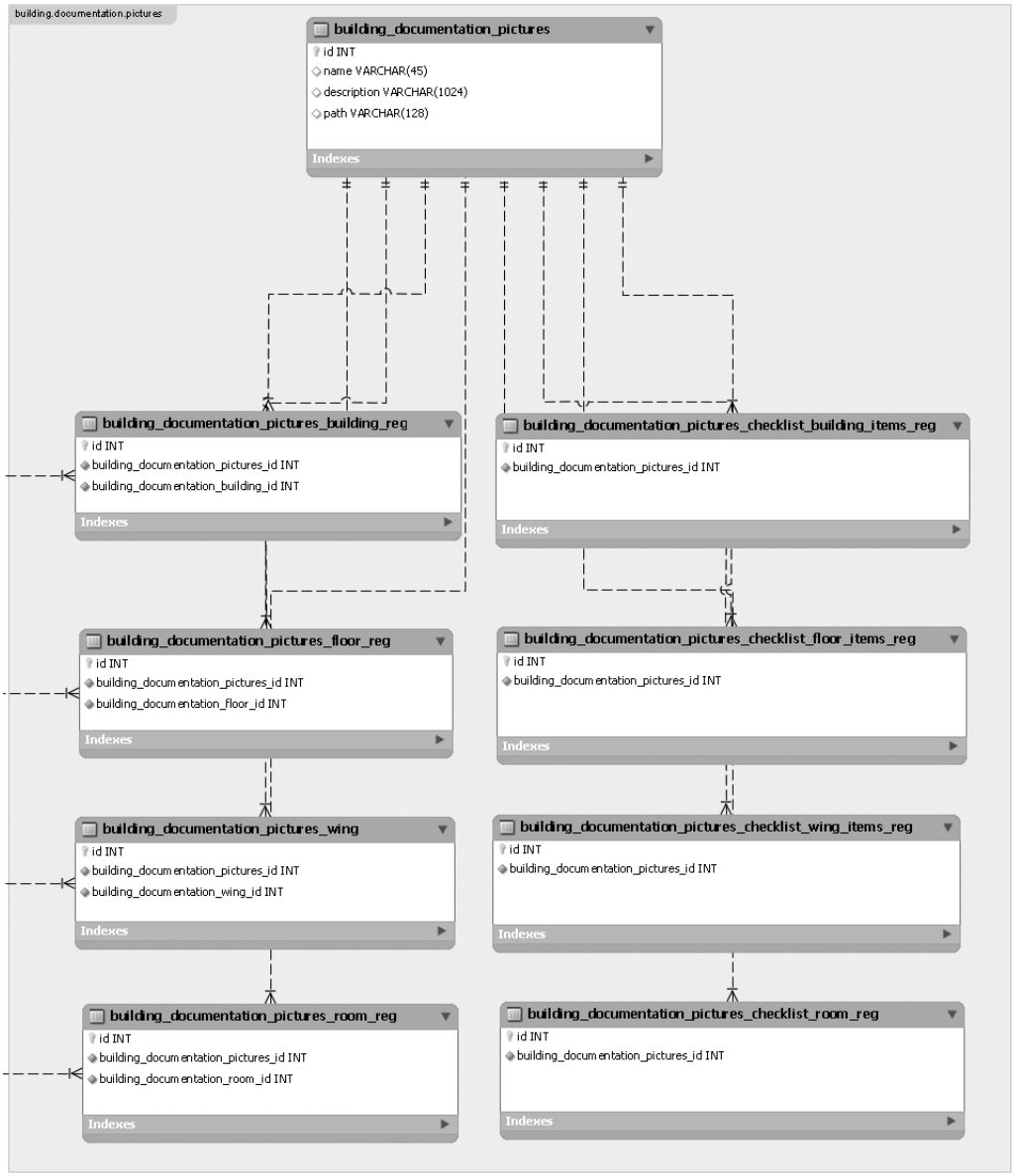


Figure 4.8: Database, building documentation pictures

Pictures are also a central part of this project and are presented in figure 4.8. There is one main table for this module, and each remaining table is a linking table, linking that picture to a specific object.

4.4.2 UML Models

The system has been designed to run fast and not use much memory, so it will be able to run smoothly on Windows Mobile based cell phones. Making instances of classes is slow on the platform and is, therefore, not often done, this will be reflected in the UML models.

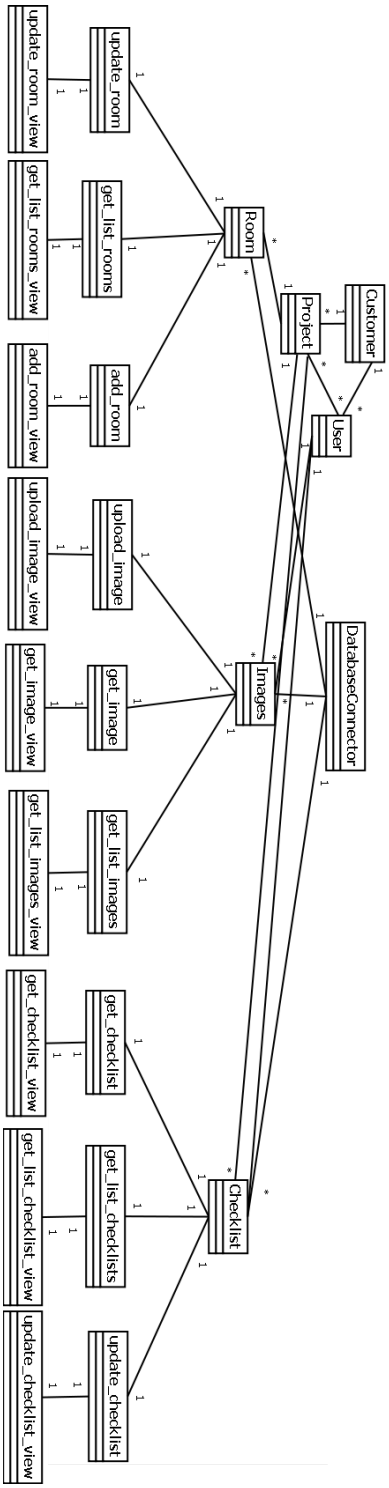


Figure 4.9: The basic UML model for the web service, this only show the class skeleton for the esential classes to make it easy to read.

4.4.3 Use Case

The use case diagrams show the options currently available to the customer. There are three types of users; craftsmen, project managers and administrators.

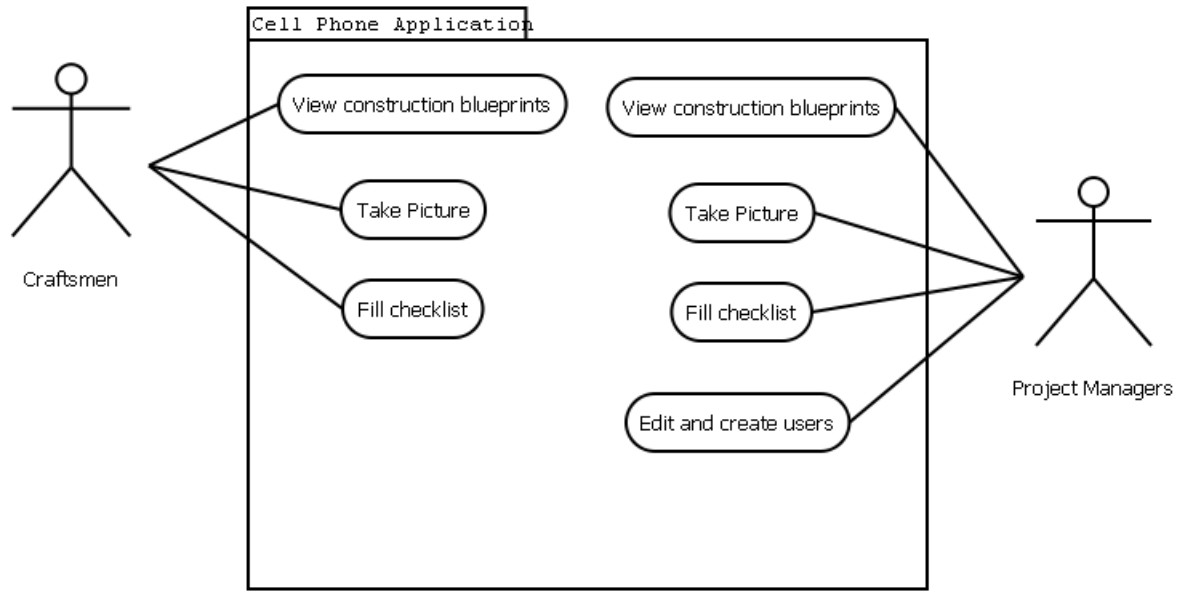


Figure 4.10: Use Case Diagram, Cell Phone Application

As seen in figure 4.10, there are two types of users for the cell phone application. They mostly have the same features available to them, but the managers can create/edit users in addition to the normal documentation features.

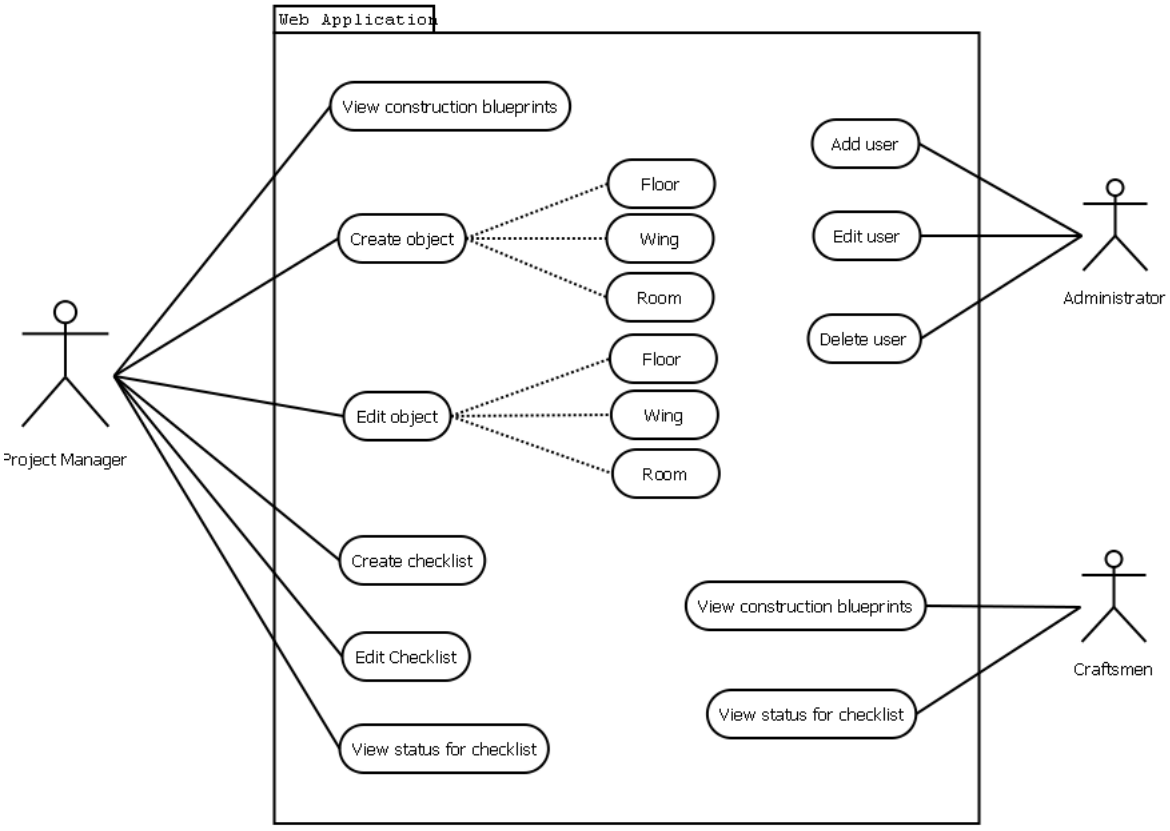


Figure 4.11: Use Case Diagram, Web Application

As seen in figure 4.11, there are three types of users for the web application. Project managers are the type with most features, being able to crate and edit objects in the construction blueprints. Administrators handles the user part of the application, while craftsmen can view the blueprints and checklists.

4.4.4 Sequence Diagram

Sequence diagrams have been made for the most important features of both the cell phone and web application. The sequence diagrams are illustrated on a high level, but still give a good insight into how the system works. An example of how the diagrams illustrate the features of the prototype is given in figure 4.12 below:

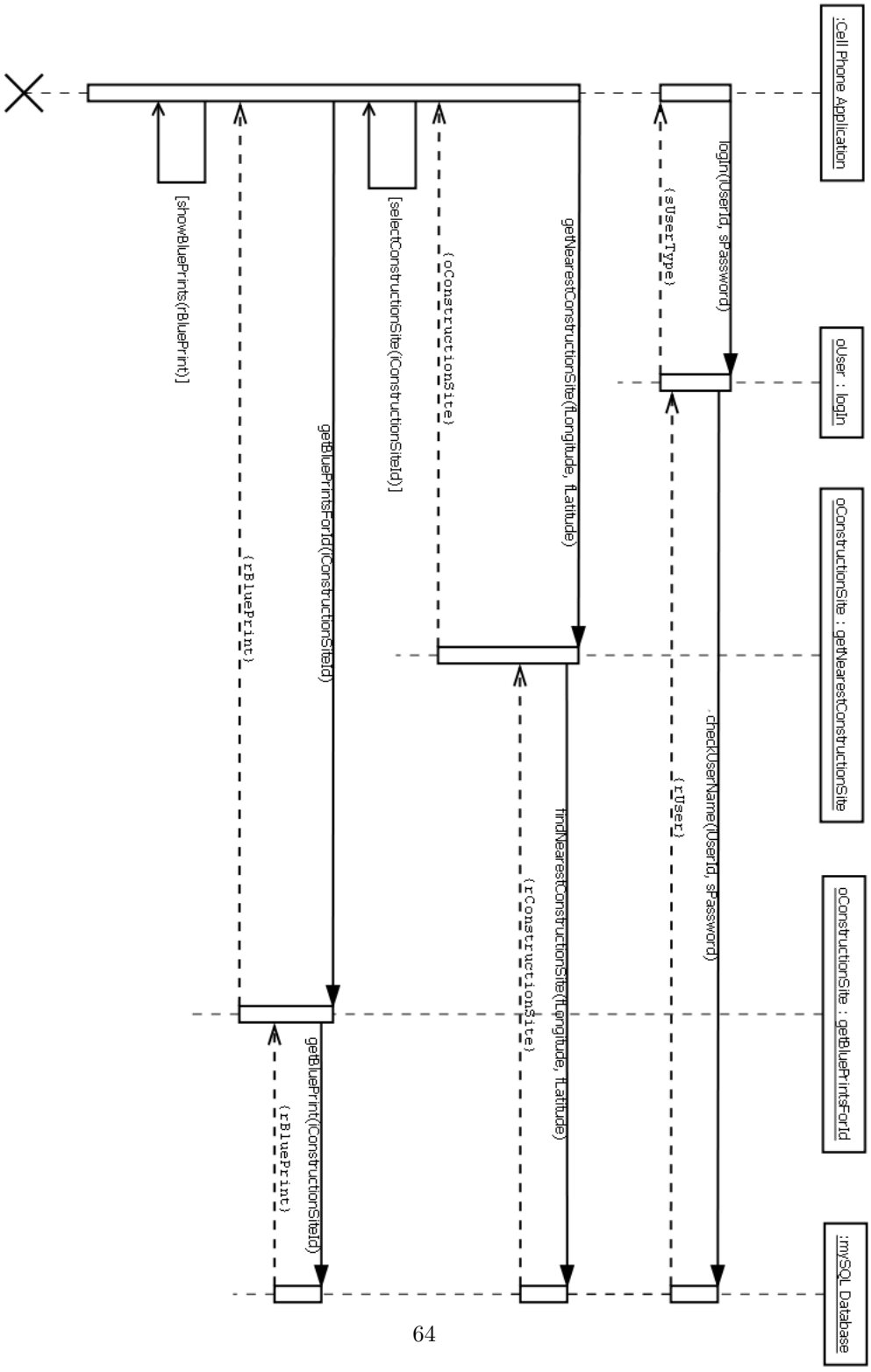


Figure 4.12: Sequence Diagram, Show Blueprints on Cell Phone

The diagram illustrates how the applications reacts from login to showing the actual blueprints. As mentioned at the beginning of this sub section, the diagram is illustrated at a high level, but still basically shows how the system works.

4.4.5 Software Engineering Architectural Pattern

Since the prototype is a complex software system, with several different parts on different platforms, it is important to use an architectural pattern [3] for the code that is easy to maintain, and which makes the software development process more rapid. One of the main concerns is that the pattern would make it possible to separate the business logic from the view. For this reason, the Model view controller (MVC) architectural pattern was chosen. The members of the group also had experience in software development using MVC and it would not be a problem to use this pattern together with the agile development process chosen.

The prototype has a modular design. All the different classes are divided in a logical way, so it is easy to change components if needed. It is also easy to add new components to this system.

MVC is a software engineering architectural pattern where the key idea is to separate the view from the business logic. This is done by using views, models and controllers. The view contains what things should look like. The controller gets all the input and calls the model to get things done, it also sends the data needed to the view. The model is the representation of the data and the business logic of the application [28].

4.5 System Documentation

Since this prototype is developed as a pilot, documentation of both source code and usage has been a primary focus. Besides the report itself, all the source code is described with PHPDoc for the web application and NDoc for the cell phone application

Both PHPDoc and NDoc has more or less the same functions and are both based on Javadoc. Their main function is to generate class library documentation from the source code, and can be saved as several different formats. This provides a good start for new developers building on existing code, and for Red Rock it is essential to any development routines.

Below are an examples of how PHPDoc has been used in this project:

Code example of how PHPDoc is used in this project

```
/**
 * function findNearestConstructionSite
```

```
 *
 * Use existing latitude and longitude values to do a search and find
 * the nearest construction site stored in db
 * @param $iLongitude - the current longitude value for the user
 * @param $iLatitude - the current latitude value for the user
 *
 */
function findNearestConstructionSite($iLongitude, $iLatitude)
{
        //Code
}
```

As seen in the code example, system Hungarian notation is used as a prefix to the variable names. This is used to clearly define the variabel type, and again makes the code easier to read and understand. More on coding standard can be read in appendix A.

4.6 Implementation

The implementation is done according to the requirements and work packages. To ensure that every work package and requirement was fulfilled, the test cases was worked out and used. This section will present the work done related to the implementation of both the web and cell phone application.

4.6.1 Web Application

The web part of the prototype is where the project manager can track the documentation progress, view the documentation and add documentation requirements.

The main view of the application where the user will do most of the work is the construction blueprint view. In this view the building blueprints for the different floors are available. Rooms or other areas can then be added to the blueprints and specific documentation needs can be added to the room or area. Access documentation that is created can also be done from the blueprint by clicking on the room. When rooms or areas are added to the blueprint, a three view of the floor is created for easy access to the different parts of the building.

Checklist templates can be created and used as a basis for other checklists. When a new project is created, checklists can be copied from the templates, and modified for that project, or new checklists can be created. The checklists can then be added to a room or an area as a requirement to complete that room or section.

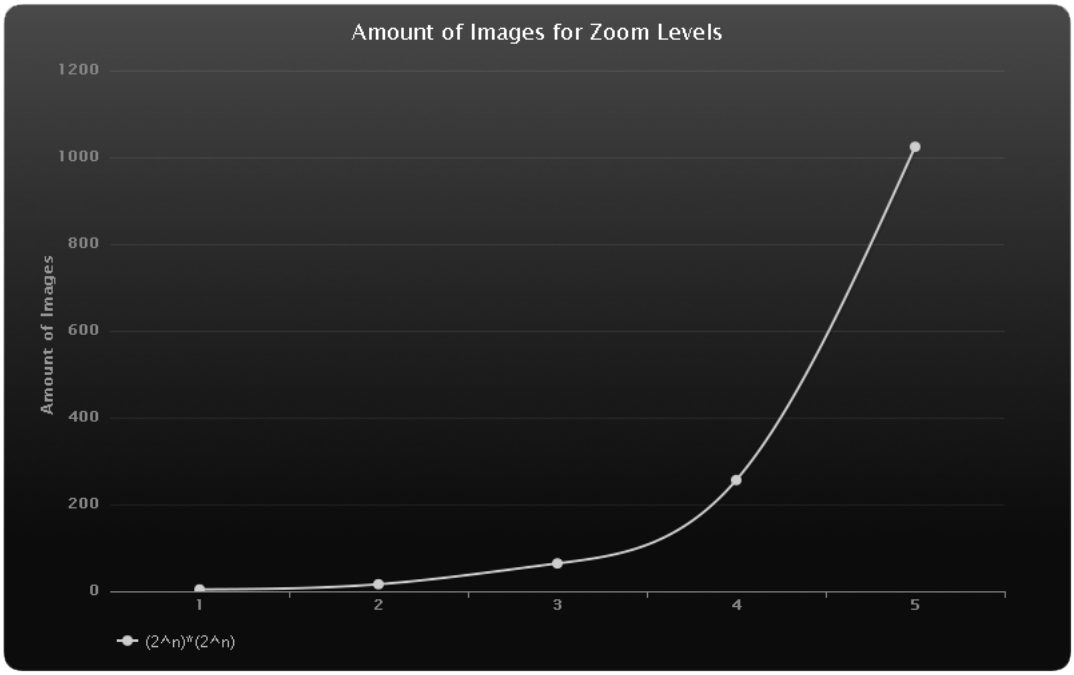


Figure 4.13: All the construction site plan tiles, created at the different zoom levels.

The construction site blueprints is split into tiles so it can be displayed on cell phones and the web. The graph shows the number of tiles for different zoom levels. The zoom levels start at zero which is the whole blueprint in one tile, then at zoom level one the number is 2 to the power of 1, zoom level 2 is 2 to the power of 2 an so on. The graph shows how fast the the amount of images increases as more zoom levels are added. Only six zoom levels are added in the graph to show the curve for this range.

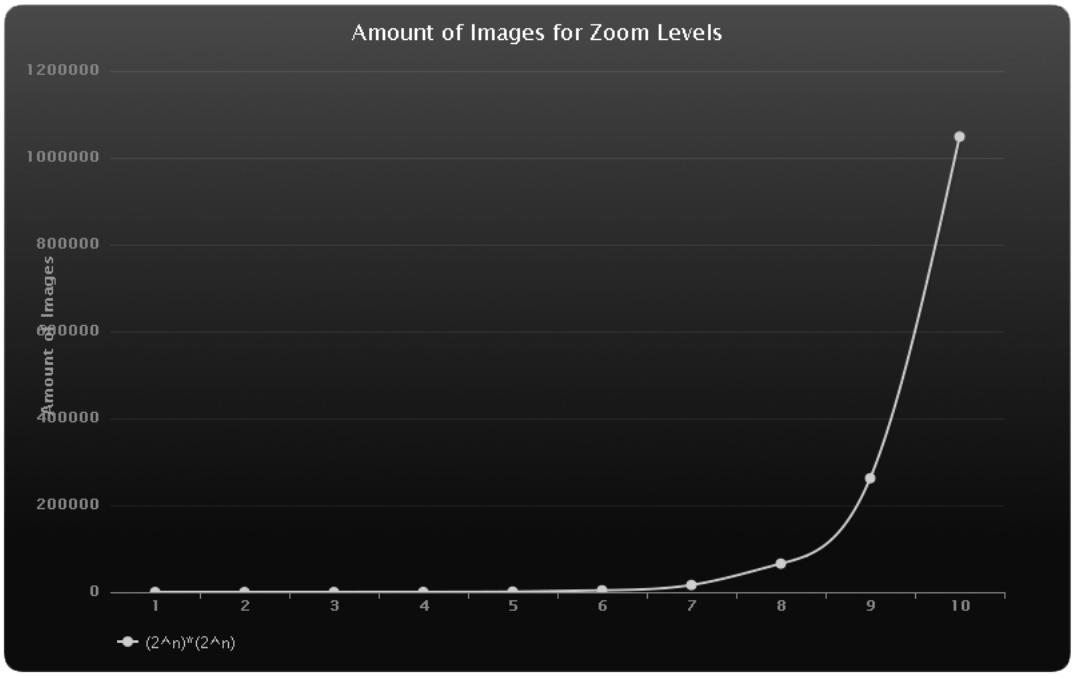


Figure 4.14: All the construction site plan tiles, created at the different zoom levels.

The graph shows the same data as the previous graph, but with more zoom levels to illustrate how many more tiles are added when the zoom level increases.

4.6.2 Cell Phone Application

The cell phone application should have focus on structure and being user friendly. What was important to have in mind when developing the cell phone application, was that a cell phone does not have as much memory and computing power as a desktop computer. The screen size is also a factor that had to be taken into consideration, since the application is supposed to show large construction site blueprints on the cell phone screen. A web service was developed to handle all the database work load, and communicates using JSON through http requests. The JSON format was chosen since it is applicable for almost any cell phone device.

The login

The first screen the user meets when the application is started is the login screen. The login screen is a simple screen consisting of the company logo and regular fields for username and password. When the credentials are submitted, a http requests sends the information in JSON encoded format, to a web service. The web service handles the communication with a database and returns if the validation of username and password was ok. The web service sends the response back to the login screen, where the response decides if the user is taken further on to the next screen, or recieves an error message.

Choose a Construction Site

If the user is logged on, the user gets a screen where he can choose amongst these actions:

- Choose a construction site from a list
  - The list of construction sites is received from the web service which gets all the construction sites that the user has access to. When a construction site is chosen, the user will be forwarded to a screen which shows the selected construction site.
- Choose a construction site using Bing Maps
  - Choosing a construction site was implemented by using the Bing Maps API from Microsoft. The Construction sites are located on the map as red rings, with the construction site project name attached to it, as shown in figure 5.3 in Chapter 5.2.3. When a construction site is chosen, the user will be forwarded to a screen which shows the selected construction site.

A clickable action on top of the screen, which suggests the nearest construction site by using the GPS on the cell phone has also been implemented. This solution was implemented by cross checking the user's current position against the company's construction sites coordinates. The nearest construction site is shown on a clickable label which will take the user to a screen which shows the selected construction site.

Choose Construction Site Actions

When the user has selected a construction site, he gets a list of actions he can choose from:

- Show the construction site blueprint
  - This action will show a new screen, where the user can scroll the construction site blueprint, insert checklists and captured images,and view or edit checklists and captured images.
- Show the checklists registered for this construction site
  - This action will show a new screen, where the user gets a list of checklists, which is received from the webservice by using http request, that has been added to the construction site. The user can choose one of these lists and look through it.
- Show the captured images for this construction site
  - This action will show a new screen, where the user gets a list of the captured images that have been added to the construction site. The user can choose one of the captured images and look at it.

View Construction Site Blueprint

If the user has chosen to view the construction site blueprint, he will be shown a blueprint, which is split in 256x256 pixels pices and loaded while the user scrolls the construction site blueprint. The reason why it is done like this, is that the cell phone is relived from the work of loading the whole construction site blueprint at once. This would have resulted in downloading and loading an image that often has a size above 30 Mb, which would have taken too much time to download and load on the screen, and would take up a lot of memory on the cell phone. The whole construction site blueprint is of high quality and is fairly large. The split algorithm uses the formula

$$NumberOfTilesOnACoordinate = 2^{zoomlevel}$$

to split the construction site blueprint into tiles. Since this formula is known by the cellphone application, it can figure out what tile coordinates it should download for the selected zoom level. The split algorithm does not include tiles that are 100% white, and therefore the cellphone application also had to take this into account. This was solved by implementing a function that holds a hashtable that has stored a boolean for every tile coordinate if an image should be downloaded or not. The function tries to download a tile, and if the image url does not exist, the hashtable adds the coordinates as key and a boolean, "false", as value.

The implementation of loading and deleting tiles while scrolling the construction site blueprint was done by creating an algorithm that checks the tile in the centre of the screen. The algorithm listens to the scroll direction, and load tiles to the screen that are the nearest neighbour of the chosen tile. This is shown by the figure 5.4 in Chapter 5.2.3.

The same algorithm also deletes image tiles that the user is scrolling away from. This ensures that there is free memory for new image tiles that are beeing loaded to the screen.

As shown in figure 5.5 in Chapter 5.2.3, the rooms are marked out as both red and green. It is implemented so that a green room is marked as finished, and a red room still needs some work.

The documentation part of this application is done by adding either checklists or capturing images of work that is finished. This is done by clicking and holding a stylus or finger at a point on the construction site blueprint. The user will then get the choice of either adding a checklist or capturing an image and add it to the specific location.

The image that has been captured is sent to a project folder on a server, and the coordinates are sent to the web service which stores them in a database, so that we can get the coordinates to an image by requesting them through the web service, and the server which holds the image.

The checklists are templates that the craftsman has to fill out. A checklist consists of fields that are related to the work they have done, and are of interest to the project manager and the company. The checklist is sent to the web service as JSON format and stored in a database.

All the checklists and captured images are shown on a construction site blueprint by icons. These are acquired by http request to the web service. The web service responds with coordinates and main information about either a checklist or captured image. Should the user want to look at an image, it will be shown by requesting the server holding the images, and loaded on the memory of the phone. A checklist will be obtained by requesting the checklist from the web service, by using the ID of the checklist.

A code example which shows an algorithm that decides if a tile coordinate should download and load an image. The algorithm will store the image url in the queue, "queueDownloadImageQueue", where another thread will download and show the image on the correct tile coordinate.

The tile cutter algorithm which splits the construction site blueprint does not process a tile image that is 100% white. To make the image download and loading process work faster, a hashtable named "hashShouldCoordinateHaveImage" stores if the tile coordinate should try to download and load an image. This is decided when the download and load image algorithm for the first time tries to download the image for the tile coordinate. If no image exists for that tile coordinate, and we know that the tile coordinate is a part of the construction site blueprint, it must be a white tile. It should not be necessary to try

and download this image tile again, and it is therefore stored in the "hashShouldCoordinateHaveImage", which is checked in this algorithm.

The algorithm also checks if there already exists an image on that tile coordinate, by checking the "hashDownloadedImageMapHolder". This algorithm is used to check a selected tile's nearest neighbour tiles, to see if they have an image on their tile coordinate. This is done to preload image tiles before the user scrolls to the tiles.

Code example of tile loading and creation while moving horizontal:

```
/*
 * Horizontal movement
 */
if (0 < iHorizontalMovement) // Going horizontal right, checking tiles at right
{
    int iNextTileYCoordinate = iThisTileCoordinatesY - iPixelPerTile;
    int iNextTileXCoordinate = iThisTileCoordinatesX + iPixelPerTile;

    // Check if the next tiles has image. The next tile is at the upper right of this tile.
    for (int y = 0; y < iMaxIterationsHorizontal; y++)
    {
        for (int x = 0; x < iMaxIterationsVertical; x++)
        {
            Point pointTileCheckedCoordinates = new Point(iNextTileXCoordinate, iNextTileYCoordinate);

            // Check if the coordinate should have an image
            if (hashShouldCoordinateHaveImage.ContainsKey(pointTileCheckedCoordinates))
            {
                /* check if the tile should have an image
                 * a tile could be set to have no image, since the cut algorithm of tiles does not include
                     images that are 100\% white.
                 * Therefore we do not need to try to download the white image
                 */
                if (true == (Boolean)hashShouldCoordinateHaveImage[pointTileCheckedCoordinates])
                {
                    // Download the image if it does not already have an image
                    if (hashDownloadedImageMapHolder.ContainsKey(pointTileCheckedCoordinates))
                    {
                        // If the bitmap is null, download the map
                        if (null == (Bitmap)hashDownloadedImageMapHolder[pointTileCheckedCoordinates])
                        {
                            int iArrayCoordinateX = (pointTileCheckedCoordinates.X / iPixelPerTile) - 1; //
                                Since our ORIGO is 256, and not 0, we need to subtract one level
                            int iArrayCoordinateY = (pointTileCheckedCoordinates.Y / iPixelPerTile) - 1; //
                                Since our ORIGO is 256, and not 0, we need to subtract one level
                            String sBitmapDownloadUrl = sImageUrl + z + "-" + iArrayCoordinateX + "-" +
                                iArrayCoordinateY + sImgExt; // Get the imageurl of the tile that we are
                                checking

                            // If we don't already have the image in the queue, don't download it
                            if (!queueDownloadImageQueue.Contains(sBitmapDownloadUrl) &&
                                !hashDownloadedImageScrollBarHolder.Contains(pointTileCheckedCoordinates))
                            {
                                // Upload the image url to the queue, and let a thread take care of it
                                queueDownloadImageQueue.Enqueue(sBitmapDownloadUrl);
                                hashDownloadedImageScrollBarHolder.Add(pointTileCheckedCoordinates, coord); //
                                    Add the scollbarposition to the current pixelcoordinates
                            }
                        }
                    }
                }
            }

            // Check the next horizontal tile
            iNextTileXCoordinate = iNextTileXCoordinate + iPixelPerTile;
        }

        // Check the next vertical tile, and reset the horizontal tile
```

```
        iNextTileXCoordinate = iThisTileCoordinatesX + iPixelPerTile;
        iNextTileYCoordinate = iNextTileYCoordinate + iPixelPerTile;
    }

}
```

4.6.3 Blueprints

The application needs to show several different kinds of blueprints including architectural, electrical etc. This blueprint is designed in a CAD application, it should then be exported to PDF and uploaded to the application from its web interface. ByggDoc will convert the PDF to a set of images called tiles. The tiles represent a part of the blueprint at a zoom level; they are 256X256 pixels. The reason for this size is that they should work on low end cell phones that might have limited memory. A typical blueprint will typically have 8 zoom levels and about 1700 tiles.

The tiles are stored on a server designed to server static content; it only runs a light weight web server. The server has 4 sub domains that point to the same directory, example: static1.domain.com, static2.domain.com, static3.domain.com and static4.domain.com. The reason for this setup is that some browsers and devices has a limit on the amount of connections to the same server, ex. Internet Explorer can only have 2 connections to the same server (a sub domain to the same server counts as a new server). With a setup without the sub domains Internet Explorer would never load more than two tiles at the same time, but with 4 sub domains it can load up to 8. Fast loading of tiles is critical for a good user experience.

4.6.4 Software Development Approach

Agile software development is a good choice for a small group with a relative short time period to develop high quality software. Such a development method indicates what the problems are and how they can be solved at each stage of the project.

Agile Development

Agile development emphasises on clear goals and planning, and the most important thing is that it ensures the completion of the development at the end of each iteration. The procedure of agile web development consists of planning, requirement analysis and designing, coding, and testing. Documentation is parallel with each stage of the development. It can be the most effective development method for a small group and short time period projects.

Coding standard

One important factor in writing quality code is to follow a coding standard. For this prototype all the code that has been written has followed the same coding standard, with some adjustments for the different languages. The coding standard covers how the code is written, indentation, syntax and how variables, classes and functions are named. The basic coding standard is covered in Appendix A.

Software development best practices

It is important to adopt some best practices when developing applications so the product will be of a high enough quality to be easy to maintain, and so that it can be put in a production environment. The following list includes some of the important best practices used for this project.

1. **Requirements** - All the requirements are set before any code is written, this is important so large portions of the code do not need to be re-written.
2. **Code documentation** - The code is documented both with a JavaDoc style and comments in the code.
3. **Code style** - All the code follows the same coding style.
4. **Testing** - All the features have test cases that have to be completed before the feature is complete. Each unit of the code is also tested by itself when it is written.
5. **Architecture** - To create good code an architecture is needed. The MVC model is used in this project.

4.6.5 Testing

All the code is designed for test, and test cases are made for every functionality in the solution. JIRA was used as a project management tool. JIRA combines issue tracking and test management to increase the velocity of the development. Unit testing were executed to verify that all the use cases was done and worked. At the end of each sprint, working code for that sprint was delivered and not accepted before all the test cases had passed. Automated unit testing was considered but decided against. The reason for this is simply that the various functions do not always have a clearly defined test case that would show if the code worked or not.

To further ensure that the coding has been carried out in a fast and efficient fashion, several steps has been taken under consideration during the entire pilot development.

1. **Source Control:** Tortoise SVN has been used as a source control tool. With SVN, mistakes can be easily rolled back and since more then one programmer will be working on the same pieces of code, it is easy to see what other people have done.
2. **Fix bugs before writing new code:** In general, if bug fixing is delayed, it will be costlier to fix the problem. If the bug is fixed imediatly after writing the code, it will be done a lot faster since the code is still fresh. If the bug is somewhere in a piece of code written several days ago it will consume much more time to find and fix the problem. Also, if the bug count keeps rising and the bug fixing keeps getting delayed, it will be much harder to actually sit down and start fixing.
3. **Specification text:** Software that is not built after a specification text, usually ends up badly designed. Much time has therefore been used in designing all parts of the pilot. Mock-up screens have been produced for every part of the pilot, and can be seen in the appendix.
4. **Bug tracker database:** Each bug must include complete steps to reproduce the bug, expected and observed behavior, who it is assigned to and whether or not it has been fixed.

4.7 Development Tools

To support the multi platform development done in this project several tools have been used.

4.7.1 Development Tools

For software and web-development, tools like an integrated development enterprises (IDE), servers and database tools are essential. The following development tools have been used.

Visual Studio 2008

The IDE used for Windows Mobile development. The code is written in C#.

Zend Studio

Zend Studioe is the IDE for writing code both for the web service and the web interface. Both PHP and JavaScript are written in this IDE.

XAMPP

XAMPP is used do easily install the environment to run and test both the web interface and the web service. XAMPP includes a web server (Apache), PHP and a database server (MySQL).

MySQL Workbench

MySQL Workbench is used to make the database schema. It is a tool that makes it easy to see the relationships between tables.

Windows Mobile Emulator

This emulator is used to test the mobile applications on the development computer.

4.7.2 Frameworks and Libraries

Using existing frameworks usually provides several advantages. Libraries are usually implemented to extend the basic functions with better or entirely new functions. Below are the frameworks and libraries used in this project, and the reason for choosing them. Using existing frameworks, usually it will provide several advantages. Libraries are usually implemented to extend the basic functions with better or entirely new functions. Below are the frameworks and libraries used in this project, and the reason for choosing them.

Code Igniter

Code Igniter is the framework used for both the web service and the web interface. The main feature that code igniter is needed for is its Model-View-Controller code design.

MooTools

MooTools is used as the JavaScript library. It extends JavScript itself making it more suitable to build web applications and making it easier to get the code to run on different platforms.

.net Compact Framework 3.5

The framework used to develop the cell phone version of the application.

4.7.3 Configuration Management

As seen in the previous sections, the configuration management (CM) plan proposed in chapter 2 has been followed exactly as proposed. In addition, to ensure that the developers can trace back code to an earlier version, Tortoise SVN has been used as a CM system.

Tortoise SVN

Tortoise SVN is a free-of-charge and open source subversion system used by Visual SVN to execute all subversion commands. The icon overlay shows which feature keeps all members of the team informed with the latest version information.

Chapter 5

Results

This chapter presents results for both the background research and the prototype development. The user experience is an important factor for the customer and will be presented by screen dumps. The test cases were made to verify that the different use cases and work packages were completed and worked as they should, and these results will also be presented in this chapter.

5.1 Construction Site Survey

As described throughout the report, a survey was conducted to get accurate results on how the documentation is done today and how it can be improved. The survey started by observing workers at a selected construction site and continued with meetings at Oras Agder in Kristiansand. The observation provided most of the raw data, and in the meetings that data was carefully analyzed. After several open discussions with the employees at Oras Agder, the requirements presented in this report were finally worked out.

5.1.1 Field Notes

The field notes where written manually during the field observation, and below is a summary of the three field notes written:

Field Notes Summary

The field observation started by signing in at the workmen's hut for safety reasons. The observation participants were also given helmets and iron clad shoes.

- There should be a method of signing in and out in the application. If not in the first version, it should at least be included in a future version.

The project leader guided the participants around the construction site as a group first and gave basic instructions on how to safely move around the construction site.

- One note here is the different set of rules and instructions for the construction site. If the rules vary from site to site, this might be something to include when defining a project in the application.

The building itself was quite large with several storeys. The participants never got higher than fourth floor, but there were at least 2-3 additional floors.

- Since there are this many floors, there must be an easy and fast way to navigate from floor to floor in the application.

After the basic instructions where complete, the participants divided into separate groups and started their observation routines. There were a lot of workers and craftsmen, and the participants started out by asking some of them about their daily, basic routines at the construction site. None of the asked workers had done any documentation themselves, and they did not like the thought of doing it either. However, when explaining to them about the basic concept of the application, they showed great interest and some came with interesting ideas and inputs listed below:

- Construction sites usually have a lot of dark areas without light, the camera on the cell phone device should have a light source to improve the quality of the pictures taken.
- The cell phone should have a large screen and a stylus for selecting items on the screen.
- Several of the workers where a bit nervous for the possible complexity of the application, so the application should be designed with ease of use as a main focus.
- The cell phone should be robust.

After an hour of questioning and observation the participants met up with the project leader, thanked him for the support and left to the workmen's hut, signed out and left the construction site.

5.2 Implementation

The prototype has been developed and has been implemented according to the requirements and specifications. All the functional and non functional requirements were implemented. The solution was tested both on an emulator and was deployed to a Windows Mobile cell phone.

5.2.1 System Architecture

The following figure presents the system architecture on a high level, for both the cell phone and web application developed for this project.

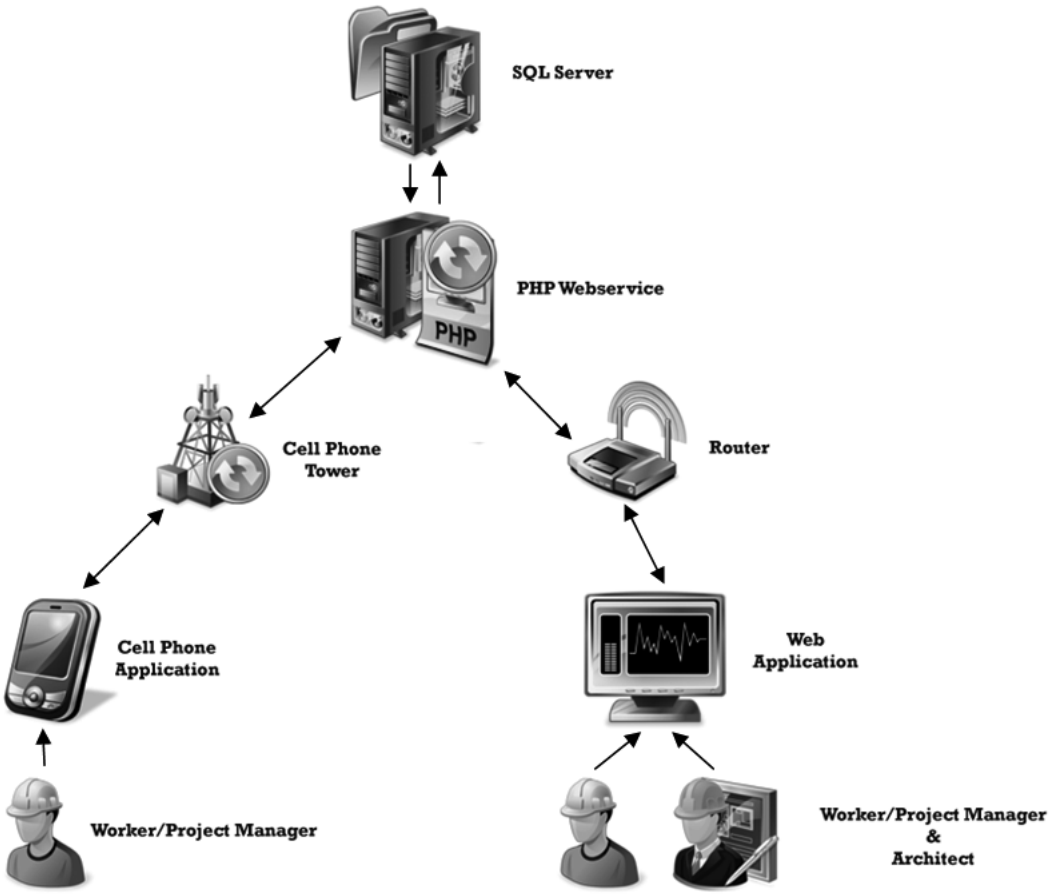


Figure 5.1: System Architecture, a model of how the system is put together

As seen in figure 5.1, all data is stored on the SQL server. The SQL server communicates with the PHP Web service, which again communicates with both the cell phone and web application. This is a web-based application and all communication goes through the web service.

5.2.2 Servers

To show in more detail the servers used for this project the following figure has been made.

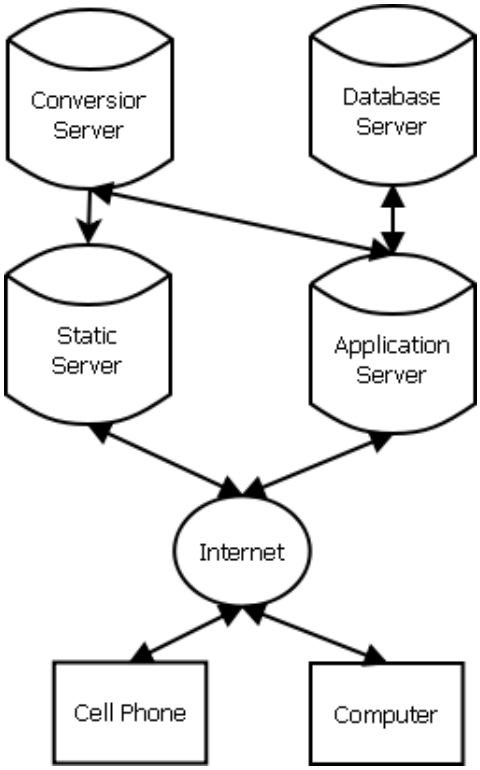


Figure 5.2: Illustrate the server structure for the prototype.

The application should run on several servers for optimal performance. The reason for this is that the server setup can be specialized for the tasks intended both in hardware and software. This setup will support a large amount of users and activity. The four different servers are as follows.

1. **Conversion Server** - The conversion server converts CAD vector based construction site blueprints in PDF format to create the image tiles of the blueprint. The server only needs to run the conversion script from Photoshop and an FTP server.

2. **Database Server** - The database server is running the MySQL database.
3. **Static Server** - This server will serve all the static content of the applications like images, CSS and JavaScript. The main reason this server is needed is the number of images in the converted blueprints. This server only needs a light weight web server and an ftp server.
4. **Application Server** - The application server runs the main PHP application it connects to the database to get and store information, and it creates and servers the web pages.

5.2.3 Cell Phone Application

The cell phone application was developed for the Windows Mobile 6.0 platform and resulted in a prototype that can be used on a construction site. The application was developed in modules where each module was tested properly before starting to develop on another module. The project group worked by following a user-driven, iterative development process to be able to meet the end users expectations, where end user feedback was an important factor. This process resulted in a user friendly and useful prototype, where the end users got what they expected.

Below, figure 5.3 shows the implementation result of choosing a construction site on a map. The construction sites have the correct coordinates when comparing the coordinates from the database and Bing Maps. The result is a user friendly procedure to locate and use a construction site further on in the cell phone application.

Figure 5.3: Choosing a construction site project by using a map

Figure 5.4, points out how the tile loading was implemented. This resulted in an algorithm that checks and loads tiles to the nearest neighbors of the center tile. If they already have an image or they are not supposed to have an image, because it is 100% white, the algorithm skips the image loading part. If the algorithm finds that a tile is supposed to load an image, it stores the image url in a queue, and other threads check the queue, download the image, and place the image on the cell phone screen. By using more threads, the application ensures that the user experience is intact and that the blueprint scrolling works smoothly. The algorithm is executed in the direction the end user scrolls the construction site blueprint. The same algorithm is used for deleting previously watched image tiles that is not on screen, which ensures that there is enough memory for loading image tiles.

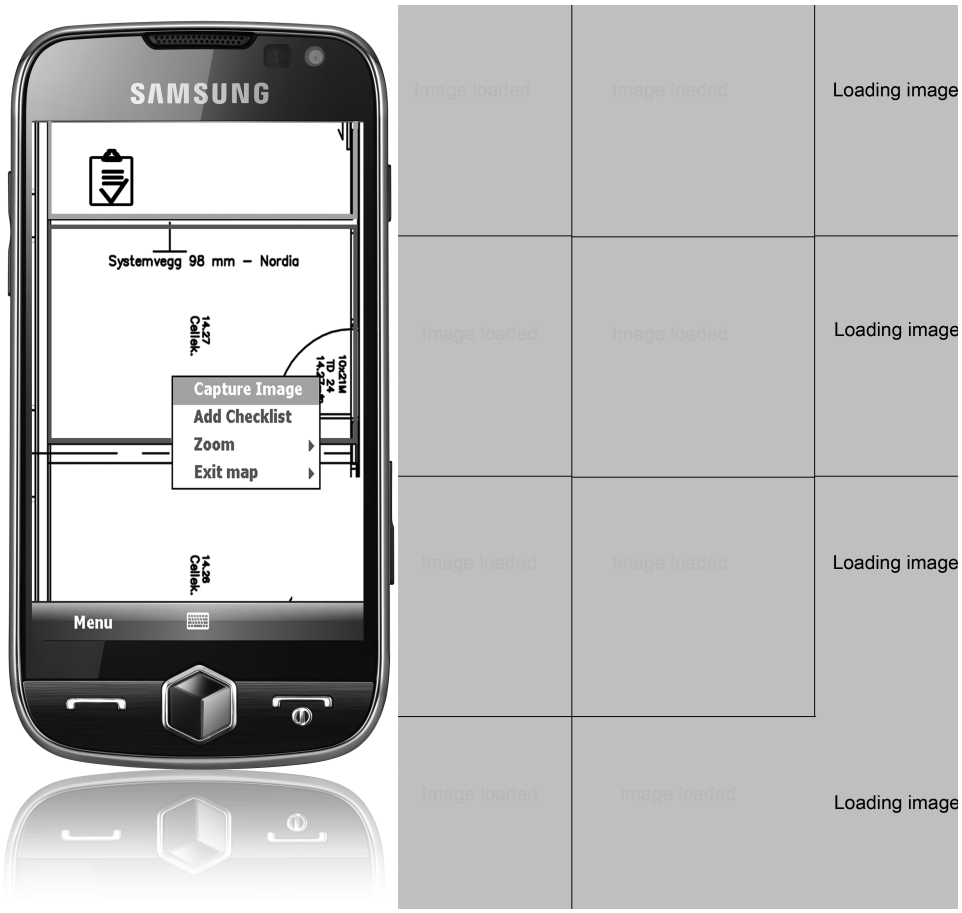


Figure 5.4: The user is scrolling the construction site blueprint to the right, checking and loading tiles at the right.

The tile loading algorithm described above ensures that the construction site blueprint is loaded quickly and accuratly for the end user, assuming that the user has a network connection, at least EDGE, but preferably 3G. This was done instead of loading the whole construction site blueprint at once, which would have resulted in a huge load time and memory consumption, which a cell phone cannot afford.

Figure 5.5 shows the construction site blueprint view and actions. The result of this view is that the rooms that a project manager has marked out using the web application, is shown on the cell phone application, and is either marked by red lines or green lines, where red equals unfinished and green equals finished. There is also a possibility to mark a coordinate on the blueprint and attach either a captured image or a checklist, which all the users that are attached to the chosen construction site, can view.

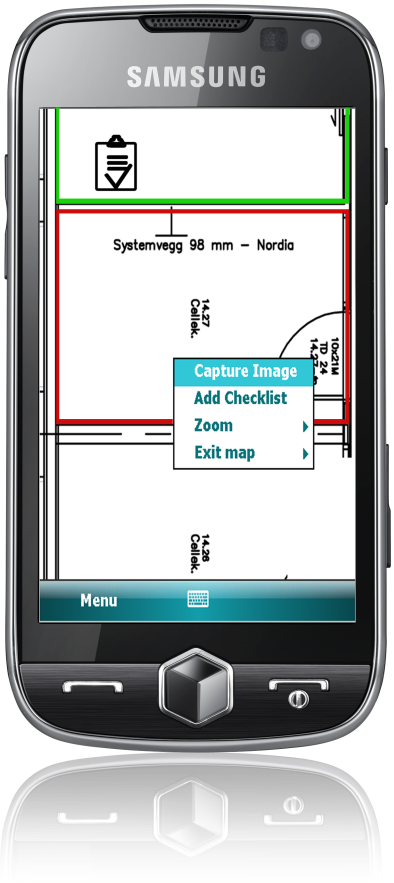


Figure 5.5: The cell phone application showing a construction site blueprint where a project manager has marked some rooms in the blueprint. The green room has been marked as finished, while there is still work left on the red room.

Before release one (R1) of the cell phone application, the project group made sure that the application was working as it should, by processing the test cases made for the cell phone application. The project group cross checked the test cases against the work packages, and all the test cases were successfully executed as seen in table 5.2 in section 5.2.6, Tests.

5.2.4 Web Application

The web application was developed, following the principles of software as a service or SaaS. It is developed for the web platform and can be run by a browser on any kind of operating system.

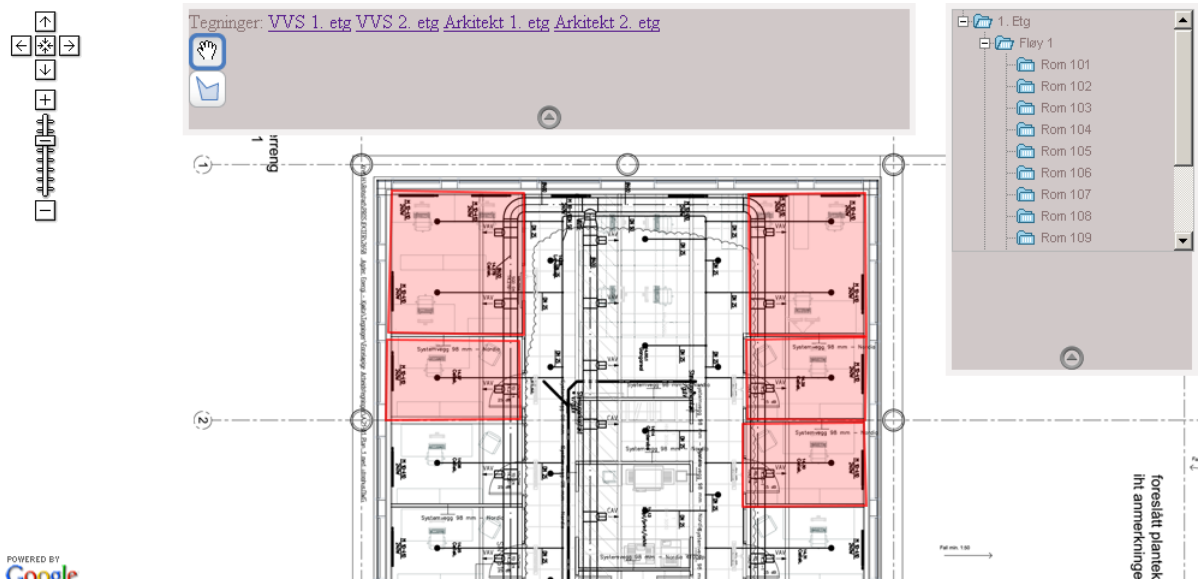


Figure 5.6: The interface shown in this example image is the screen where the users can add rooms in vector format to building blueprints.

As seen in figure 5.6, the display contains a lot of choices for the user. The most basic functions are the move and select tools in the upper left corner. The select tool (hand icon) is used to navigate the blueprints, while the select tool below it is used to create or change rooms, wings or objects. To delete a selection, a simple right click with the mouse on the selection will bring up a menu that contains the delete option. Above the move and selection tool is the floors available for that blueprint. By selecting a different floor, the position in the blueprint will remain the same. The right menu contains the objects created. The objects are created in a tree-structure with the following sorting order:

- Floor
  - Wing
    - Room
      - Specific Object
      - Specific Object
    - Room
  - Wing
- Floor
- Floor

Besides these features, the blueprint also inherits the basic functions from Google maps. This includes both zooming and basic navigation.

Building Blueprint Tiles

The tiles tested were from both architectural and pipe blueprints, and they contain no color information. The results found in this subsection will probably be different if the blueprints contain more colors. The best way to compress the blueprints tested is in gray scale as a PNG file. There was conducted some basics tests with ordinary maps that contains more colors and they showed that JPG might be a better format for that kind of images, the test result for that test is not shown in this report.

The construction blueprint tiles that show the pipes of the building have more data then the architectural blueprints. This is reflected in the total size of the tiles. There was no or almost no visual difference in the images regardless of color pallet and file type.

	Pipe		Architect	
	JPG	PNG	JPG	PNG
Full color pallet	46.7 MB	27.5 MB	31.8 MB	10.4 MB
Grey scale	42.1 MB	18.9 MB	27.5 MB	6.25 MB

Table 5.1: Shows the total tile size of two different blueprints, it includes different color pallet and file format.

5.2.5 Documentation

All the classes and class function in this project were documented using JavaDoc and PHPDoc and HTML documents were generated so it would be easy to read for new developers. The code itself is also well documented with comments for each function and code segment. System Hungarian notation is used to describe variable types.

5.2.6 Testing

Test cases were made to verify that the various work packages were completed. Each work package has a specific set of test cases that need to be finished before that specific work package is complete.

Most test cases were derived from the work packages, but some were worked out during the development. If a new type of bug or error occurred during the testing, a test case was immediately made for that

occurrence. In the end, a large list of test cases has been made, where each test case has been assigned to a work package.

Figure 5.2 below shows an example of the relation between work packages and test cases.

Test cases \ Work packages	W-01	W-02	W-03	W-04	W-05	W-06	W-07	W-08	W-09	W-10	W-11	W-12	W-13	W-14	W-15	W-16	W-17
T-01	x					x											
T-02	x	x															
T-03		x									x						
T-04					x	x											
T-05													x				
T-06						x			x	x	x		x				
T-07													x	x			
T-08																	x
T-09										x	x						
T-10			x				x										
T-11														x		x	
T-12				x					x							x	
T-13															x		
T-14															x		

Table 5.2: Relation between work packages and test cases

5.2.7 User experience

The user experience has been one of the most important considerations when building the ByggDoc prototype. The whole development process has been done iteratively with the pilot customer. The pilot customer has included both management and the laborer in these meetings so feedback on the user experience has been provided througout the whole process.

The feedback on the final prototype of ByggDoc has been good from both management and laborers. They think it is an easy and convenient way of documenting the work.

Chapter 6

Discussion

The discussion will interpret and compare the results and point out the features and limitations of the work. The results will be related to current practice in the field and to the original purpose in undertaking the project. The prototype is tested, all the test cases passed and the results are valid.

6.1 Discussion Criteria

There are several criteria to take into consideration when discussing this master thesis. The following list of criterias will will help point out the features and limitiations of the work.

- **Ease of use**

  Discussion criterion for the current construction site documentation and ByggDoc. Ease of use is perhaps the most talked about and least-understood aspect of software design. The finished product must be natural to operate and easy to use. The ease of use for this discussion should be evaluated towards a normal user which in this case will be a worker from a relevant construction site.

- **Efficiency**

  Discussion criterion for the existing construction site documentation and the implementation. To measure the efficiency, the results should be compared against the current practice in the field. The time from input to the desired output will be the deciding factor in the increased or decreased efficiency ratio.

- **Compatibility**

Discussion criterion for the implementation, regarding the support of different types of cell phones.

- **Mobility**

  Discussion criterion for the implementation, regarding the mobility and whats required to use the documentation system.

- **User Reach** Discussion criterion for the existing construction site documentation and the implementation, regarding who can use the type of documentation.

- **Integrity**

  Discussion criterion for the existing construction site documentation and the implementation, regarding the integrity of the documentation system. The integrity can be measured in what degree the system or component prevents unauthorised access to, or modification, of data.

- **Privacy**

  Discussion criterion for the existing construction site documentation and the implementation, regarding the privacy (preventing unauthorized personnel from accessing information).

- **Cost**

  Discussion criterion for the existing construction site documentation and the implementation, regarding the cost of the documentation system.

6.2 Current Practice in the Field

In this section, the current practice in the field will be discussed related to the discussion criteria presented in the previous section. Not all of the criteria are relevant for the current documentation procedures, but most of them will be discussed below.

Ease of use

The current procedures for documentation are easy to use on most occasions. The only knowledge required for a craftsman is how to operate a digital camera and where the relevant pictures should be taken. For the project manager, the ease of use for the current procedures is perhaps a bit more intricate.

The project manager must have knowledge of the current electronic document management (EDM) system that the company uses. This is in most cases a custom made software that might be complex to use. By using the EDM system, the project manager can find the checklist template and modify it according to the usage.

Efficiency

The categorizing of the current documentation is done manually, where an employee receives the documentation done and stored manually. The procedures for categorizing are easy to perform, but time consuming and takes away focus from the core business for the customer. If a craftsman or project manager need to study some of the created documentation, they need to contact the main office, ask for the documentation, and receive an email with the documentation asked for. Again, this is easy to perform, but very time consuming and inefficient.

During the construction site survey, this was a main topic when interviewing the project manager and workers. The time consumption of the current documentation procedures is perhaps the main drawback. In fact, several of the interviewees choose to skip the documentation entirely because of this. The new solution must provide a more efficient alternative for documenting the work done on construction sites.

User Reach

Most of the subjects interviewed at the construction site had heard of the documentation procedures for the company, but never done them themselves. The project manager was the only person on the construction site visited that had personal experience in documentation work.

This proves that the current documentation method does not have a good user reach. The procedures are easy to perform, but because of tedious and inefficient routines, only project managers for the construction sites are reached. The new solution should provide an easier alternative for reaching a wider range of users.

Integrity

The documentation is only handed on to employees within the company, and when the documents and pictures are printed and stored at the office. If a project leader need an image or filled checklist concerning a construction site, he or she must contact the employee in charged and manually go get them. This provides a good sense of integrity, and it will be a challenge to uphold this integrity for the new system developed.

Cost

The cost of the current system can be defined either as a cheap or costly. The specific price tag of the system is very low. The EDM system mentioned earlier is a custom made system that does not provide much monthly costs. Apart from this, the company has to pay for the digital cameras and printing of checklists, but not much more. Looking at it from that angle, the current system is very cheap in use.

From another point of view, the current documentation routines are very costly. The manpower needed for the documentation done today is a lot more than necessary. In addition, since the documentation

procedures are often skipped, the repercussions will sometimes be very costly for the company.

6.3 ByggDoc

In this section, the ByggDoc application will be discussed related to the discussion criteria presented in section 6.1.

Ease of use

The craftsman only needs a cell phone device with Windows Mobile 6.0, with the application installed. According to the user feedback, ByggDoc is an application that is intuitive and easy to understand. The documentation is stored on a server, and is easy to find and view, using the digital construction site blueprint, where documentation items is attached to coordinates.

The cell phone application interface is based on few, but large buttons. The web application interface is a bit more advanced since it has more options, but is still a well arranged interface that is easy to use.

ByggDoc will of course lead to a phase where the users need to learn how to operate the application, which may be time consuming. When this phase is over, the construction company will surely experience an improvement of the documentation process.

Efficiency

The categorizing was moved from being categorized manually, to being categorized digitally on a server by using the ByggDoc. By doing it digitally, it is much easier to archive the documentation. What the users have to do is to capture images and fill in checklists digitally, and the documentation is automatically stored. The documentation is archived in a way that makes it easy for a project manager to find it again. The digital construction site blueprint has stored the coordinates for the documentation items, which shows what room the documentation belongs to. This is valuable information for the project managers and is easily accessible.

Considering the documentation procedures, the time consumption has decreased by using the ByggDoc. It is not any more necessary to fill out checklists and archive them physically with the captured images.

Regarding the manual categorizing, the digital categorizing is much more efficient and safe. Backup of the documentation is created which decreases the chance of loosing the documentation work, and in addition makes the documentation work faster.

Compatibility

The ByggDoc works with several cell phones that has an operative system above Windows Mobile 6.0 and

below Windows Phone 7.0. This was the operative system that Oras Agder was using, and therefore the first platform that ByggDoc was developed on. To make ByggDoc more versatile, it is planned that the application will be released to several smartphone platforms, so that other construction site companies can take use of it.

Mobility

Since ByggDoc is made both as a web and cell phone application, you can use it anywhere you have a network connection. The web application is made for the project managers who want to follow the progress from the office. The cell phone application is made for both the craftsman and the project managers, who either want to document their work or see the documentation onsite.

A problem that may appear is that the mobile network connection speed could decrease, especially if the user is down in a basement. This has been taken into consideration and is going to be solved in one of the next releases of ByggApp. What could be done to increase the mobility is to install Wi-Fi networks at the construction site, so that the mobile network would not be a problem.

User reach

The application can be used by any employed that has a cell phone with Windows Mobile with the ByggDoc installed. The users are divided into three groups. The project managers, the craftsmen and administrators.

Integrity

The application sends accurate information from the user that is logged in. If a documentation item is edited, the user that edited the item will always leave a trace, so that the project managers always know who has made the change.

Security

The users have to log in to use the application, where the login is sha-1 hashed. The cell phone does not have a direct connection towards a database, but connects to a webservice that handles all the database requests. All documentation is stored on a server and a backup server. The main server is located in a server room located in a different location than the backup server.

Privacy

There are different users for different tasks, and their access level are defined when a user is created. A project manager will be able to both view, edit, delete and create documentation items in all the construction projects he is related to. He is also able to divide the digital construction site blueprint into floors, wings, corridors, and rooms, and set what kind of checklist templates that should be available for

the current construction project.

A craftsman is only able to view a construction site blueprint, and add or edit documentation items, while the administrator user is able to create users and customers in the database.

Cost

Considering the costs of the current practice, using manpower to document and archive, ByggDoc has decreased the cost of the documentation process by doing the documentation and archiving in one process, by only using a cell phone.

What may be one of the biggest costs could be the mobile network connection costs. It is recommended to try to set up Wi-Fi spots at the construction site, to both save money and to always ensure that the cell phone has a network connection.

6.4 Software Testing and Quality Assurance

The test program presented in Chapter 2, Methods, was made early in the development process and has helped significantly during the system validation.

The application was unit tested manually; no automated unit testing was used. This approach did not bring too much overhead to the testing and development compared to what automated unit testing might have added. It is not likely that the workload would have been reduced by automating the unit testing. In fact, by introducing automated unit testing it can lead to a new source of errors and more work.

The test program was completed and test cases was made to validate the work packages. To complete an extensive test program like this is time consuming, but many bugs was found and fixed. The overall quality of the application is better after completing the test program.

Testing was also done by the pilot customer Oras Agder so they could get a feel of the application. This was a good way of knowing if the application was what Oras Agder needed and to get feedback from them.

Chapter 7

Conclusion

This report considers the problem of improving the current documentation practice on construction sites. Whether or not the new solution is superior to the old will be concluded in this chapter. The new solution developed for this project is however only the beginning. Several improvements can be made and will be presented in the last section of this chapter.

7.1 Motivation and Problem

The project's main goal, improving documentation procedures on construction sites, has provided the project group with several interesting discoveries during the research and implementation period.

The results from the background research gave clear indications that something needs to be changed in the documentation procedures used today, gave a lot of motivation for creating the set of requirements presented in chapter 4. The list grew as meetings with Oras Agder provided more detailed specifications, and more objectives were worked out than what was previously anticipated.

There were several challenges, but completing the main goals and objectives by using a cell phone to do the documentation was, perhaps, one of the main challenges in this project. A substantial amount of work was essential in order to make the new procedures user friendly and efficient, but the prototype developed, is without a doubt, well worth the total of approximately 3000 man-hours spent.

7.2 Construction Site Survey

The performed survey gave several interesting results that significantly changed the requirements for the application. First of all, it gave important insight into how the documentation is performed today, and pointed out some of the drawbacks that were anticipated. Secondly, it pointed out new challenges, like the reduced light conditions.

If a subsequent field observation should be carried out, it might be beneficial to do the procedures slightly differently. A full set of questions with specific relation to the current prototype should be worked out beforehand, and each observation participant should use a cell phone device with the prototype installed. Workers and project managers should try the prototype themselves and give feedback on how it operates.

7.3 ByggDoc Implementation

All the functional requirements FR1-FR15 are completed. This has been a major focus, and with all the requirements fulfilled, the prototype is ready to be sent out on a test period for Oras Agder. The test period is already planned and is scheduled to begin shortly after the delivery of this master thesis.

The test period will be an exciting phase for this project, and probably give a new set of improvements that must be implemented before the product is ready for sale.

7.3.1 Web Application

As seen in chapter 5, Results, the web application has been developed and is fully functional. It has been developed with regards to the end user, and all the requirements have been fulfilled and the feedback from Oras Agder has been very promising. By using the solutions developed, the employees at Oras Agder will reduce the workload required when distributing blueprints and checklists to construction sites.

In addition, the project managers can more efficiently check the status for rooms, floors or wings in construction sites by navigating the blueprints. When selecting a room, wing or floor, the project manager can see uploaded photographs or filled in checklists for the selected object.

Lastly, as mentioned throughout the report, much effort has been put in to develop the web application according to the "Software as a Service" model. This has been a focus during the development, and has been successfully fulfilled. The system is deployed over the Internet, and the customers can access the software without any specific hardware requirements. The heavy calculations are handled by the server.

7.3.2 Cell Phone Application

The cell phone application has also been developed in consideration of the end user. It is fully functional and all the requirements have been fulfilled. The cell phone application has not yet been tested on a large scale, but several project managers have tried the latest version and the feedback has been excellent. The user interface is perceived as a smooth and user friendly experience, and especially the features regarding checklists and photographs are seen as the most vital new features for the application.

Not only will the usage of ByggDoc for cell phones increase the quality of documentation done at construction sites today, it will also increase the documentation ratio generally because of the simplified procedures. The process of either taking a picture or filling in a checklist in regard to a specific room on a construction site is now faster than ever, and the user doing the documentation is significantly reducing the amount of man-hours required.

7.3.3 Solution Testing

The solution is fully tested and all the test cases are completed. Test cases for all the features of the work packages have been created and all of them have been executed and completed successfully. Testing and demonstration has also been done with the pilot customer to make sure the user interface and user experience met their expectations.

7.3.4 Non-Functional Requirements

All the non-functional requirements NFR1-NFR7 are fulfilled. When developing ByggDoc the non-functional requirements have been an important factor in how the applications have been developed. By following the non-functional requirements, the application runs smoothly and without any major problems.

7.3.5 Advantages

There are several advantages to using ByggDoc compared to how construction site documentation is currently created. Currently, building documentation is created on paper and it is difficult to capture images and relate them to a place or item within a construction site. ByggDoc provides an easy-to-use alternative where the user can select the place on a blueprint shown on a map, and take pictures as documentation from that place. ByggDoc provides an easy-to-use alternative where the user can select

a room, wing, section or corridor on a construction blueprint shown on a map, and capture images as documentation from that place. Checklists are also presented to the user in an easy-to-use format.

When the documentation is done in this way, project managers can see the status of the construction project in real time. The documentation is stored in a way that makes it easy to access for the project managers, and the owner of the building can use the documentation when the building goes in to an operating phase. This improves quality, reduces the chance of errors and saves man hours.

7.3.6 Ease of Use

The presented solution is easy to use. The web control panel is intuitive and lets the user upload blue prints, add rooms, add documentation requirements and view the documentation created. The users out in the field, can based on where they are on the construction site, view the construction blueprints, the documentation needs and the checklists for that part of the construction site. It is then easy to fill in the checklist and, if needed, add image documentation. This is all done from a large touch screen cell phone with a stylus; this makes it convenient for users with large fingers.

7.4 Implications

The implication of this work has different implications for different user groups that will be affected by the implementation of ByggDoc. These groups are the construction company, the user of the application and the building owner.

- **Construction company implications**
  - ByggDoc will save man hours. Therefore, making the construction of the building faster and cheaper.
  - The amount of undiscovered errors that might surface later and be expensive to repair will be reduced.
  - Project managers can easily keep track of the documentation progress. This will make it easy to know how far into the process the building is.
  - The productivity might be lower during the learning process of this system.
- **User implications**
  - The user has to learn a new system which might be frustrating for users that are not familiar with cell phone and web applications. This is reduced by a user friendly interface.

  - Documentation tasks will be faster and easier in ByggDoc then how it is practiced now. This will make the documentation tasks more pleasant for the user and therefore more likely to be done.

- **Building owner implications**
  - When a building is fully documented the resell value of the building will be higher than if it is undocumented.
  - Maintenance will be easier and therefore quicker if the building is fully documented, this will save the owner money.

7.5 Summary

To summarize the chapter, the main conclusions will be mentioned in this section. The ByggDoc prototype is fully functional, both for the web and cell phone applications. All the requirements have been fulfilled during a total of approximately 3000 man hours. The work has been shared equally among three persons, but still, for a project spanning over five months, 3000 man hours is a lot of work. However, the end result is rewarding in several ways.

Since the main goal for this project was to improve upon the existing documentation procedures on construction sites, the best feedback one can get is that the application leads to improved and more efficient work routines. This has been the general feedback from employees at Oras Agder and proves that the project has indeed been a successful attempt on improving the documentation procedures.

The process of handing out checklists, assigning them to a room and executing the items on the list is now simpler than ever, and requires no categorizing routines from the customer; everything is handled by the system. With maintenance reduced, the employees for the particular customer can now focus on their core business instead of tedious procedures that are now handed by the application.

In the final evaluation at Oras Agder it was clearly determined that the new system was both cheaper and more efficient. The thourough background research They were asked for a closing comment and the following quote was given:

"I wish we had this application earlier. The documentation procedures is now more complete, accurate, timely, in electronic instead of paper form, and thereby more reliable and more easily accessible throughout the process, and a very valuable contribution to a future facility management system."

7.6 Further Work

A fully tested and functioning prototype of ByggDoc has been developed, but there is a lot of further work that can be done. Some of the most important improvements to ByggDoc that can be done will be covered in this section.

- **Add cell phone platforms** - The system is only developed for Windows Mobile devices, as this was the operating system in used by Oras Agder AS. ByggDoc could be developed to support several more of the cell phone platforms like iPhone, Android and Symbian.
- **Add support for 3D blueprints** - Use of 3D tools to design buildings is growing in construction projects and it would be natural for ByggDoc to support this in the future.
- **Add facility management features** - When all the building documentation is available in ByggDoc it would be an efficient solution to use the same data and application in the management of the building, adding facility management features would therefore be a logical part of the application in the future.
- **Research indoor positioning** - The ByggDoc application would be greatly improved if all the blueprints and documentation was positioned at the user's current position in the building. Adding indoor positioning capabilities would therefore be a research area of great importance to ByggDoc.

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Appendix A

Coding Standards

General

Character Encoding

All code and content should be UTF8 encoded. Remember to use UTF8 on tables, the database connection, and the format for saving the files and also set the header of the output to be UTF8.

Control Structures

- Curly brackets on their own line.
- No space between the control keyword and the opening parenthesis.
- Always use curly brackets even when they are optional.

Example 1:

```
if(condition1 || condition2)
{
   action1;
}
else if(condition3 && condition4)
{
   action2;
}
else
{
   defaultaction;
}
```

Example 2:

```
switch(condition)
{
  case 1:
    action1;
```

```
    break;

  case 2:
    action2;
    break;

  default:
    defaultaction;
}
```

Function Calls

No space between the function name and the opening parenthesis. Space after a comma that separate the input parameters.

Example 3:

```
$iColor = getColor($sName, $iBlue);
```

Example 4:

```
function getName($sName)
{
   return $sName;
}
```

Variable Names

The variables should have logical names that describe the content they hold. System Hungarian notation should be used as a prefix to the variable names. Use camel case on the names so each new word start with a capital letter. Look at the spesific programming language for variabel name examples.

PHP

The exceptions or special cases for the PHP programming language will be listed in this section.

Variable Names

Example 5:

```
$iNumer = 10; // Integer.
$sName = 'Atle'; // String.
$dAmmount = 12.41; // Double;
$aCars = array('dodge' => array('caliber', 'ram'), 'ford'); // Array.
$mData = getData(); // Mixed, can contain various data.
$oCar = new Car(); // Instance of a class.
$rDb = mysql_connect(); // Resource
```

JavaScript

The exceptions or special cases for the JavaScript programming language will be listed in this section.

Variable Names

```
var iAge = 5;
var sCarname = 'Volvo';
```

Control Structures

The control structures in JavaScript are a bit different from the other programming languages. The reason for this is to maximize compatibility with web browsers.

C#

The exceptions or special cases for the C# programming language will be listed in this section.

Appendix B

Work packages

Work Package 01: [Cell phone application]

Convert the raw construction designs to a format suitable for cell phones

User story

What: - As a user I want to be able to convert the construction design to a proper format for cell phones.

Why: - So that I can see the overview of the construction design when I am out in the construction yard, using a cell phone.

Purpose of Work Package

This work package will make the user able to convert a large ".cad" file to a large amount of ".png" images, so that he can see them as a construction design on a cell phone.

Man hours estimate: 100 hours

Work Package Description

The construction designs, received in a ".cad" format should be converted to a format that is suitable for a cell phone. The converted file should then be split to a set of image files. The cell phone should be able to use the set of images and show the construction designs on its screen.

List of deliverables:

- The construction design converted to a set of split image files, which should be 256x256 of size and compatible with a cell phone.

Product Description(s)

The user uploads a ".cad" formatted file to a server which does all the work to convert the file to an image file, and split it in image tiles so that the construction design can be shown on a cell phone.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 02: [Cell phone application]

Easy and user-friendly methods for navigating through the construction designs on a cell phone

User story

What: - As a user I want to be able to navigate the construction designs with multiple floors, using my cell phone.

Why: - Because I want to be able to look at an overview of the construction design while I am in the field.

Purpose of Work package

This work package will make it easy for the user to navigate through the different construction designs on the cell phone. The work package should make it easy for the user to navigate and zoom a construction design.

Man hours estimate: 100 hours

Work Package Description

Download some of the tiled images to the cell phone by using z_x_y.png, where z is the zoom level, and x_y presents the tile coordinate that we should download.

Place the downloaded tiles in sequence referring to the tile coordinates.

The construction must be touch enabled, so that the user is able to scroll the construction design vertical and horizontal.

While scrolling the construction design, an algorithm must check the nearest neighbor of the current tile, and download images to them, if they do not have any.

As the current zoom level has downloaded the images, store the images as an object, and save it as a file that can be used instead of downloading the images the next time the user wants to navigate the construction designs.

List of deliverables:

- User friendly GUI.
- Easy-to-navigate construction design on the phone.
- Fast loading image tiles.

Product Description(s)

The user is able to navigate the construction design by scrolling vertical, horizontal, and zoom in and out on the construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 03: [Cell phone application]

Capture images with a cell phone and attach them to the building designs at the current position

User story

What: - As a user I want to capture an image of the work I have done, and store the coordinates on the construction design.

Why: - Because I want to archive my work, so that it is documented.

Purpose of Work package

This work package will make the user able to capture an image to document his work and upload the image and the coordinates of the image to a server which archives it.

Man hours estimate: 10 hours

Work Package Description

The user should be able to set his current position at the construction design and capture an image with the camera.

The image should be uploaded to a server, together with the coordinates

There could be a connection problem, there must be a possibility to store the image, and upload it to the server when there is a connection.

List of deliverables:

- A function that uploads a captured image to a server with the position and information of the captured image.
- The image should be tagged on the construction design where it has its coordinates.

If time allows:

- A function which gets the captured image's current position and direction, and sends this to a server.
- A function which gets the angle of the camera when capturing an image.

Product Description(s)

The user holds down the stylus on the construction design, where he want to capture an image, drags the stylus towards where he is going to capture the image and releases the stylus from the construction design. A menu appears where the user can choose among many settings. The user chooses "Capture image". The user captures an image, and it is being stored at a server together with the coordinates. The construction design is updated and showing that an image has been captured at that location.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 04: [Cell phone application]

View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest

User story

What: - As a user I want to navigate the building designs and be able to get points of interest on a wall, ceiling or in a room/place. The points of interest (POI) can be images, product information or digital checklists.

Why: - So that I can see the documentation of the work that has been performed in the chosen position.

Purpose of Work package

This work package will make the user able to see all the points of interests in the construction design.

Man hours estimate: 130 hours

Work Package Description

Use JSON to communicate with a webservice, where the points of interests can be downloaded from.

The points of interests should include coordinates.

Map the points of interests to the construction design.

List of deliverables:

- The construction site design should show points of interest at the coordinates that they have been set.
- The points of interest should be clickable and bring up a menu of actions that the user can perform on the current point of interest.

Product Description(s)

The user can see points of interests on the construction design, click them and get information about them. The POI's can be images, product information, or digital checklists that have been created for this construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 05: [Cell phone application]

Make use of positioning technology to suggest the nearest construction sites with designs available

User story

What: - As a user I want to get suggestions of the nearest construction site, by using positioning technology.

Why: - So that it is easy for me to choose the construction site I want to see construction designs and documentation for.

Purpose of Work package

This work package will make the user able to see construction sites using Google Maps or Bing Maps, and positioning technology. The user will also get suggestions for which construction site to choose.

Man hours estimate: 20 hours

Work Package Description

List of deliverables:

- A map that shows construction sites that is close to the user's current position.
- The user should get a suggestion on what construction site he is currently located at.
- The user should be able to choose a construction site from the map.
- When a construction site is chosen, the user should be redirected to the construction site design.

Product Description(s)

The user can see a world map, zoomed in where he is located. The surroundings on the map would be different construction sites, which the user can choose and then be redirected to the construction designs and documentation. The user will also get suggestions of what construction site to choose based on his location.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 06: [Cell phone application] (If time allows)

Orientate the construction design based on a cell phones inbuilt compass

User story

What: - As a user I want to orientate the construction design, using the compass on the cell phone.

Why: - So that it is easy for me to orientate the construction design.

Purpose of Work package

This work package will make the user able to orientate the construction design using an inbuilt compass on the cell phone.

Man hours estimate: 20 hours

Work Package Description

List of deliverables:

- When turning around in the building, the construction design should hold their correct orientation, even if the person holding the cell phone moves or turns.

Product Description(s)

The user can move/turn around and the construction design will still have the correct orientation.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 07: [Cell phone application] (If time allows)

Add points on the construction designs that describe the corresponding features on the drawing

User story

What: - As a user I want to be able to set points of interests (POI) on the construction design, using my cell phone.

Why: - So that I can document the work I have done on the specific location.

Purpose of Work package

This work package will make the user able to set points of interests on the construction design, using his cell phone. The points of interests could be images, product information, or check lists.

Man hours estimate: 40 hours

Work Package Description

List of deliverables:

- The user should be able to set POI's at the desired location.
- The user should get a menu of different POI's to insert.
- The user should be redirected to the creation of the specific POI.
- The user should then create the POI and it should refer to the location the user has chosen.
- The POI should be uploaded to a webservice.

Product Description(s)

The user holds down the stylus on the construction design, where he want to set a POI, drags the stylus towards where he is going to refer the POI to, and releases the stylus from the construction design to set the POI.
A menu appears where the user can choose among many types of POI's. The user chooses the wanted POI, and is redirected to the creation of the POI (e.g: creating a checklist). After creation of the POI, the POI is uploaded to a webservice, and shown on the construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 08: [Web application]

Convert the raw construction designs to a format suitable for a web interface

User story

What: - As a user I want to be able to convert the construction design to a proper format for Web browsers.

Why: - So that I can see an overview of the construction design when working in the office.

Purpose of Work package

This work package will make the user able to convert a large ".cad" file to a large amount of ".png" images, so that he can see them as a construction design on a web browser.

Man hours estimate: 100 hours

Work Package Description

The construction designs, received in a ".cad" format should be converted to a format that is suitable for a web browser. The web browser should be able to use the new format and show the construction design.

List of deliverables:

- The construction design converted to a set of split image files, which should be 256x256 of size and compatible with browsers.

Product Description(s)

The user uploads a ".cad" formatted file to a server which does all the work to convert the file to an image file, and splits it in many tiles so that the construction design can be shown in a web browser.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 09: [Web application]

Easy and user-friendly methods for navigating through the designs on a web interface

User story

What: - As a user I want to be able to navigate the construction designs with multiple floors, using a web browser.

Why: - Because I want to be able to look at an overview of the construction design while I am working in my office.

Purpose of Work package

This work package will make it easy for the user to navigate through the different construction designs, using a web browser. The work package should make it easy for the user to navigate and zoom a construction design.

Man hours estimate: 60 hours

Work Package Description

The construction designs, received in a ".cad" format should be converted to a format that is suitable for a web browser. The web browser should be able to use the new format and show the construction design.

Download and show tiles to the application

Place the downloaded tiles in sequence referring to the tile coordinates.

Make use of Google Map API to make it easy to navigate the construction design.

List of deliverables:

- User friendly GUI.
- Easy-to-navigate construction design on the browser.
- Fast loading image tiles.

Product Description(s)

The user is able to navigate the construction design by scrolling vertical, horizontal, and zoom in and out on the construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 10: [Web application]

View the documentation overlay by navigating the building designs and selecting the room, wall or ceiling that is of interest

User story

What: - As a user I want to navigate the building designs and be able to get points of interest on a wall, ceiling or in a room/place. The points of interest can be images, product information or digital checklists.

Why: - So that I can see the documentation of the work that has been performed in the chosen position.

Purpose of Work package

This work package will make the user able to see all the points of interests in the construction design.

Man hours estimate: 10 hours

Work Package Description

The points of interests should include coordinates.

Map the points of interests to the construction design.

List of deliverables:

- The construction site design should show points of interest at the coordinates that they have been set.
- The points of interest should be clickable and bring up a menu of actions that the user can perform on the current point of interest.

Product Description(s)

The user can see points of interests on the construction design, click them and get information about them. The POI's can be images, product information, or digital checklists that have been created for this construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 11: [Web application]

Integrating the web application in Red Rock's existing user and customer service

User story

What: - As a user I want to integrate the web service with Red Rock's existing user and customer service.

Why: - So that the product will be a part of Red Rock's integrated system.

Purpose of Work package

Red Rock AS has an advanced user and customer service, where all the services are integrated as a single user experience.

This work package will make the product available for Red Rock's existing user and customer service.

Man hours estimate: 10 hours

Work Package Description

List of deliverables:

- An integration of the web application in Red Rock's existing user and customer service

Product Description(s)

By making this "connection", a user will be able to order this product through Red Rock's user and customer service.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 12: [Web application]

Adding or editing users, using the web interface

User story

What: - As an administrator I want to be able to add or edit users/customers using the web application.

Why: - So that I can add or edit users/customers.

Purpose of Work package

This work package will make an administrator able to add or edit users/customers.

Man hours estimate: 6 hours

Work Package Description

There must be at least two kinds of administrators, each with their own rights.

One of them controls the rights for users within a specific company.

The other controls the rights of adding or editing the companies themselves.

List of deliverables:

- Function that makes an administrator able to add users.
- Function that makes an administrator able to edit users.

Product Description(s)

The administrator will use a web interface to add or edit users/customers.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 13: [Cell phone application]

Adding or editing users using the cell phone

User story

What: - As an administrator I want to be able to add or edit users/customers using the cell phone.

Why: - So that I can add or edit users/customers using my cell phone.

Purpose of Work package

This work package will make an administrator able to add or edit users/customers using the cell phone.

Man hours estimate: 6 hours

Work Package Description

List of deliverables:

- There must be at least two kinds of administrators, each with their own rights.
- One of them controls the rights for users within a specific company.
- The other controls the rights of adding or editing the companies themselves.
- To create/edit a user, a connection through the webservice must be made.

Product Description(s)

The administrator will use a web interface to add or edit users/customers.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 14: [Web application] (If time allows)

Add points on the construction designs that describe the corresponding features on the drawing

User story

What: - As a user I want to be able to set points of interests on the construction design, using the web application.

Why: - So that I can set points of interests where I want the field worker to document what he has done.

Purpose of Work package

This work package will make the user able to set points of interests on the construction design, using the web application. The points of interests (POI) could be images, product information, or check lists.

Man hours estimate: 40 hours

Work Package Description

List of deliverables:

- The user should be able to set POI's at the location he wants.
- The user should get a menu of different POI's to insert.
- The user should be redirected to the creation of the specific POI.
- The user should then create the POI and it should refer to the location the user has chosen.
- The POI information should be inserted into the database.

Product Description(s)

The user holds down the mousebutton on the construction design, where he want to set a POI, drags the mouse towards where he is going to refer the POI to, and releases the mousebutton from the construction design to set the POI.

A menu appears where the user can choose among many types of POI's. The user chooses the wanted POI, and is redirected to the creation of the POI (e.g: creating a checklist). After creation of the POI, the POI is inserted into the database, and shown on the construction design.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 15: [Servers]

Images, instructions and digital checklist must be stored on the server for further usage

User story

What: - As a developer I want to have a webservice that takes care of the heavy functions and communicates with a database.

Why: - So that it makes it easier to create a cell phone application for more platforms, and the cell phone.

Purpose of Work package

This work package will result in a webservice that takes care of the communication to/from the database, and does heavy load operations for the cell phone, if needed.

Man hours estimate: 60 hours

Work Package Description

List of deliverables:

- Make a connection to the database.
- Create functions related to inserting/selecting information from/to the database.
- Create functions for storing images received from a cell phone on a server.

Product Description(s)

A webservice that holds a connection to the database. The webservice will also do heavy load operations for the cell phone, if needed.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 16: [Servers]

Images, instructions and digital checklist must be stored on the server for further usage

User story

What: - As a developer I want to be able to handle the communication generically between a cell phone and the webservice.

Why: - So that most cell phones will be able to communicate with the webservice.

Purpose of Work package

This work package will result in generic communication between a cell phone and the webservice.

Man hours estimate: 4 hours

Work Package Description

List of deliverables:

- The communication will be done using the JSON format over a HTTP connection.
- The incoming requests are decoded and processed by the server.
- Store or send back the proper information depending on the request.

Product Description(s)

The communication between a cell phone and the webservice

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Unit testing while developing code.
Automated post commit check of coding style.
Make test cases for all features.

Completion

Approved

WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Work Package 17: [Project management]

All the project management tasks must be defined.

User story

What: - As a project manager I want to have an overview of the project's administration tasks.

Why: - So that I know what needs to be done to complete this project.

Purpose of Work package

This work package will result in a project management overview which will show how many hours that will be used for project administration.

Work Package Description

List of deliverables:

- Milestone chart
- Man hour estimate
- Test cases
- Work packages

Product Description(s)

An overview of the project management.

Interfaces

[Add user interface mock ups here]
[List web service interfaces if there are any]

Quality Checking Method

Completion
Completion when: - All the test cases and work packages are made. - Man hours have been estimated

Approved			
WORK PACKAGE ENGINEER		Date:	
WORK PACKAGE RESPONSIBLE		Date:	

Test cases

Appendix C

Red Rock Customer User System

Account

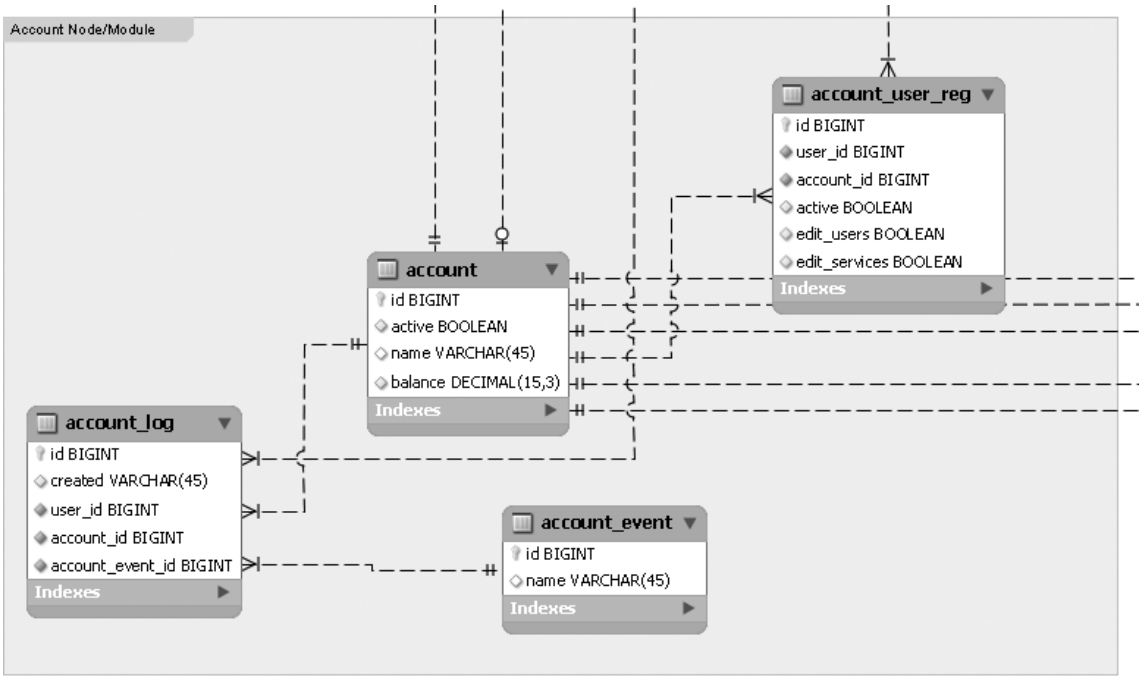

Figure 7.1: Red Rock Database, Account

Address and User

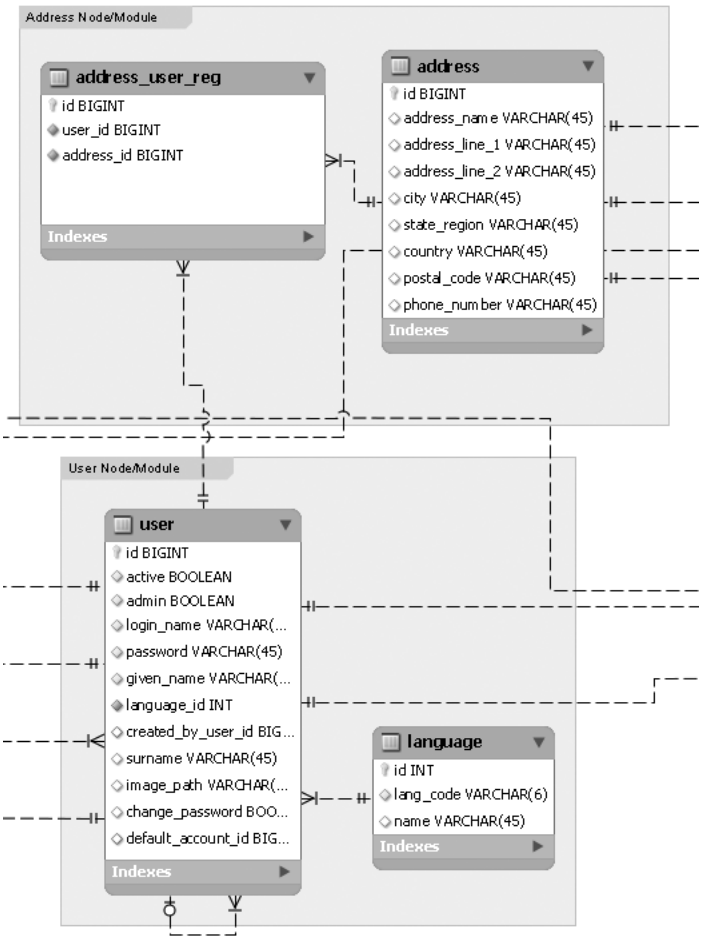

Figure 7.2: Red Rock Database, Address and User

Services

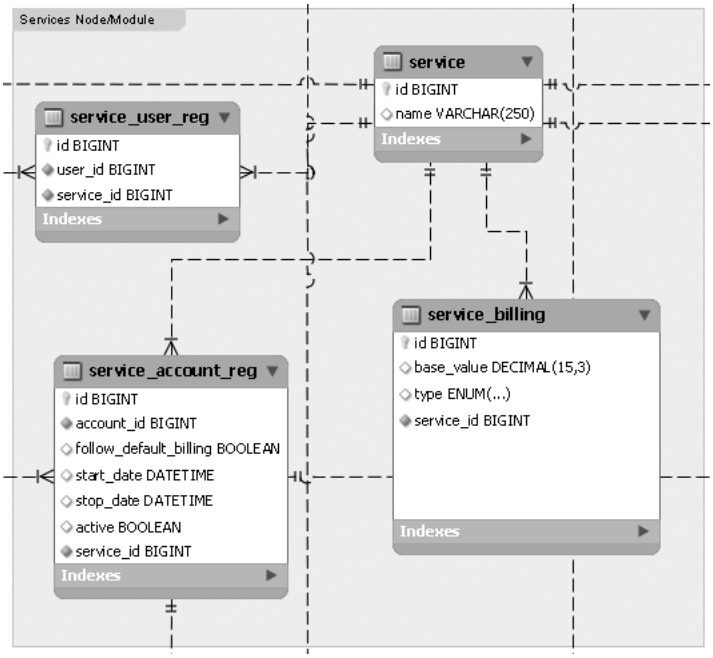

Figure 7.3: Red Rock Database, Services

Billing

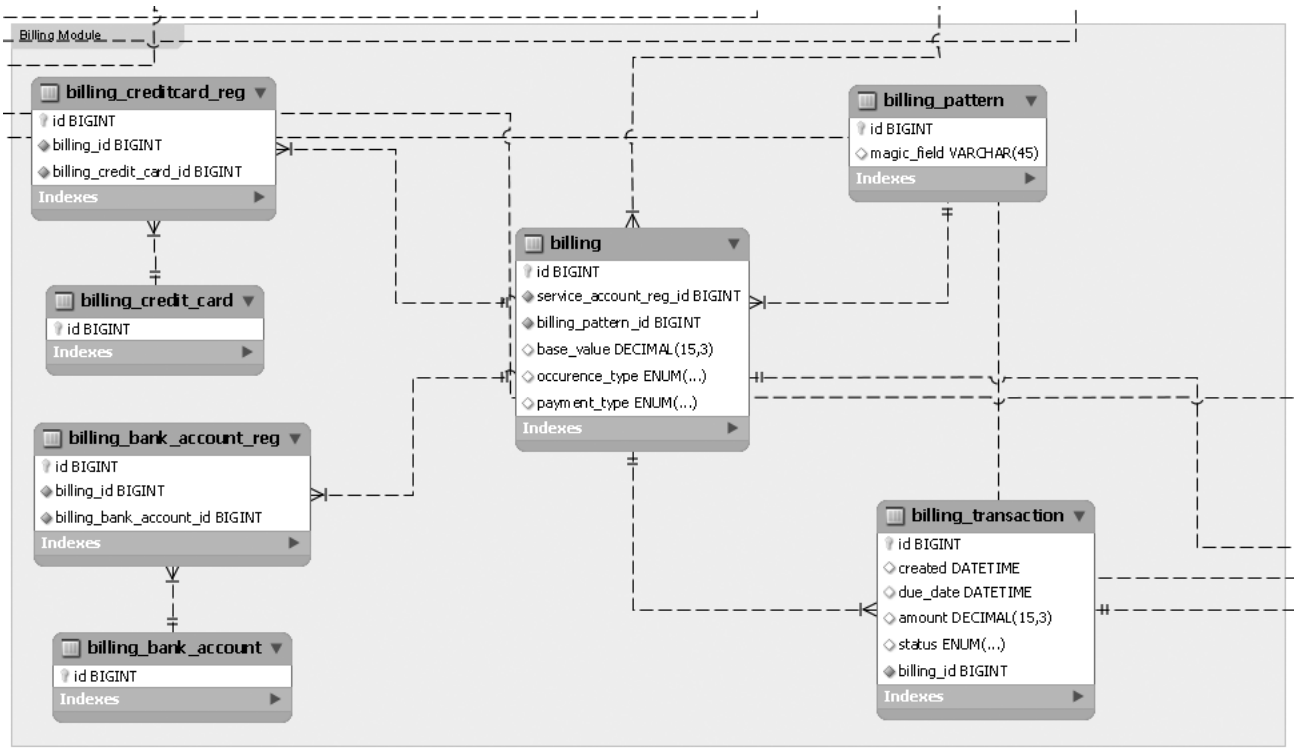

Figure 7.4: Red Rock Database, Billing

Company

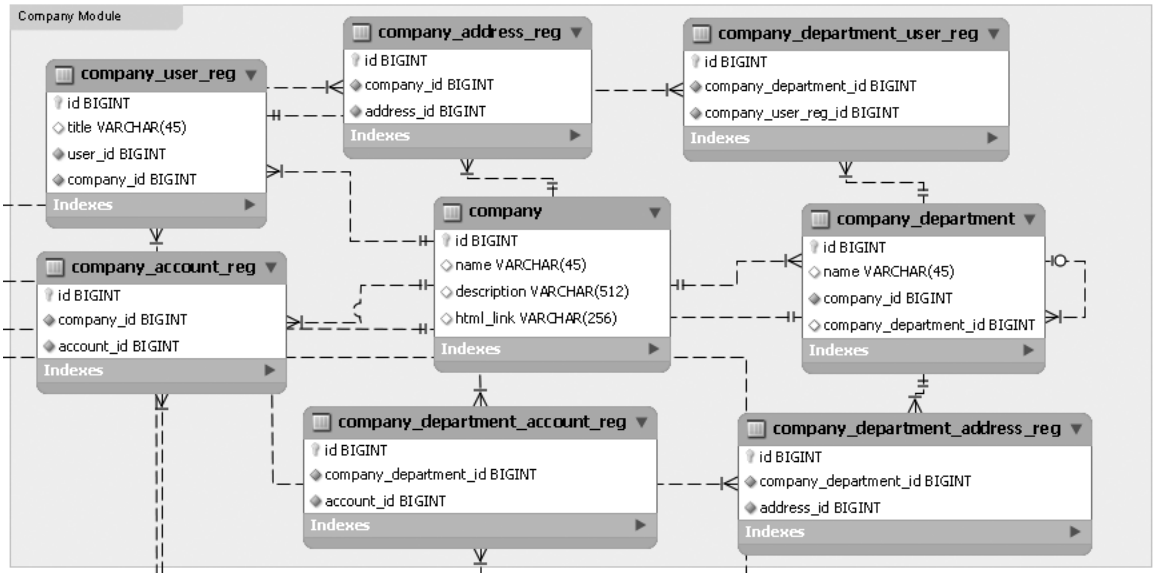

Figure 7.5: Red Rock Database, Company

Contract

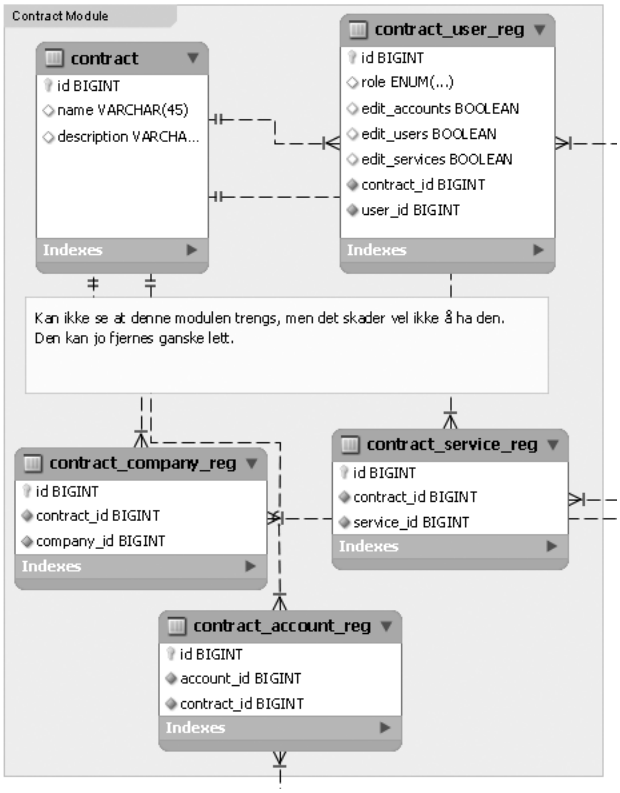

Figure 7.6: Red Rock Database, Contract

Invoice

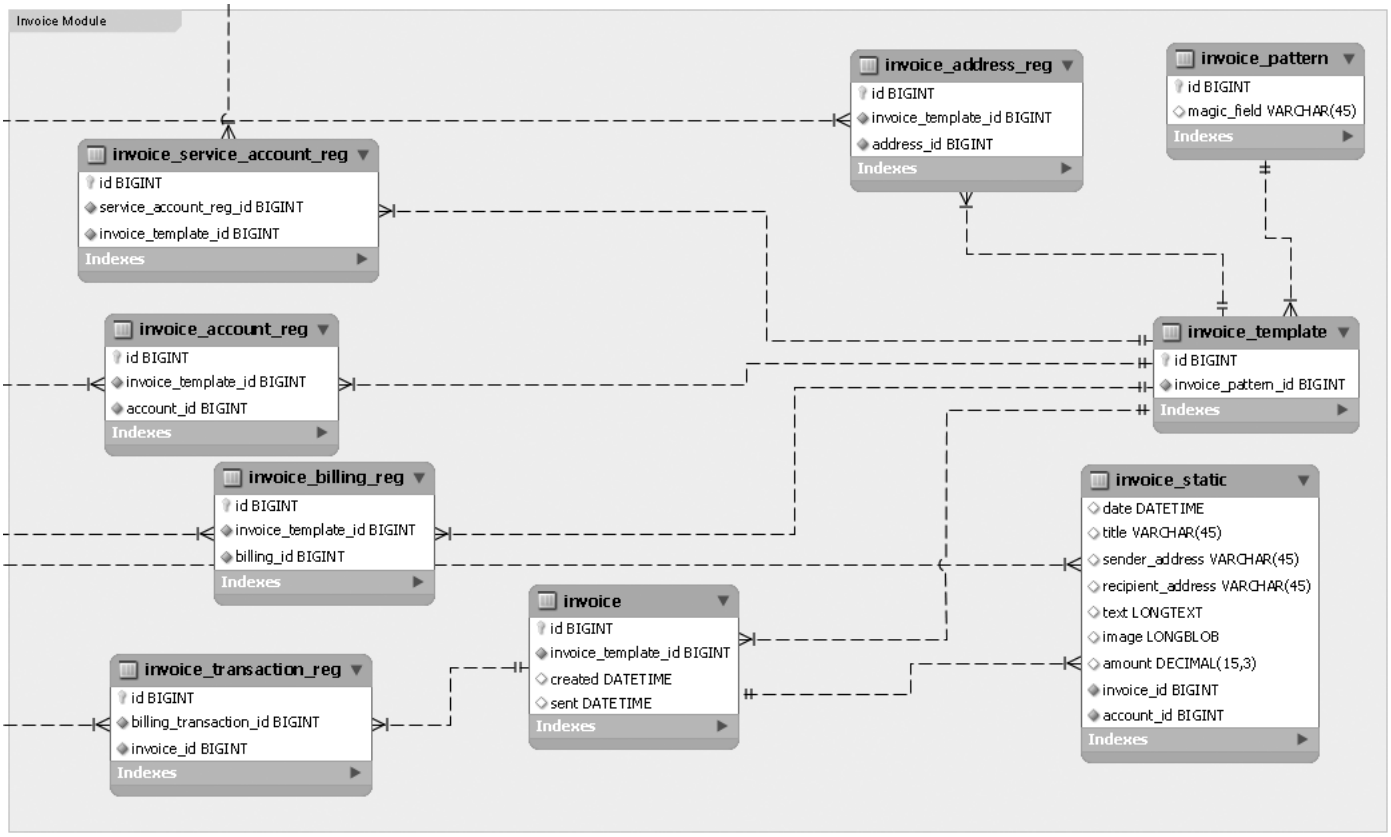

Figure 7.7: Red Rock Database, Invoice

Database and Web Design

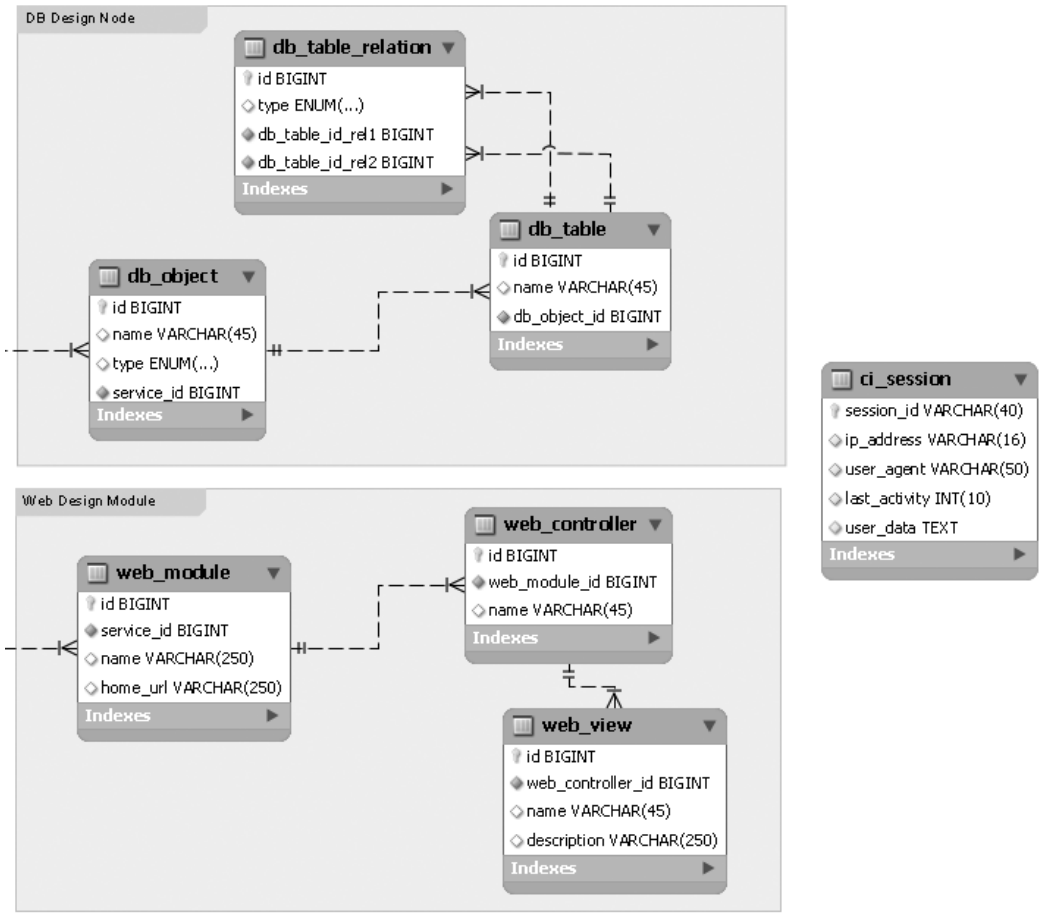

Figure 7.8: Red Rock Database, Design