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Improve Expert Estimation Process

Practice Assessment And Proposals For A Consultant Company.

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Master of Science in Computer Science
Submission date: July 2007
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Problem Description

Estimation of software development effort for a company can be quite difficult. When people are using their own estimation methods and there are different tools to do the work, it gets even more cumbersome.

The goal of this thesis is to:

- Improve estimation process using best practices available.
- Improve estimation process by studying project reports and the general project process.
- Propose early estimation method.

Assignment given: 12. February 2007
Supervisor: Reidar Conradi, IDI

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Abstract

This thesis presents results of the estimation effort improvement study for a major consultant company in Norway. The company have already established an effort estimation process, but want additional help in improving the estimation process and tools. Two major problems are identified; some estimates have very low accuracy, and they use multiple estimation tools and methodologies.

Part of the main research on the state of practice was to determine the effort estimation models used and effort estimation accuracy. To better understand how the effort estimation process worked we compared the effort estimation practice against best practices and looked further into the relation between estimation models and expert judgement. The last part of the state of practice research was to check project reports to see if they used a common tool and had a risk checklist.

The main part of the work has consisted of researching the state of practice at the consultant company and comparing it against known best practices and proposing improvements. Based on literature available this thesis presents practical improvements for the estimation process. The state of practice was determined by conducting interviews and going through project reports. The state of practice showed that they lacked a too for early effort estimation, so we conducted a case study for early estimation using use case point.

This thesis proposes solutions to issues on tools and practices. The main contribution is a powerful effort estimation template.

Preface

This document represents my master thesis at the Department of Computer and Information Science (IDI), at the Norwegian University of Science and Technology (NTNU) in Trondheim. It was carried out at the Department of Computer and Information Science.

I would like to express my thanks to my supervisor at NTNU, Reidar Conradi for support in initiating and completing this thesis. I would also like to thank Jingyue Li for providing valuable feedback on the report and making the field of software estimation easier. Lastly I would like to thank key personnel at the consultant company which would like to be anonymous. They have granted me extremely valuable insight in their state of practice of estimation and worked together with me to provide answers along the way.

Trondheim, 16 July, 2007

Knut Drange

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1. Introduction

Computers science is a relatively new field. History has shown a rapid development in both hardware and software, and shows no sign of stopping. New methods and tools are introduced along the way while others disappear. One of the fields that have still a lot of work to be done is effort estimation.

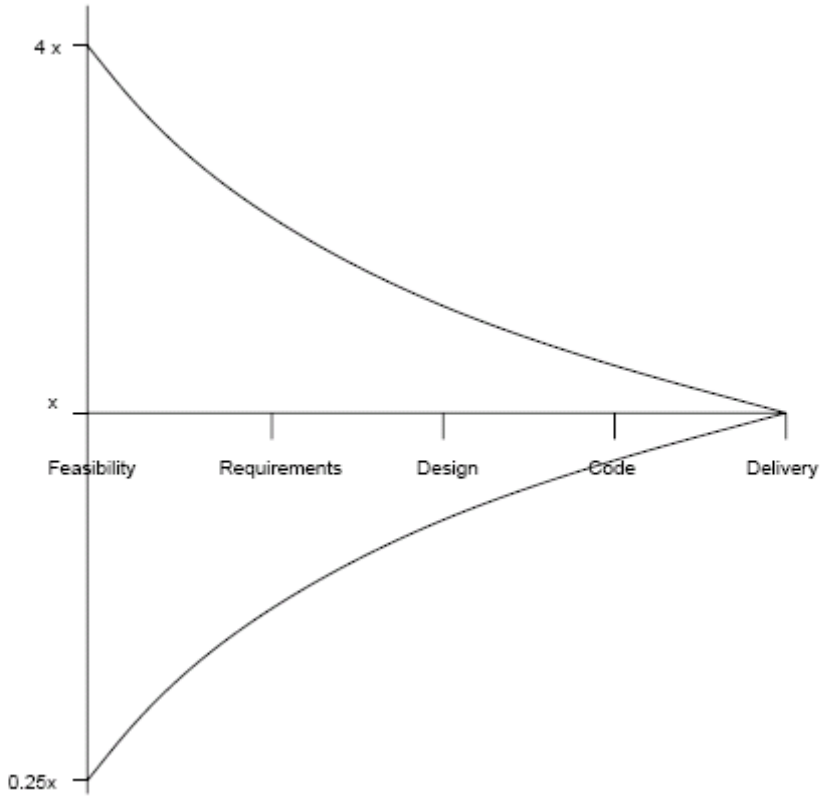
Jørgensen [Jørg04b] has done some research to try to find out what is most used effort estimation method. Interestingly his conclusions are that expert effort estimation is the dominant strategy. There is also no evidence that support the theory that models are superior to expert effort estimation.

The number of researchers with a long term interest in software effort estimation is quite few [Jørg07a]. This review has also investigated the origins of the different studies. Most of the papers are based on the same sources. This evidence might suggest that the field of software effort estimation is currently done by too few with too narrow criteria as to produce better software effort estimation methods.

1.1 Research motivation

Software effort estimation is an important task which has some major challenges. There is no doubt that software effort estimation is difficult. Most of us have heard about projects delayed, changed or cancelled.

One of the challenges for software effort estimation is called the Cone of uncertainty. This goes back to research by NASA [Nasa90], which concluded that before gathering of requirements to the project the effort estimation has a general uncertainty factor of 4. This means that the effort based on an early estimate could be 4 times as high or use ¼ of the estimated effort. This factor will decrease as the project gets closer to the end. Although this factor could be different for different factors, the conclusion is still the same. When you need the estimate the most the least information is known, which makes it difficult to do an accurate early estimate.
This cone can be seen in the figure 1:



[Figure 1] The cone of uncertainty.

There are two major types of effort estimation methods, algorithmic and non-algorithmic. Algorithmic based models, also called formal models, may be based on just simple formulas, or more advanced like regressions or differential equations. Non-algorithmic methods might be based on analogy or expert judgement. The latter is

often referred to as expert estimation. While arithmetic methods use some kind of formula, non-algorithmic might be purely based on the insights of one or more persons.

Many effort estimation models have ways of calibrating them to suit a company's needs. But with the many uncertainties on most methods the companies must find their own way of adjusting and performing estimates. Wrong estimates could lead to a major loss of profit or even bankruptcy.

In this thesis the goal is to help improve the effort estimation process for a major consultant company in Norway. They have already made some tools and established methods to help them make better estimates. However the company has identified two major problems. While most of the estimates are quite good some misses with over 100 %. Another problem is that due to several acquisitions of other companies both tools and methodology varies between the different departments and locations.

1.2 Research questions

The origin of this thesis starts at a meeting in September 2006, where NTNU and the company agreed to perform the effort estimation study to improve the effort estimation practices of the company.

With no background information regarding the effort estimation process in the company, an initial discussion was conducted. In order to improve the software effort estimation process and get more background information on the process in the company, there were conducted a survey to find the answer to the following:

- RQ1: What is the accuracy of current effort estimation in the company?

- RQ2: How formal models have been used to estimate the project effort?
- RQ3: How the expert based best practices have been used to estimate the project effort?
- RQ4: In case estimator is combing the formal model with expert adjustment, how the combination is performed?

These research questions were created to get better insight to the effort estimation process and the current difficulties. In turn this made it possible to build a baseline and investigate the state of practice further. This survey made it clear that further research questions were needed.

- RQ5: Do they have a common tool to make the estimates?
- RQ6: How do they report activity for ongoing and finished projects?
- RQ7: How do they make the risk evaluation?

The company also wanted to be able to do better early estimates. In addition they wanted to be able to perform early estimates without too much in dept knowledge of the project. There are several occasions when the company need fast estimates, like bidding phases. Comparing reports with estimates and actual effort would make it possible to check if other methods could be more accurate. We wanted to try the Use case points effort estimation method, because this is based some expert effort estimation and is a top down effort estimation method. In order to propose an accurate early estimate the following question needed an answer:

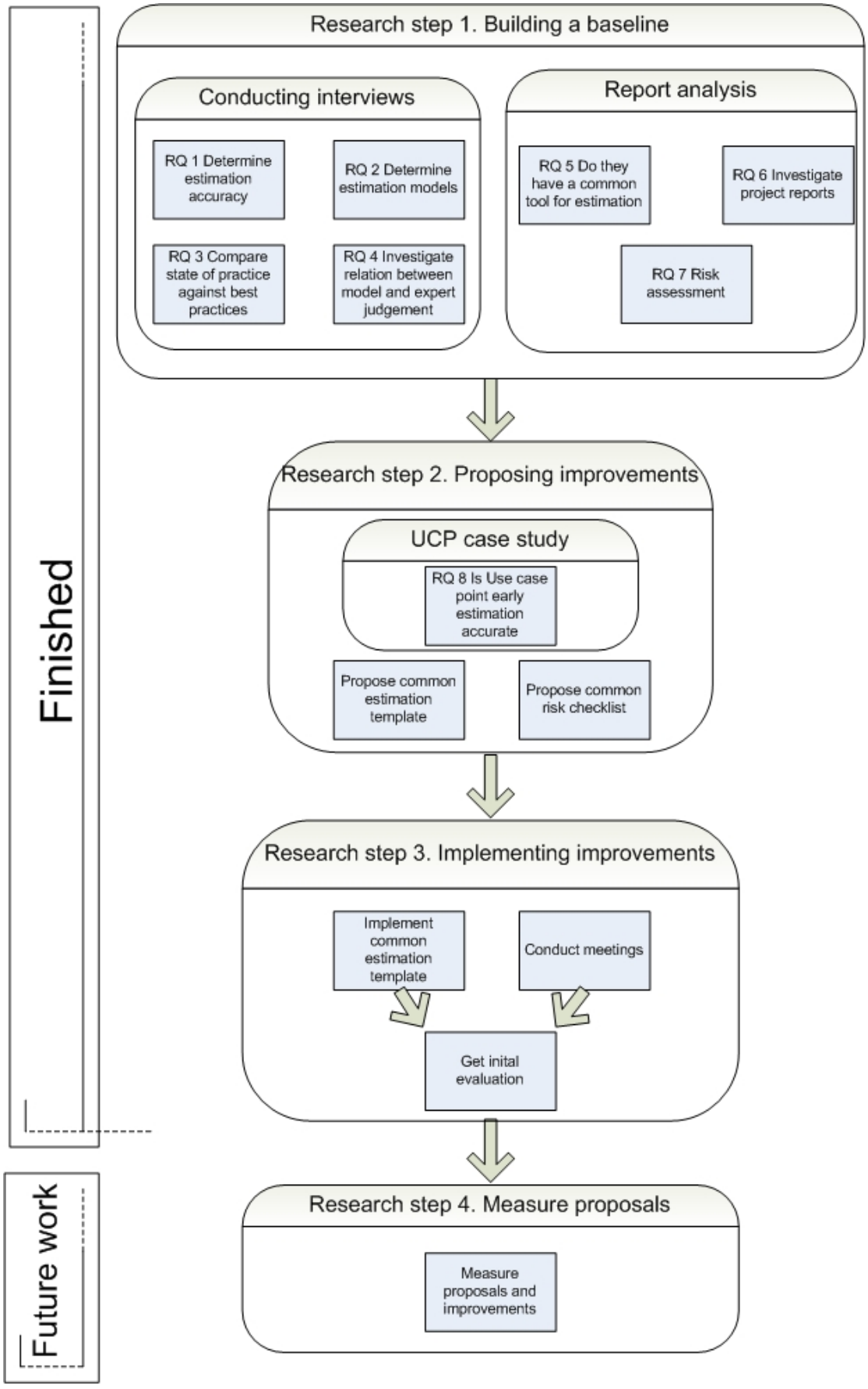
- RQ8: Can Use case points be used as an early effort estimation method in the company context?

1.3 Research design

The research is designed to include four steps, i.e., building a baseline, proposing improvements, implementing improvements, and measuring and analyzing the results of the proposals.

- **Step 1. Building a baseline**: Summarizing the historical effort estimation results and observing the current effort estimation practices in the company
- **Step 2. Proposing improvements**: Proposing and discussing possible improvements by comparing the state-of-the-practice in the company with effort estimation theories and best practices.
- **Step 3. Implementing improvements**: Performing the proposed improvement in new projects in order to verify the proposals.
- **Step 4. Measuring the results of proposals**: Measuring the accuracies of effort estimation after improvement and comparing the accuracies with those before improvement.

These steps can be seen in figure 2.



[Figure 2] Research design

Research design for each question is described in the list below:

To get answers to research questions RQ1- RQ4 we designed an interview to be done with key personnel that should give more insight in the state of practice. For RQ1 to RQ4 the interview should give us data that would bring answers to the questions.

From the initial discussions we knew that the company used expert estimation. In addition several acquisitions of other companies had showed several differences in how estimation was done. In order to be able to improve the expert effort estimation process we first searched for available best practices. These best practices in the field of expert effort estimation made us able to design questions that would bring us the answer to RQ3. Jørgensen [Jørg04b] proposes 12 good practices of expert based effort estimation. These practices are as follows:

- **P1**: Evaluate effort estimation accuracy, but avoid high evaluation pressure
- **P2**: Avoid conflicting goals
- **P3**: Ask estimators to justify and criticize their estimates
- **P4**: Avoid irrelevant and unreliable effort estimation information
- **P5**: Use documented data from previous development tasks
- **P6**: Find experts with relevant domain background and good effort estimation records
- **P7**: Estimate both top-down and bottom-up independently of each other
- **P8**: Use effort estimation checklists
- **P9**: Combine estimates from different sources
- **P10**: Assess the uncertainty of the estimate
- **P11**: Provide feedback on effort estimation accuracy and development task relations
- **P12**: Provide effort estimation training opportunities

These best practices and the current implementation created a baseline for further research and proposals. It also gave us a good picture on the state of practice in these matters.

Research questions RQ5 to RQ7 are related to how the company create and report estimates and actual effort. To get answers to these questions we decided to read through the project reports and see what the state of practice showed.

As for the last research question RQ8, we wanted to create estimates on finished projects with the use case points effort estimation method, and compare the results with the original estimates and actual effort for finished projects. The use case points were calculated based on the use cases specified in the design documents.

1.4 Contribution

RQ1: What is the accuracy of current effort estimation in the company?

The survey concluded that on average of under or over effort estimation was 9% from a set of 25 valid projects. However some of the projects had extreme differences between effort estimation and actual effort. As one can see in table 14, two projects were under estimated by about 10 % and four was over estimated by around 40%.

RQ2: How formal models have been used to estimate the project effort?

All of the subjects in the survey used more or less WBS (Work breakdown structure) and tools like Excel. By interviewing five project managers we discovered that surprisingly four of the five interview subjects used a different tool or used the same tool differently.

RQ3: How the expert based best practices have been used to estimate the project effort?

Jørgensen [Jørg04b] proposes 12 good practices of expert based effort estimation. The survey showed that six were properly performed. Three practices were only partially performed, and the other three have not been properly performed.

RQ4: In case estimator is combing the formal model with expert adjustment, how the combination is performed?

Combination of a formal method with expert based effort estimation is done in four steps.

- Using expert knowledge the system is broken down into small tasks with WBS.
- Each specific task in the WBS chart was estimated by the practitioner who was going to perform the task.
- Each task was then adjusted based on the experience of the project managers.
- At the end the project managers' experience on the possible risks were used to calibrate the result.

RQ5: Do they have a common tool to make the estimates?

Analysing the reports showed that they usually had some excel template to report the estimates. The excel templates could be different from each project and contain different information. Some did account for the uncertainties in the estimates while other did not include this information at all. They have a common time registration system where the project managers set up activities prior to starting a project.

We proposed a new template with a set of properties that should be reported and a way of calculating the estimate. This template has several benefits. It does not add extra workload for the project manager. It may improve the work efficiency by automatically generating output for several reports. A common tool and reporting system may help the estimators learn better from previous effort estimation errors, and make it easier to share experience between the different branches.

RQ6: How do they report activity for ongoing and finished projects?

Analysing the project reports showed that reports for ongoing and finished projects were updated manually. All the employees registered hours in a time registration system. Today there is no direct link between the planned work and the actual effort. This makes it very hard to analyze reasons for over- and under-estimations. Since there were several ways of reporting and creating estimates it was hard to learn from other similar projects. The project manager got information from the time registration system and updated the reports manually. This is quite a demanding job, which takes a lot of time.

Our proposed template makes it possible to get the needed figures automatically, both in linking the time registration system with the project reports and calculating the report data. The template makes it easy to analyze each specific task and makes it easy to pinpoint where the difficulties were and might help to avoid it in the future.

RQ7: How do they make the risk evaluation?

A risk assessment is now done when the project starts and is updated in the ongoing project process. The final reports showed that there were several issues that repeated themselves for multiple projects. These issues were categorized and presented in the effort estimation template as a guideline to what common risks could affect a project. In the template we have generalized 13 risks items that one should take into account when creating an estimate. The list of risks might create a better awareness on which problems might appear during the project.

RQ8: Can Use case points be used as an early effort estimation method in the company context?

When comparing two projects with the use case points we got a result that was quite close to the actual effort. But there are some uncertainties on determining the complexities for use cases. Our results were compared against actual effort and expert estimates and showed promising results for early effort estimation. The effort estimation template includes the functions to use the use case points method.

1.5 Thesis overview

The structure of the rest of the thesis is as follows:

Chapter 2 presents the state of the art with a brief history on software effort estimation and some of the most important software effort estimation methods.

Chapter 3 takes a look at the research design and methods.

Chapter 4 presents the results of the thesis.

Chapter 5 is a discussion around the result and validity.

Chapter 6 contains conclusion and future work.

2. State of the art

This chapter will go through some of the history of software effort estimation. During this time many different models and techniques have been introduced, and we will look further on a few of the most commonly known. In addition we will take a look of the state of art in the company.

2.1 History of effort estimation

In computer history there are a lot of examples that shows three large problems for software projects [UKHEC]:

- Time, did the project finish on time?
- Cost, did the project finish within its budget?
- Quality, did the software successfully do what the customer wanted?

Overestimating a project is could also give wrong results, as Parkinson's Law states: Work expands so as to fill the time available for its completion [Park58]. The work for finding a method to understand the size of a software project which should be valid for all types of projects was begun in the sixties. Today there is no such method available for effort estimation. Below is a summary of some of the major contributions to the field of software effort estimation.

Dr-Ing. Horst Zuse provides a lot of information about effort estimation history on his web pages [HorstWeb]. Some information is also collected from Wikipedia [WikiWeb]. The history of software effort estimation is considered to begin in the sixties. One of the first effort

estimation models Delphi were introduced by Nelson in 1966[Nels66]. This model uses expert effort estimation and a panel of experts to provide the estimate effort. Some useful partial models were made in the late 1960s and 1970s.

One other approach in expert effort estimation is the use of top down and bottom up. Top down was promoted by Harlan Mills and Niklaus Wirth in the 1970s [Mill88]. Bottom up uses a Work Breakdown Structure (WBS) to decompose the project tasks. I have not been able to find any references to the origin of WBS and the bottom up method. These are methods to organize and structure information in general project management.

In 1974 Wolverton [Wolv74] made one of the earliest attempts to formally measure programmer productivity by introducing lines of code (LOC). He proposed that the work of a programmer could be measured by object instructions per man-month and showed typical code rates. Many papers and effort estimation models use or mention LOC or SLOC (source lines of code).

F. Freiman and Dr. R. Park developed the model PRICE-S [Park88] in 1977. The primary input to this model is source lines of code (SLOC). Other key inputs are application type, productivity factor, complexities, platform, utilization, integration, schedule and optional input parameters.

Putman introduced in 1978 a model named SLIM [Putm78]. This model is based on Putman's own analysis of the software life cycle. The total life cycle in years K is dependent of size in LOC, t development time, and a technology constant C.

$$K = (size / (CC \times t\ 4/3))\ 3$$

Albrecht introduced in 1979 the Function-Point method in order to measure the application development productivity [Albr79]. Basic function points are categorized into outputs, inquiries, inputs, files and interfaces. Each function point is defined as one end-user business function. This made it easy to map against user requirements, but tended to hide internal functions.

The constructive cost model COCOMO was proposed in 1981 by Boehm [Boeh81], also called COCOMO 81 to discern it from COCOMO II which were introduced in 1990 [Boeh00a] . COCOMO defines a relationship between effort for a program and size as follows, where a and b are factors that depend on the development mode (organic, semi-detached, embedded):

$$Effort(P) = a * LOC^{b} \quad \text{where } a, b > 0.$$

System Evaluation and Estimation of Resources - Software Estimating Model (SEER-SEM) was introduced by R.Jensen [Jens83] in 1983. This model has lines of code, function points or both as input. Knowledge bases should provide inputs describing complexity, personnel capabilities and experience, development support environment, product development requirements, product reusability requirements, development environment complexity, target environment, schedule, staffing and probability.

In 1988 Symons proposed some changes to the original Function point method, with the MARK II Function points, which should address the difficulties with the original method. This method proposes that the size of a system can be estimated by information processing size (unadjusted function points); technical complexity factors (TCF) and function points.

$$FP = UFP \times (0.65 + 0.01 \times TCF)$$

In 1989 Abdel-Hamid and Madnick [Abde89] proposed an article to integrate software development including both management functions like planning, staff, etc, as well as software production like design, code and test. This article is grounded in the feedback systems principles of system dynamics. This model is the first widely available dynamics-based effort estimation model, which involve a set of coupled, nonlinear differential equations. Dynamics-based techniques explicitly acknowledge that software project effort or cost factors change over the duration of the system development; that is, they are dynamic rather than static over time. It is solved numerically by a simulation tool like Euler, Runge-Kutta.

As mentioned above the original COCOMO was used as a foundation as COCOMO II in 1990. COCOMO II provides a three-stage series of models for effort estimation. The earliest phase will generally involve prototyping, using the application composition model capabilities. The next phase will generally involve incremental development strategies or exploration of architectural alternatives. The second phase uses the early design model. The third and last phase has a life cycle architecture that provides more accurate information on cost drivers. The last phase uses the post-architecture model.

In 1992 Karunanithi [Karu92] introduced neural networks as a method to estimate effort. Artificial neural networks (ANN) are described in [Barc06] as massively parallel systems inspired by architecture of biological neural networks, with interconnected units (artificial neurons). The neuron computes a weighted sum of its inputs and generates an output if the sum exceeds a certain threshold. The output then becomes input to other neurons on the network.

In 1993 Use case points effort estimation were introduced by Karner [Karn93][Karn93a], in order to estimate effort based on use-cases. This method estimates effort based on use cases that mainly specify requirements of a system.

Mohagheghi et al. [Moha05] proposed an adapted use case points effort estimation method for incremental large-scale software development. This method combines use case points to estimate new functionally and COCOMO II for estimating cost of software reuse. The effort for new functionality is calculated using the use case points method. The effort for new or modified functionality in existing use cases are calculated using COCOMO-II.

During the years several reviews have been conducted to find which the best method is or which the most used method is. Different reviews shows different results and hence no finite conclusion can be made. Jørgensen [Jørg07b] concludes that models fail to perform systematically better than the experts when estimating the effort to complete software development tasks.

2.2 Effort estimation models

As said in the introduction Jørgensen [Jørg04b] has discovered that expert effort estimation seems to be the most used effort estimation method. But there are still a lot of projects that uses other methods.

Below are some software effort estimation methods that are classified in [Boeh00b] and additional information from Wikipedia [WikiWeb].

Model-Based: These are methods that use a mathematical model as their foundation. The models use an algorithm which is often based on results from known projects.

Expert judgment: These methods rely on the opinions of people who have past experience on software development to be used in the domain of the application.

Learning-Oriented: This is a method that uses analogy with previous projects to produce estimates. This is done through artificial intelligence techniques like neural networks.

Dynamics-Based: These methods explicitly recognize attributes like staff effort, skills, and costs of a software project over its duration.

Composite: This is a mix, often with expert judgment and models.

2.2.1 Model based

COCOMO

Basic COCOMO is a form of the COCOMO model. COCOMO applies to three classes of software projects:

- Organic projects - are relatively small, simple software projects in which small teams with good application experience work to a set of less than rigid requirements.
- Semi-detached projects - are intermediate (in size and complexity) software projects in which teams with mixed experience levels must meet a mix of rigid and less than rigid requirements.
- Embedded projects - are software projects that must be developed within a set of tight hardware, software, and operational constraints.

The basic COCOMO equations take the form
E=ab(KLOC)bb
D=cb(E)db
P=E/D

where E is the effort applied in person-months, D is the development time in chronological months, KLOC is the estimated number of delivered lines of code for the project (expressed in thousands), and P is the number of people required. The coefficients ab, bb, cb and db are given in the following table 1.

Software project	ab	bb	Cb	db
Organic	2,4	1,05	2,5	0,38
Semi-detached	3,0	1,12	2,5	0,35
Embedded	3,6	1,20	2,5	0,32

[Table 1] COCOMO coefficients

Basic COCOMO is good for quick, early, rough order of magnitude estimates of software costs, but it does not account for differences in hardware constraints, personnel quality and experience, use of modern tools and techniques, and other project attributes known to have a significant influence on software costs, which limits its accuracy.

Function Points [Albr79]

Albrecht proposed a method of estimating effort by measuring the functionality of a system, named function point. The first approach is to identify and count a number of unique function types:

- External inputs, like file names
- External outputs, like reports, messages
- Queries , that is interactive inputs that needs a response
- External files or interfaces, which are files that are shared with other software systems.
- Internal files, which are invisible outside the system.

The estimator can calculate the functionality of the system to be developed by focusing on the requirements specification document. The function types are identified as described in the list above. The sum of all occurrences is computed by multiplying each function

count with a weight and adding up the values. The weights are based on the complexity of the feature counted and classified as follows:

Function type	**Simple**	**Average**	**Complex**
External input	3	4	6
External output	4	6	7
Queries	3	4	6
External files	5	7	10
Internal files	7	10	15

[Table 2] Complexity classification using function points

The unadjusted function point is then adjusted against 14 complexity factors. Each complexity factor is rated on the basis of its degree of influence which varies from no influence, 0, to high influence, 5. See list below for the technical complexity factors.

- Data communications
- Performance
- Heavily used configuration
- Transaction rate
- Online data entry
- End user efficiency
- Online update
- Complex processing
- Reusability
- Installation ease
- Operations ease
- Multiple sites
- Facilitate change
- Distributed functions

The technical complexity factor can then be calculated with the formula:

TCF = 0,65 + (sum of factors) / 100

The function point can then be calculated

FP = UFP * TCF

Step	Rule	Output
1	Identify the function type	Unadjusted function point from table. UFP
2	Calculate the technical complexity factor	TCF = 0,65 + (Sum of factors) / 100
3	Calculate function point	FP = UFP * TCF

[Table 3] function point effort estimation

2.2.2 Expert judgment

Top down

The top down method was originally proposed by Mills [Mill88]. In a top down approach an overview of the system is first formulated. The first level subsystems are specified, but not detailed. This process is done on each subsystem, until the entire specification is reduced to base elements. The implementation of top-down varies so this thesis will cite the framework from Tsuneo Yamamura [Yama98] and Tohru Kikuno, which proposes three steps for top-down cost estimation (TCE). The project tasks are compared to previous completed projects and estimations are made. Also one should note as a study from Magne Jørgensen [Jørg04a] shows that very similar previous projects

gives accurate top-down estimates, while less similar led to poor estimates.

Start the process by searching for software functional classification table for the same type of software with matching functions, such as a word processor, and identify the standard cost for that type of software.

The next step is to adjust the standard cost by considering the developer's business strategy such as "the top priority is maintaining the shipping date" rather than "the top priority is maintaining quality".

The last step is to re-adjust the above adjusted standard cost by considering the development environment (such as the ability of the programmers or the availability of hardware and software tools).

This framework makes two assumptions. The first assumption is that each software program has intrinsic characteristics. In contradiction to COCOMO which assume 10 KLOC for a online program will have the same cost as 10KLOC of a batch program. TCE assumes that each type of software has its own complexity.

The second assumption is that functions, strategy and environment affect the cost. Three major components that affect software development cost and required effort are:

- Software characteristics (like functional complexity, performance requirements)
- Corporate strategic characteristics (for instance, ship now and fix later or fix now and ship later)
- Development environment characteristics (like available hardware and software tools)

To build a TCE system one should follow the following steps.

Step	Rule	Output
1	Construct a software taxonomy table	Software taxonomy table that covers all software products.
2	Construct a standard cost table	Information for each type of software for standard cost, weights to correspond to emphasized goals and GUI goals
3	Develop adjusting procedures	Weights for reflecting corporate strategic and environmental characteristics
4	Perform experimental evaluation of the TCE	Evaluate the predictability and sensitivity of the TCE

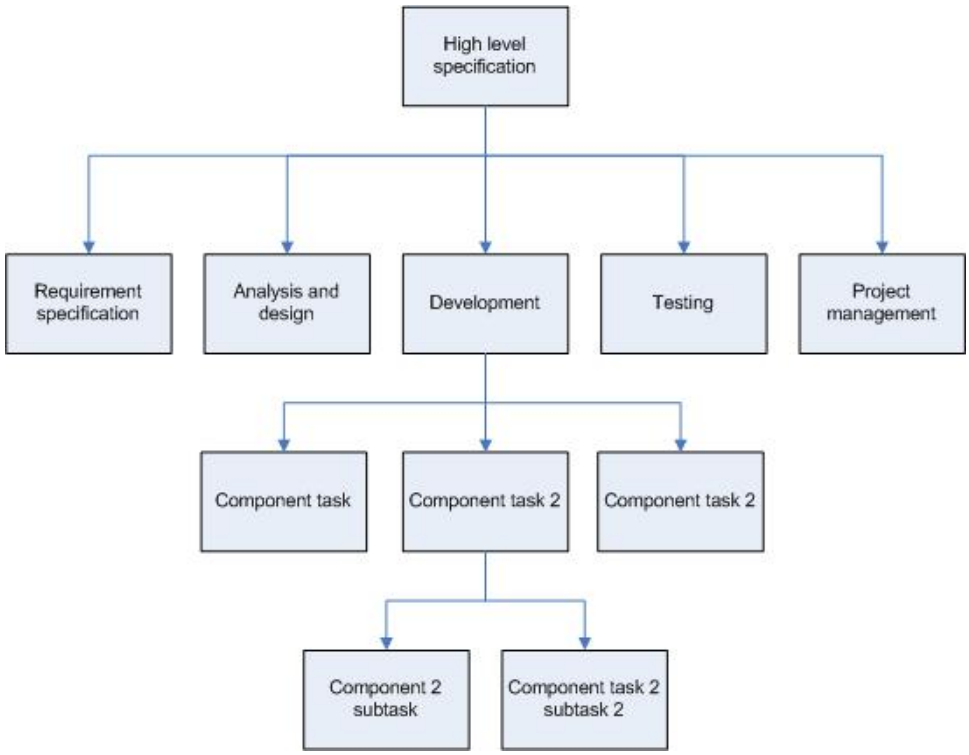
[Table 4] Top down cost estimation steps

Bottom up

Bottom up with work breakdown structure (WBS) has been around for quite a while. I have not been able to pinpoint the origin for this method in software effort estimation. The method with WBS is known in project management for many different disciplines.

Hughes and Cotterell advices that bottom up should be used where a project is completely new or there is no historical data available [Hugh04]. In bottom up the estimator breaks the project into component tasks. This process breaks down each subtask into components until there are only components left that can be executed by a single person in a couple of weeks. This is often referred to as a work breakdown structure (WBS). Jørgensen [Jørg04a] proposes the following structure for WBS:

- Administration
- Meetings
- Analysis (not already completed)
- Design
- Programming
- Data base work
- Test
- Documentation
- Installation/system integration



[Figure 3] Example of WBS structure in bottom up effort estimation

Delphi

The Delphi technique is a method for obtaining forecasts from a panel of independent experts over two or more rounds. Experts are asked to predict quantities. After each round, an administrator provides an anonymous summary of the experts' forecasts and their reasons for them. When experts' forecasts have changed little between rounds, the process is stopped and the final round forecasts are combined by averaging.

2.2.3 Effort estimation by analogy (learning oriented)

Artificial neural network (ANN), often just called a "neural network" (NN) is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network. Estimations done with this method requires several levels of computation and handling of inputs for each level.

2.2.4 Dynamics based

Dynamics-based techniques explicitly acknowledge that software project effort or cost factors change over the duration of the system development; that is, they are dynamic rather than static over time. This is a significant departure from the other techniques highlighted in this paper, which tend to rely on static models and predictions based upon snapshots of a development situation at a particular moment in time. However, factors like deadlines, staffing levels, design requirements, training needs, budget, etc., all fluctuate over the course of development and cause corresponding fluctuations in the productivity of project personnel. This in turn has consequences for the likelihood of a project coming in on schedule and within budget – usually negative.

2.2.5 Composite

COCOMO-II

But COCOMO '81 along with had experienced difficulties in estimating the costs of software developed to new life-cycle processes and capabilities. The COCOMO II research effort was started in 1994 at USC to address the issues on non-sequential and rapid development process models, reengineering, reuse driven approaches, object oriented approaches etc. The model has three sub models, Applications Composition, Early Design and Post-Architecture, which can be combined in various ways to deal with the current and likely future software practices marketplace.

Use Case Points [Karn93][Karn93a]

A use case model defines the functional scope of the system to be developed. The size and complexity of the functionality can be determined by the attributes of the use case model. The use case points (UCP) effort estimation method is an extension of [Symo91] Function points analysis and MK II function points analysis. The weights factors (WF) and formula for each step is borrowed from the Function points method by Albrecht[Albr79]. For environmental factors Karner interviewed experienced personnel and proposed the weights. The formula for environmental factors is based on some effort estimation results. This method is a top down model based effort estimation method.

Below is a table showing the process of the UCP effort estimation method.

Step	**Rule**	**Output**
1	Classify actors:	Unadjusted actor weights. UAW = ∑(#Actors * WF)
2	Classify use cases:	Unadjusted use case weights UUCW = ∑(#Use cases * WF)
3	Calculate the unadjusted use case point	UUCP = UAW + UUCW
4	Assign values to the technical and environmental factors, and multiply them by their weights, and calculate weighted sums (TFactor and EFactor). Calculate TCF and EF	Technical complexity factor TCF = 0,6 + (0,01 * TFactor) Environmental factor EF = 1,4 + (-0,03 * EFactor)
5	Calculate the adjusted use case points (UCP)	UCP = UUCP * TCF * EF
6	Estimate effort (E) in person hours	E = UCP * PHperUCP

[Table 5] Use case point effort estimation method

2.2.6 Summary

Below is a historical summary of the effort estimation models.

Year	Method	Model	Advantage	Disadvantage
1966	Delphi	Expert judgement	Accurate if the system has been designed in detail. Easy, inexpensive, utilizes expertise of several people	May suffer from biases such as unknown manipulation of a group and silencing of minorities in order to see a preset outcome of a meeting.
Ca 1970	Bottom up	Expert judgement	Accurate if the system has been designed in detail.	Need to know system architecture and components. May underestimate non development costs such as documentation.
Ca 1970	Top down	Expert judgement	Can be used in the initial phase. Not technical dependent.	Need very similar projects to be accurate. Needs systematically maintained cost database
1974	LOC introduced	Size measurement of software	Easily measured.	Code generators produce excess code.
1977	PRICE-S	Model based	Commonly understood	Difficult to estimate early in cycle

			metric. Permits specific comparison. Actuals easily measured.	Counts vary by language Many costs not considered (ex: requirements) Code generators produce excess code
1978	SLIM	Model based	Commonly understood metric. Permits specific comparison. Actuals easily measured.	Difficult to estimate early in cycle Counts vary by language Many costs not considered (ex: requirements) Code generators produce excess code
1979	Function point	Model based	Can be used in the initial phase. Not technical dependent. Language independent. Layout independent.	Counting of function points is subjective. Hard to automate. Ignores quality of output.
1981	COCOMO	Model based	Commonly understood metric. Permits specific comparison. Actuals easily	Difficult to estimate early in cycle Counts vary by language Many costs not considered (ex: requirements) Code

			measured.	generators produce excess code
1983	SEER-SEM	Model based	Commonly understood metric. Permits specific comparison. Actuals easily measured.	Difficult to estimate early in cycle Counts vary by language Many costs not considered (ex: requirements) Code generators produce excess code
1989	Abdel-Hamid and Madnick	Dynamics based	Takes into account changing project and cost factors.	Difficult to calibrate.
1990	COCOMO II	Composite	Commonly understood metric. Permits specific comparison. Actuals easily measured. Might be better than COCOMO. Large amount of users, and ongoing development	Difficult to estimate early in cycle Counts vary by language Many costs not considered (ex: requirements) Code generators produce excess code
1992	Neural	Learning	Single model	Requires a lot of

	networks	oriented	for different levels of precision.	input. Complex to see the actual calculations.
1993	Use case points	Model based	There are tools available to assist in use case creation and extract values from them.	Needs use cases. Might be hard to determine actors and technical details.
2005	Adapted use case points	Composite	There are tools available to assist in use case creation and extract values from them. Takes into account reusability of code	Needs use cases. Might be hard to determine actors and technical details. Additional disadvantage might come from the model used to estimate reusability.

[Table 6] Historical summary of the effort estimation models

3 Research design

In the meeting of the in September 2006, NTNU and the company agreed to perform the effort estimation study to improve the effort estimation practices of the company. There is a simple standard process being used to estimate the possible effort of a project in the company. The company has in the recent years acquired several other companies. This has lead to many different local practices that complement the effort estimation process. There were also no systematic investigations on the historical data to measure the actual accuracy of the effort estimation. In addition, there were no investigations on the reasons of under or over effort estimation. Mostly the estimations done in the company are quite accurate, but there are some extreme cases of under estimation.

The main research motivation is to figure out the possible reasons of under- or over- estimation of effort in typical projects and to propose improvements based on effort estimation theories and best practices.

The company also lacked methods to do accurate early estimations. They were aware of a large study involving use case points at a company called Ericsson, and wanted to test this method on their data.

3.1 Research method

The research is designed to include four steps, i.e., building a baseline, proposing improvements, implementing improvements, and measuring and analyzing the results of the proposals.

Step 1: Building a baseline:

In order to build a baseline we had to conduct a study to determine the state of the practice in the company and how to improve the effort estimation process. Knowledge of this process is vital to propose improvements. By interviewing key personnel that are involved in the effort estimation process we wanted to get some idea on how that state of practice is today, and how it could be improved. We also analyzed project reports to get better insight in the project process and to try to see what could be improved. This step contains 2 studies and 7 research questions.

Step 2: Proposing improvements:

After we had knowledge on the baseline we saw that they did not have an adequate tool for early effort estimation. We then did a use case point study for early effort estimation and proposed a common estimation template. The findings from step 1 and comparison with best practices were merged into the estimation template. This step contains 1 study and 1 research question.

Step 3: Implementing improvements:

After proposing improvements we had to implement them at the company. This was basically done in iterations by evaluating the proposed template and updates it based on feedback from the company.

Step 4: Measuring the results of proposals:

The last part of the research has not been conducted due to the time scope of this thesis. Implementing the improvements throughout the company takes time. Additional time is used to complete projects with these improvements. When these projects are finished the last step may be conducted.

3.2 Design of research step 1.

This section focuses on the first step of the whole effort estimation study, i.e., building baseline. To summarize the state-of-the-practice of effort estimation in typical projects, we designed four research questions from RQ1 to RQ4. To get an answer to these research questions five personal interviews were conducted, interviewing key personnel at the company.

3.2.1 Research questions

To compare the results of software process improvement, it is necessary to record the status before the improvement. Thus, the first research question RQ1 is:

> **RQ1: What is the accuracy of current effort estimation in the company?**

Based on the results of a brief discussion in September 2006, we assume that project managers are using certain formal models to estimate the project effort. However, there are no detailed summaries on:

- Which model has been used?
- How has the model been used?
- Are there any adaptations of using the model in different projects?
- Do people use the same model in all projects or they use different models in different projects?
- What are the lessons learned and experience from using the models?

Therefore, the second research question RQ2 is:

> **RQ2: How formal models have been used to estimate the project effort ?**

In a literature review of the expert effort estimation of software development, Magne Jørgensen [Jørg04b] summarized 12 good practices as:

- **P1**: Evaluate effort estimation accuracy, but avoid high evaluation pressure
- **P2**: Avoid conflicting goals
- **P3**: Ask estimators to justify and criticize their estimates
- **P4**: Avoid irrelevant and unreliable effort estimation information
- **P5**: Use documented data from previous development tasks
- **P6**: Find experts with relevant domain background and good effort estimation records
- **P7**: Estimate both top-down and bottom-up independently of each other
- **P8**: Use effort estimation checklists
- **P9**: Combine estimates from different sources
- **P10**: Assess the uncertainty of the estimate

- **P11**: Provide feedback on effort estimation accuracy and development task relations
- **P12**: Provide effort estimation training opportunities

It is interesting to know how often these practices have been performed and the lessons learned of performing them. The research question RQ3 is:

> **RQ3: How the expert based best practices have been used to estimate the project effort?**

There is no substantial evidence supporting the superiority of model estimates over expert estimates [Jørg04b]. In most cases, the effort estimation is performed by combing the formal model with expert adjustment. We assume thin the company is also doing effort estimation the same way. It is therefore interesting to know how the effort estimators combine the formal method with expert adjustment. Thus, the RQ4 is:

> **RQ4: In case estimator is combing the formal model with expert adjustment, how the combination is performed?**

The company is quite large and consists of many different departments. All projects create their own estimates, but it is not clear which tool they use to create their estimates. The RQ5 is:

> **RQ5: Do they have a common tool to make the estimates?**

Throughout the project's ongoing process activities and tasks are completed or changed. They report how their standing is at current times and when the project is finished, but it is not quite clear how they do this and what they report on. The RQ6 is:

RQ6: How do they report activity for ongoing and finished projects?

All software projects are subject to different risks. These risks could be related a number of different factors, like hardware failure, personnel, customers, internal problems. To find out more on how they evaluate this, the RQ7 is simply:

RQ7: How do they make the risk evaluation?

3.2.2 Data collection

Since the main purpose of this step is to investigate the effort estimation practices, we used semi-structured interviews with an interview guide as the data collection method. The study unit is a finished project with more than 100 person-hours effort. The results part includes questions about the background of the projects and interviewees, and the main questions to investigate research questions.

To get even more insight in the effort estimation process several estimates and project reports were investigated. These reports should give more insight in how they create their estimates and how the estimates are connected with the rest of the ongoing project process. To get answers to our other research questions in this step we simply read through 23 estimates and 26 final project reports at the company. Estimates for 3 projects were not available.

3.3 Research design of step 2.

Results from step 1 revealed that the company does not have a good early effort estimation tool today. This makes it difficult get decent estimates early in the project phase. These phases are often the bidding phases and it is not sure that the projects will be conducted.

3.3.1 Research questions

The company is aware of another study which had promising results with Use case points. Basically this method is to determine the complexity on use cases and actors involved in use cases. These points are then adjusted based on technical complexity of the project and other factors like personnel and programming language. This method is described in detail in appendix B.

When building a baseline in research step 1, we did not find a tool for early estimation. In order to improve in the field of early effort estimation and validate a method for the company, RQ8 is:

RQ8: Can Use case points be used as an early effort estimation method in the company context?

3.3.2 Data collection

The data for this step were collected from two effort estimation reports and design documents. The effort estimation reports had original expert estimations. Use cases to be used in the use case points method were provided for the projects. Additionally feedback from project managers was provided to calculate TCF (Technical Complexity Factor) and EF (Environment Factor) in the use case point method.

3.4 Research design of step 3.

The main focus in this step was to create and prepare a template for integration with the company. In this step more concrete deliverables to be included in the template were discussed with the company. After presenting the results of the initial survey and reports we had to verify the proposals with the company. This was done by informal discussions on phone or by email. Changes to our template proposal were updated as new issues came up during this process. We had a lot of positive feedback from the company and carried out this process for five iterations until we finalized the template.

3.5 Research design of step 4.

This step is not included in the thesis and remains to be done. See future work for more details.

4. Results

This chapter presents the results of this thesis. When investigating the state of practice there were several issues that could benefit of further improvements. The initial research on state of practice served as a baseline for further research.

4.1 Results from step 1.

The study lasted for one month. We interviewed five senior project managers from the company. Each interview includes by two researchers and one interviewee and takes about one hour in average.

4.1.1 Background of the interviewees

All interviewees participated this study have solid experience on effort estimation. Their background is summarized in Table 7.

ID	Location	Department	Role in the project	Experiences on effort estimation
1	Trondheim		Project manager Estimation coordinator	More than 20 projects
2	Bergen		Project manager Estimation leader	10 projects
3	Oslo		Project manager Estimation leader	4-5 projects
4	Oslo		Project manager Estimation coordinator	1 project within the company More than 10 projects in other companies
5	Oslo		Project manager Estimation coordinator	4 projects

[Table 7] Background information of the interviewees

4.1.2 Answers to research questions

The interview results give detailed answers to RQ2, RQ3, and RQ4. However, the answers to RQ1 need to be supplemented by investigating the final reports of more projects.

Answers to RQ1: The current accuracy of effort estimation

The information of the estimated effort and the actual effort of the investigated projects are summarized in Table 8. There are only three valid data because one respondent did not a select specific project to answer the interview and another selected an on-going project. By reading reports of other 22 projects (last 2 years), we collect information of the estimated effort and the actual effort of these projects. The summary of effort estimation accuracy of the 25 (3 plus 22) projects are in Table 9. It shows that 14 projects over estimated (i.e., the estimated effort is more than the actual effort) the effort. The mean accuracy of over estimation of these 14 project calculated using the formula (1) is -18.8% (with standard deviation of 15.13%).

$$\left(\left(\sum_{i=1}^{n}(estimated\_effort - actual\_effort)/estimated\_effort\right)/n\right)\times 100\% \quad (1)$$

Here n is the number of over estimated projects

Data in Table 9 also shows that there are 11 projects under estimated (i.e., the estimated effort is less than the actual effort) the effort. The mean accuracy of under estimation of these 11 projects calculated using the formula (2) is 24.9% (with standard deviation of 38.0%).

$$\left(\left(\sum_{i=1}^{n}(estimated\_effort - actual\_effort)/estimated\_effort\right)/n\right)\times 100\% \quad (2)$$

Here n is the number of under estimated projects

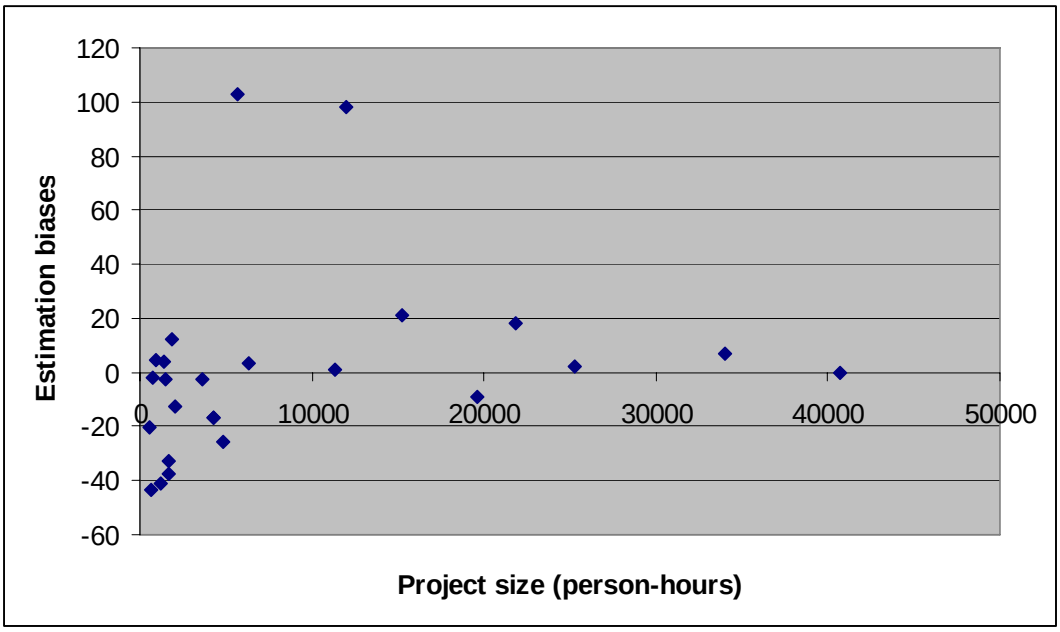
ID	Location	Estimated effort (Person-hours)	Actual effort (Person-hours)	Percentage of under/over estimation
1	Trondheim	N/A	N/A	N/A
2	Bergen	1347	1401	**Under** estimation 4%
3	Oslo	31,692	34,039	**Under** estimation 7%
4	Oslo	22400 with 50% probability	Still going on	N/A
5	Oslo	5084	4229	**Over** estimation 17%

[Table 8] The effort estimation accuracy of the interviewed projects

	Valid samples	Mean	Standard deviation	Minimum	Maximum
Over estimation	14	-18.8%	15.1%	-43.3%	-.04%
Under estimation	11	24.9%	38.0%	0.7%	103.0%

[Table 9] The effort estimation accuracy of 25 projects within the last 2 years

The relationship between the project size (by person-hours) and the accuracy of effort estimation is shown in Figure 4. It shows that there is no correlation between the project size and the effort estimation accuracy. Large projects may predict the effort better or worse than the small projects. As one can see on the figure, two projects missed by around 100 % and 5 were below -20%.



[Figure 4] The correlations between the project size and effort estimation accuracy

Answers to RQ2: The usage of formal methods

All interviewees used more or less WBS (work Breakdown Structure) with the auxiliary of effort estimation tools (i.e., Excel sheets). Surprisingly, five interviewees used four different tools. For the two interviewees using the same tool, they used the tool in different manners. The summary of the formal methods and tools used are shown in Table 10.

ID	Formal methods or tools used
Trondheim	– Used WBS to breakdown the projects into small tasks – Each task in the WBS chart was listed in the tool – and Excel sheet acquired from internal department. – The effort estimation of each task in the tool was added to get an initial effort estimation

	– The initial effort estimation was calibrated based on statistical theory and the results of risk analysis
Bergen	The same process and tool were used as in Trondheim. However, the initial effort estimation was not adjusted based on risk analysis result without considering the statistic theory
Oslo1	– Used WBS to breakdown the projects into small tasks – Each task in the WBS chart was listed in the tool - a self-made Excel sheet – The effort estimation of each task in the tool was added get an initial effort estimation – The get an initial effort estimation was calibrated based on the results of risk analysis
Oslo2	– Used WBS to breakdown the projects into small tasks – Each task in the WBS chart was listed in the tool - an Excel sheet acquired from the project office – The effort estimation of each task in the tool was added get an initial effort estimation – The get an initial effort estimation was calibrated based on the results of risk analysis
Oslo3	– In the early stage of the project, the estimation was performed by combining three estimation approaches, i.e., SLIM model, COCOMO 2.0 and Monte Carlo simulation – After the details (i.e., requirements and architecture) of the project were ready, WBS was used. The WBS tool is the same as those used by Oslo2

[Table 10] The formal methods or tools used in effort estimation

Answers to RQ3: The usage of expert based effort estimation

For the 12 good practices of expert-based effort estimation listed by Magne Jørgensen [Magne04], six of them have been properly performed as shown in Table 11. Three practices have been partially performed and therefore need to be improved, as shown in Table 12. The other three practices have not been properly performed and need to be greatly improved, as shown in Table 13.

Best practices in theory	**Current practices of the company**
P3: Ask estimators to **justify** and **criticize** their estimates	In all projects, the estimators were asked to justify their estimations by discussing with project managers or other senior project members.
P6: Experts with **good effort estimation records** were involved	– In four projects, only the project participants were involved. – In one project, project leaders and team leaders from other projects were also involved in effort estimation.
P7: Estimate both **top-down** and **bottom-up** independently of each other	– The WBS was used to break the project into small tasks, i.e., bottom-up – The effort of every small task was estimated based on the analogy with similar task in previous projects, i.e., top-down
P8: Use effort estimation **checklists**	The checklist being used is composed of two parts. One part is the predefined categories in the standard spreadsheet, such as the administrative cost, the travel cost, and so on. The other part includes the small tasks of a project. The small tasks are initiated as the results of WBS.

P9: Combine estimates from **different sources**	– All projects used group discussion to breakdown the projects – To estimate the effort of each task after WBS, four projects used group discussion, and one project used one-to-one discussion between the estimator and the project manager
P10: Assess the **uncertainty** of the estimate	The risk analysis process has been followed very well. The checklists of the risk analysis report have been filled in properly

[Table 11] Six properly performed best practices

Best practices in theory	Current practices of the company
P2: Avoid **conflicting goals**	– Two interviewees complain that their effort estimations were dramatically affected by the companies marketing strategy to win the bid – One interviewee complains that the project members' multiple duties in several projects in parallel and the interdependencies between several projects caused wrong effort estimation
P4: Avoid **irrelevant** and **unreliable** estimation information	– One project was over-estimated because their domain knowledge on the application was not good enough – One interviewee points out that the developers' productivities are dramatically different. The information of productivity of each developer is not available
P5: A database/document with p**revious experience**/data was used	– Two projects did not use any effort effort estimation experience DB – One project used a self-made effort estimation experience DB some times – One project used the self-made effort estimation experience DB often. The results of using it is very positive – One project used the effort estimation experience DB of COCOMO and SLIM. The results is also positive

[Table 12] Three practices need to be IMPROVED SOMEWHAT

Best practices in theory	Current practices fo the company
P1: Avoid **high** evaluation **pressure**	Four interviewees complain that they were asked to give the effort estimation in the very early stages of the project. Without detailed information of the project and stable requirements, the early estimated effort was usually not good
P11: Provide **feedback** on estimation accuracy and development task relations	– Although all the investigated projects have final report. Four interviewees are not sure that the estimators have been given feedback. Only one interviewee gave feedbacks to the estimator. – In addition, one interviewee pointed out that the project documents (e.g., requirement specification, design specifications, and WBS charts) were not updated and maintained very well. It is therefore difficult for estimators to trace the reasons of wrong estimation
P12: Provide estimation **training** opportunities	No project performed formal training to their effort estimators. All effort estimations were based on experience

[Table 13] Three practices need to be GREATLY IMPROVED

Answers to RQ4: The combination of formal method with expert based effort estimation

The knowledge of the expertise has been combined with the formal method as following:

- First, the experts' knowledge was used to break down the system into small tasks with WBS.
- To estimate the possible effort of a specific task in the WBS chart, the practitioners, i.e., the person who are going to perform the task, were usually asked to give an effort estimation based on their own experience.
- The experience (e.g., the knowledge of the productivity of the practitioner) of the project managers were then used to adjust the practitioners' effort estimation of each task.
- At the end, the project managers' experiences on the possible risks of the project were used to calibrate the estimated effort in total.

Experience of effort estimation

From answers of research questions RQ2 to RQ4, we summarize the experience presented by the interviewees as following:

- **WBS is properly performed.** WBS gives the estimator and the developers a good overview of what is included in the project. It is very useful as a base for planning, effort estimation. It is also a good tool for communicate with project members, also with customers. In large project, it can be used to give an overview first. The tasks can then be analyzed more and more in detail. Developers can also be involved into the WBS design. It will help to illustrate the parts that the developers are lack of competence.

- **Decisions are made by group discussions**. It is helpful to discuss the effort estimation of each task in the WBS by group discussions. Project managers' knowledge on the productivity of each project member and the knowledge on the possible risks helped to adjust under- or over- estimates made by the practitioner, i.e., the person who is going to perform the task. In addition, the involvement of other experts, such as domain experts, architect, senior developers, also helped to avoid possible effort estimation errors.

- **Risk analysis process is very well followed**. Project managers in the company followed the risk analysis process very well. Most project managers completed the risk analysis sheet at the beginning of the project. In most cases, the risk analysis sheet was regularly updated in the process of the project.

Lessons learned of effort estimation

The interview results also collected several lessons learned or complains from interviewees. This information and the study of reports could be summarized as following:

- **Project managers and marketing people have conflicting goals of effort estimation.** Project managers were always required to give an effort estimation based on the customers call for proposal within two weeks for a project, which may need 10,000 person hours. The limited information of requirements and tough time-constrain make it was not possible to do the effort estimation systematically and to give a right number. In addition, the estimations of some projects were dramatically affected by the marking strategy of the company to give lower price in order to compete with the competitors

- **Estimators are lack of training and feedback.** Although the effort estimation of detailed task in the WBS chart is always performed by the project member who is going to do the task, these estimators are not given feedback on their effort estimation errors in previous projects. In addition, the project documents (e.g., requirement specification, design specifications, and WBS charts) are not updated and maintained very well. It is therefore difficult for estimators to trace their effort estimation errors and to learn from failures. It is lack of formal training on effort estimation. Most effort estimations are still based on the informal experiences. Thus, the effort estimation skills of estimators are not improved much. Moreover, the parameters used in the effort estimation are not adjusted based on the feedback.

- **The experience of effort estimation from previous projects was not analyzed and shared properly**. Although some experience databases have been used to facilitate effort estimation, the information of the database is not complete and precise. The information included in the current database is in informal text, such as:
    - Developing a test plan for a project of 30000 hours usually takes 80 hours
    - The unit test is normally 50% of the total development
    - The integration test effort is normally 6 to 7 % of the total development effort, not including administration cost

  First, this information needs to be formalized. Second, this information needs to be adjusted based on project context, such as application domain, project complexity, and technology used. Furthermore, other information, such as the typical productivity of a project member, should also be included.

- **There were no unified effort estimation processes and tools.** Project managers used different tools to do effort estimation. The differences between processes and tools make it is difficult to share experience.

- **The interdependencies between projects inside the company were not handled properly.** Some developers have to work on several projects in parallel. For example, one person may have 10% responsibility for supporting other work, 5% for maintaining other project, and 75-80% for developing a new project. It is difficult to solve the resource conflicts. Thus, one responsibility of a person might affect his/her other duties. In addition, some projects' lifecycles depend on the lifecycle of other projects. The overhead related to the communication or dependencies between projects are difficult to be estimated correctly.

Answers to RQ5: Do they have a common tool to make the estimates?

All effort estimation is done using a template in Excel. The contents of the template however are very different from one office location to another. The differences are for both tasks and what is registered for the specific task. The different functions and other tasks to be estimated are usually displayed in a list. There are some differences between projects on what they estimate in cases like risk, maximum, minimum and probably. Some even don't include all of them.

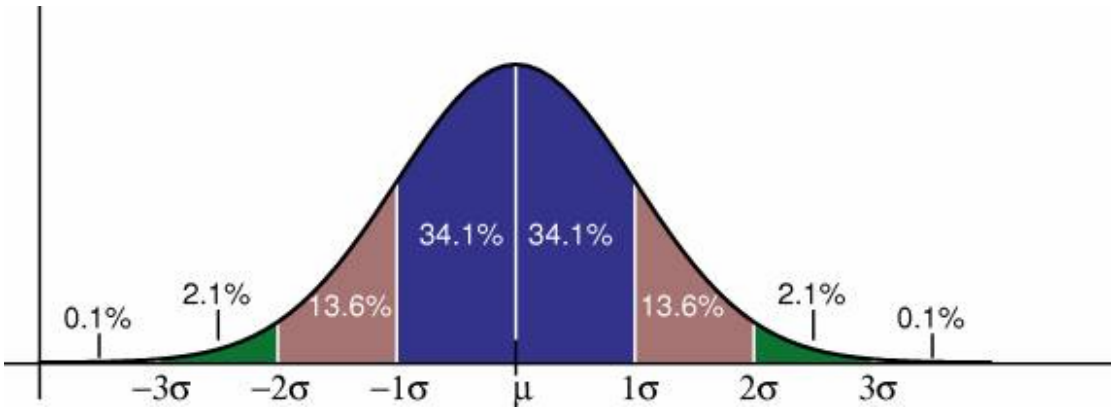
When it comes to determining the probability of the estimates, the company have analyzed the estimations with normal distribution. This does not seem to be correct for their projects. So they have weighted their according to the findings in the PERT method which is described in appendix C.

When using normal distribution on the effort estimates you can say something about the probability on the effort estimate. Table 14 shows the relation between standard deviation and probability.

σ	68.26894921371%
2σ	95.44997361036%
3σ	99.73002039367%
4σ	99.99366575163%
5σ	99.99994266969%
6σ	99.99999980268%
7σ	99.99999999974%

[Table 14] Probability for standard deviations

Another way of showing how probability and standard deviation is related can be seen in figure 5. As can be seen in figure 5 a standard deviation of three gives very high probability.



[Figure 5] Normal distribution for assessing probability in estimates

The company was initially using a standard deviation of three. Using a normal distribution a standard deviation of three will weight the estimation model with 1/6 for the standard deviation, since you go

three steps to each side as seen in figure 5. Using a standard deviation of three will give a probability of 99.7%. This point out that 0.3% of the projects will have an effort greater than maximum estimated effort. However it became apparent that this was not correct for the company. The experience in the company is more that the distribution between min and max is rather too narrow than too wide.

By using the PERT method they have discovered that a standard deviation of 2.5 is more correct. A standard deviation of 2.5 will give a weight of 1/5 which is used in the estimation template.

Most effort estimation is done by expert judgement and a bottom up technique supported by WBS charts similar to the one shown in Figure 3.

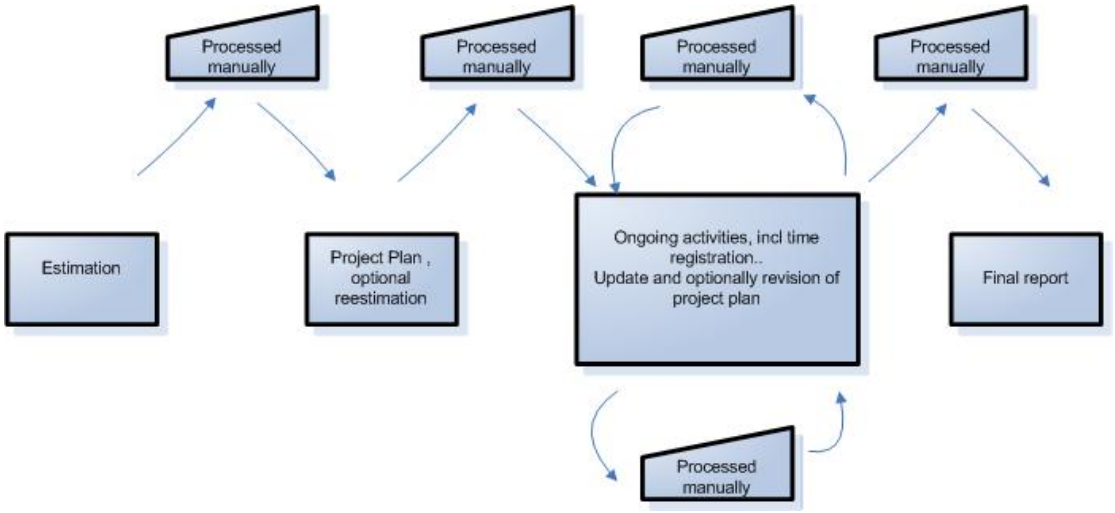
In addition, different tasks were categorized and the following activity categories were found. Table 15 shows some typical activity categories and the number of instances discovered in the 23 effort estimation documents.

Activity category	**Number of instances effort estimation documents**
Development	23
Design	18
Optional	1
Test (incl bugfiks)	22
Administration	17
System administration	16
Training	5

[Table 15] Activity categories and number of instances

Answers to RQ6: How do they report activity for ongoing and finished projects?

Projects in the company follow these cycles shown in Figure 6. The first process is to estimate the project. If the proposed project is accepted, the next phase is to create a project plan. The time registration system is updated during the project. During the project a monthly plan is revised and updated and effort spent is registered. When the tasks are finished, a final report is created based on the monthly reports.



[Figure 6] The current effort estimation and report process

The time registration system is updated with activities tied to the project. The project manager is responsible for monitoring the project and activities in the time registration system. During the project, the participants finish their tasks and enter effort spent daily in the time registration system.

The project plan might include a re-estimation of the project. All tasks for the project is identified and entered in the plan. The tasks

are identified manually based on the effort estimation and specification. Monthly reports are made to show how much effort have been used, how much remains and other economic figures. Monthly reports are updated manually.

When the project tasks are finished a final report is created. The final report might include the original effort estimation. Also the final report gives information on how the project has progressed and experiences learned. Input to this report are collected from the monthly reports and updated manually. Most of the reports had the figures presented in a table as shown below.

Item in the report	**Number of instances found**
Budget hours	10
Budget accumulated	17
Budget in percent	14
Earned value	11
Real	16
Real accumulated	13
Real (kr)	2
Real accumulated (kr)	2
Prognosis hours	14
Prognosis (kr)	2
Remaining	16
Remaining (kr)	2
Degree of consumption	14
Degree of completeness	14
Budget (kr)	3
Budget accumulated (kr)	3
Real (kr)	1
Real accumulated (kr)	1

Request for changes	7
Month budget	7
Variable work	7
Budget other costs	1
Accumulated other costs	1
Travel	3
Budget	2
Real	2
Deviation	1

[Table 16] Items in the monthly/final reports and their instances

Answers to RQ7: How do they make the risk evaluation?

Risk estimation is done by expert judgement in the effort estimation process. The project manager conducts the risk analysis. This analysis is a qualified guess on which risks might affect the current project. During the project plan, some projects have a risk matrix (see Figure 7) to handle possible risks during the project. Others just made a risk checklist and added certain percentages of the effort based on their risk analysis results.

The risk matrix is a graph with a likelihood of occurrence and hazard severity.

Risk = Hazard X Likelihood

The general objective of risk ranking is to arrive at a realistic evaluation of risks and to consider whether the risks associated with an activity are adequately controlled. [UnivLeedsWeb]

Where an aspect of the activity is ranked as HIGH RISK then the assessor/s should consider whether they have done all that is reasonably practicable to reduce risk taking into account the following risk control hierarchy namely:

- **avoidance /elimination** (of risks) e.g. contracting out to specialists with appropriate facilities, to

- **substitution** e.g. using a less hazardous substance or better guarded machine… or again subcontracting a dangerous activity, to

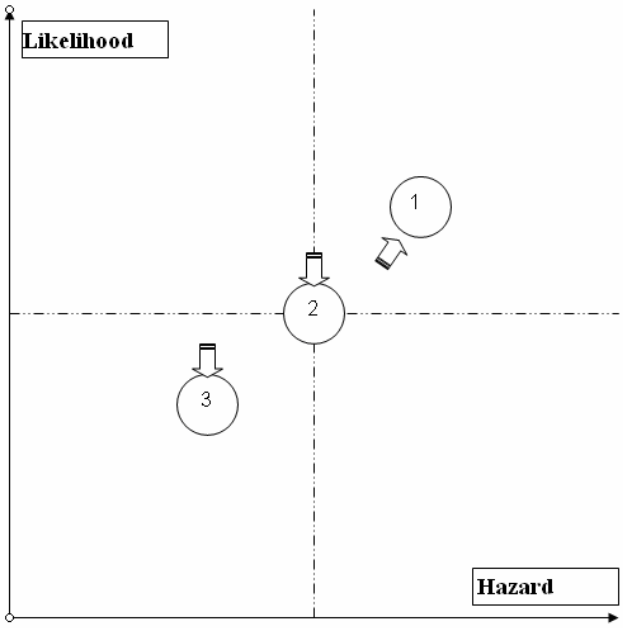
- **controlling risks at source** reviewing engineering controls which might involve re-evaluating guarding, ventilation, standard of enclosures, automation, segregation of process to considering process controls e.g. altering process or process materials to minimise emissions, or modifying so machinery remotely operated thereby removing operators from danger areas etc., to

- **safe systems of work** reviewing system of work for activity, establishing / identifying high risk aspects within this and redesigning or altering the activity to minimise or eliminate these to

- **use of personal protective equipment** to consider whether PPE, as a complementary aspect to the above, could help to reduce risk.

Similarly when an aspect of the activity is ranked as MEDIUM RISK then the research/assessment team should again consider whether risks could be reduced further by going through the above risk control hierarchy.

There is no need to do the above for LOW RISK issues but there is still an obligation to reduce risks to the lowest level reasonably practicable. Figure 7 shows an example of a risk matrix. The matrix places the high risk items in the top right corner and the low risk in the bottom left corner.



[Figure 7] Risk matrix

4.1.3 Insights from the result of step 1.

By conducting the interviews and compared them against best practices in the field of expert effort estimation we have managed to get a good picture on their current effort estimation process. This process has been compared against best practices in expert effort estimation.

The survey compared the state of practice against the best practice on expert effort estimation. The survey showed that six were properly performed. Three practices were only partially performed, and the other three have not been properly performed. We proposed solutions for the steps that were not properly performed.

Results of the interviews and report analysis in the first step show that the following problems need to be addressed to improve the effort estimation:

P1: Project managers and marketing people have conflicting goals of effort estimation
P2: Estimators are lack of training and feedback
P3: The experience of effort estimation from previous projects was not shared and analyzed properly
P4: Different effort estimation tools were used in different departments of the company
P5: The interdependencies between projects inside the company were not handled properly
P6: No tool for early estimation available

Based on the experience and lessons learned mentioned above, we propose the following improvements for discussion:

- **S1: Continue and formalize the WBS effort process**. WBS is proved to be very useful. However, the company needs to unify the effort estimation tools or sheets. The common process with tools and templates facilitates reporting and measurement (for management), and also is a basis for training and contextualizing experience.

- **S2: Increase the training in effort estimation**. One important step is to summarize the experience and lessons learned of effort estimation after each project is finished. The detailed feedback should be given to the initial estimator. In addition, it is necessary to run a formal training session on the common process.

- **S3: Build and formalize the experience database**. The experience database should be in the form of an Excel sheet to make it easy to use. The suggestions on how to adjust the information in the experience database due to different project context should also be included.

- **S4: Try to avoid conflict goals of effort estimation.** In case the estimated effort has to be adjusted according to the company's marketing strategy, the effort estimation should be performed into two steps. The first step is to get actual effort estimation, i.e., asking the estimators to give the effort estimation without considering the marketing strategy. The second is to adjust the effort estimation based on marketing strategy and offering it to the customer. However, the evaluation of the project managers' performance or effort estimation skill should be based on the actual estimation from the first step instead of adjusted effort estimation from the second step.

- **S5: Try to avoid early effort estimation.** Although it is unavoidable to ask project managers to give the effort estimation in the very early stage of a project, it is important to claim or emphasis to customers that it is an early effort estimation, so that project managers may get leeway to re-estimate.

- **S6: Eliminate and control interdependency between several projects.** The actual effort of a project can be strongly affected by organizational issues, such as multiplying projects members and interdependencies between projects. It is important to coordinate projects and developers properly. If the interdependency between projects is unavoidable, it is important to flag this as a risk and make sure that the estimates cover this uncertainty and the manager is made aware of the cost.

- **S7: Implement better common tool to support the effort estimation process.** The proposed template can solve some of the issues concerning difficulties to build a better knowledge base, compare estimates, and compare estimates and actual effort. It has also functions to automate several key figures used in reports which would reduce the amount needed to create reports considerably. The detailed month report can also give detailed information on each task as the project progresses and can make it easier to detect deviations on each task.

By reading effort estimation document, time registration documents, project reports, we have summarized the following issues need to be addressed to improve the effort estimation process:

There are no direct links between activities listed in the effort estimation documents with those activities recorded in the time registration system and various reports. Although project managers describe/code the task when recording the hours used for a specific task, they did not refer to the activities listed in the effort estimation document. As a result, it is difficult for estimators to do a detailed analysis on their effort estimation error by comparing the initial effort estimation with the actual effort used. In addition, it is not possible for project managers to generate various reports automatically. Most data in reports have to be filled in and updated manually.

The effort estimation template and report template are different in different branches in the company. Thus, it is difficult to share effort estimation experiences.

Our main proposal for addressing the above issues is that we propose to move the task coding phase from the time registration phase to the effort estimation phase. Project managers have to give task IDs of each task in the effort estimation document. All following time registration for one task must refer to its task IDs in the effort estimation documents.

The benefits of this suggestion are:

- It is easy to implement.
- Will not add extra workload for project manager. The only difference with previous process is to move the task definition/coding from the current time registration phase to the effort estimation phase.
- It can improve the working efficiency by generating various reports automatically. It can save the project managers time to fill in and update the monthly/final project reports manually.
- It can help estimator to learn from previous effort estimation errors and to share experience between different branches in the company.

4.2 Results from step 2.

Based on the results from step 1 we've come up with some proposals to improve the effort estimation at the company. This part also includes the results from the use case points study.

4.2.1 Answers to research questions

Answers to RQ8: Can Use case points be used as an early effort estimation method in the company context?

We had only two projects available with effort estimation and design documents, project A and B. Project managers provided the environmental and technical factors. Project A was a fairly small project, nearly 1900 hours and had experienced personnel. Project B was quite large, about 14500 hours. Project B was also more complex with several demands and had hired part-time staff.
Table 17 and table 18 shows the technical and environmental factors.

	Technical factor	**Weight**	**A**	**B**	**Weighted A**	**Weighted B**
t1	Distributed System	2	3	1	6	2
t2	Response time	1	2	5	2	5
t3	End user efficiency	1	1	5	1	5
t4	Complex Internal Processing	1	3	2	3	2
t5	Reusable Code	1	4	3	4	3
t6	Installation Ease	0,5	0	3	0	1,5
t7	Easy use	0,5	4	5	2	2,5
t8	Portable	2	0	3	0	6
t9	Easy to change	1	0	5	0	5
t10	Concurrent	1	0	1	0	1
t11	Security objectives	1	0	5	0	5
t12	Direct access to third parties	1	3	1	3	1
t13	User training facilities	1	0	2	0	2
	Total TFactor				21	41
	Technical complexity factor, TCF = 0,6 + 0,01 * Tfactor				0,81	1,01

[Table 17] Technical complexity factors

	Environmental Factor	Weight	A	B	Weighted A	Weighted B
e1	Familiarity with project	1,5	3	2	4,5	3
e2	Application experience	0,5	2	2	1	1
e3	Object-oriented programming experience	1	4	5	4	5
e4	Lead analyst capability	0,5	4	3	2	1,5
e5	Motivation	1	1	5	1	5
e6	Stable requirements	2	4	1	8	2
e7	Part-time Staff	-1	0	3	0	-3
e8	Difficult programming language.	-1	3	4	-3	-4
	Total Efactor				17,5	10,5
	Environmental factor, EF = 1,4 + (-0,03 * Efactor)				0,875	1,085

[Table 18] Environmental factors

Since we had no detailed information on how the use cases are made and that it is currently no standard of creating a use case, we did count transactions for use cases both with and without alternative flows.

Use case points for project A

Actor type	Count	Weight	Total
Simple	0	1	0
Average	3	2	6
Complex	4	3	12
Actor weight			18

[Table 19] Use case actor weight for A

Use case type	Count	Alt.Count	Weight	Total	Alt. Total
Simple	1		5	5	0
Average	4	3	10	40	30
Complex	2	4	15	30	60
Use case weight				75	90
Total use case point				93	108

[Table 20] Use case weight and totals for A

Use case points for project B

Actor type	Count	Weight	Total
Simple	11	1	11
Average	0	2	0
Complex	21	3	63
Actor weight			74

[Table 21] Use case actor weight for B

Use case type	Count	Alt.Count	Weight	Total	Alt.Total
Simple	4	4	5	20	20
Average	11	4	10	110	40
Complex	17	24	15	255	360
Use case weight				385	420
Total use case point				459	494

[Table 22] Use case weight and totals for B

Use case based estimated effort and comparison against expert estimate and used effort.

Counting the number of environmental factors less than 3 for E1 – E6 and factors greater than 3 for E7 – E8 gave the following results.

A: 2 which gives us PHperUCP = 20
B: 3 which gives us PHperUCP = 28

Use case based estimated total effort A:

93 UUCP * 0.81 TCF * 0.875 EF * 20 PHperUCP = 1318

Use case based estimated total alt. effort A:

108 UUCP * 0.81 TCF * 0.875 EF * 20 PHperUCP = 1531

Use case based estimated total effort B:

459 UUCP * 1.01 TCF * 1.085 EF * 28 PHperUCP = 14084

Use case based estimated total alt. effort B:

494 UUCP * 1.01 TCF * 1.085 EF * 28 PHperUCP = 15158

Expert estimate A: 1787
Expert estimate B: 13804

Total effort for A: 1889
Total effort for B: 14413

We had no information on how the use cases are created and if we should include alternative flows or not. There were also no guidelines on how large a transaction could be. What one might consider to be two transactions might be considered to be one by another. Thus we have two different counts UCP without alternative flows and Alt.UCP which includes the alternative flows.

Mohagheghi et al. states that early estimation within 20 % are quite good [Moha05]. From the final reports we can see the expert estimate and total effort spent. This is summed up in the table below:

Project	Effort	Expert	Expert %	UCP	UCP %	Alt. UCP	Alt. UCP %
A	1889	1787	95	1318	70	1531	81
B	14413	13804	96	14084	98	15158	105

[Table 23] Comparison effort against expert and UCP effort estimation

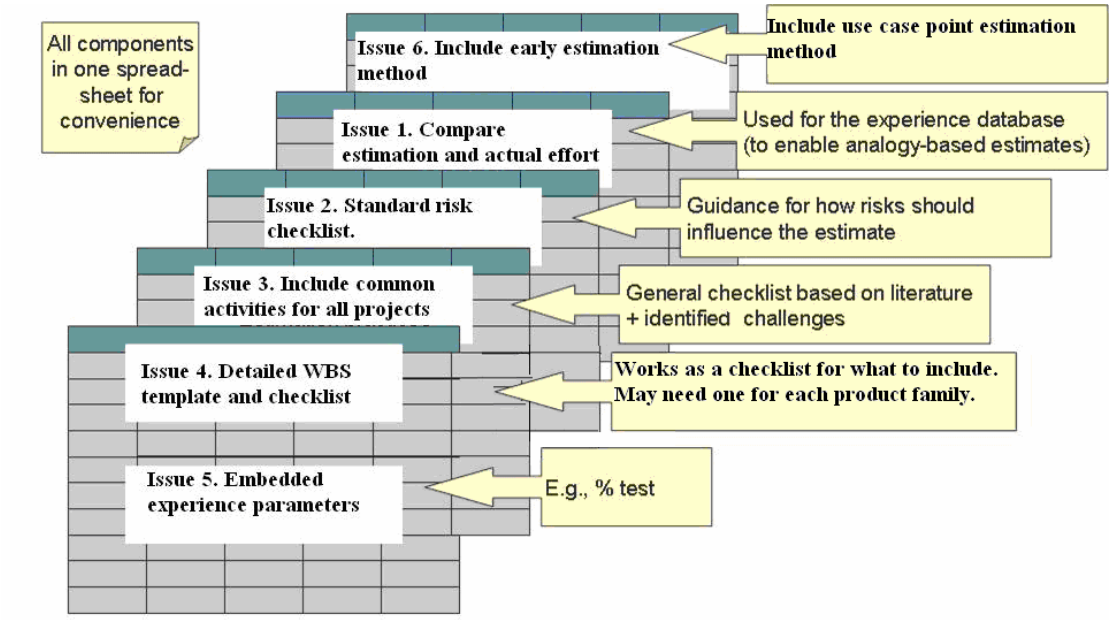
The columns for table 23 are calculated as follows:

- The column with effort represents the actual effort for the project.
- Expert represents the expert estimate from the initial estimation.
- Expert % = Expert / Effort * 100
- UCP represents the newly created UCP estimate.
- UCP % = UCP / Effort * 100
- Alt. UCP represents the alternative way of determining complexity by including all the alternative flows in the use cases.
- Alt. UCP % = Alt.UCP / Effort * 100

4.2.2 Improve effort estimation practice

Since one of the major motivations of effort estimation improvement is to build a unified effort estimation process, the purpose of this study is to standardize the WBS (work-breakdown structure) effort estimation, which has been popularly used in the company. In this study, we will address the problems P2, P3, and P4, and focus on the suggestions S1, S2, S3, as described in chapter

4.1.3. The motivation of this study is to fill in items in our proposed effort estimation structure as shown in Figure 8.



[Figure 8] WBS effort estimation template

The links between P2, P3, P4, P6, S1, S2, S3, as described in chapter 4.1.3, and items in the template in Figure 8 are explained in the table below.

P	S	Items in the template		
		Definition	Explanation	Issues to be addressed
P2 P3	S2 S3	Actual vs. estimated follow up	Input to experience database, so that estimators can learn from the previous wrong effort estimation.	I1: The effort estimation and report process tool should provide functions, so that estimator can compare their initial effort estimation and the actual effort in a very detailed level.
		Project classification parameters	Used for the experience database to enable analogy-based estimates	Not addressed in this report
P3 P4	S1 S2 S3	Risk checklist	Guidance for how risks should influence the estimate	I2: The standard risk checklist should be build so that people will not forget the important risk items.
P4	S1	Effort estimation practices checklist	General checklist for all kind of projects	I3: The standard checklist should be build to include common activities in all kind of project. It can help project

				managers to include all necessary activities in their effort estimation.
P4	S1	Detailed WBS template and checklist	Works as a checklist for what activities to include in a project effort estimation	I4: The differences (variations) between different kinds of projects should be reported, so that estimator can select the specific activities that are related to their project contexts.
P3 P4	S2 S3	Embedded experience parameters	The correlations of efforts between different activities of a project, e.g., system test effort is 30% of the coding	I5: The correlations between related items in the activity checklist should be summarized, so that estimators can easily estimate the effort of one activity (i.e., the activity difficult to be estimated) based on the effort estimation of another activity (i.e., the activity easier to be estimated).
P6	S7	Early estimation	Early estimation method	I6: The estimation tool should include an early estimation method.

[Table 24] Links between problems, suggestions, and items in effort estimation template

4.2.3. Proposals for I1

Based on the current practise of the company, and issues **I1** shown in Table 24, we propose to *give standard task ID to each task listed in the effort estimation document.*

Concerning **I1** (i.e., the effort estimation and report process tool should provide functions, so that estimator can compare their initial effort estimation and the actual effort in a very detailed level), the current process and tool used in the company cannot give support to help estimator to learn from previous failures.

People just fill in the hours used for performing a specific activity (*described by free text or a self-defined code*) into the time registration system without referring to the activities listed in the effort estimation document. The activities recorded in the time registration system and those written in the effort estimation document are quite different. As a result, people cannot compare the actual effort used for each activity with the estimated effort for such an activity. Although people may know the gap between the total number of the initial effort estimation and the total number of the actual effort of a project, they cannot easily figure out the causes of the gap. The reason is that there is no direct links between activities listed in the effort estimation document, activities recorded in the time registration system, and activities summarized in the monthly/final report.

Our proposal is to move this task coding phase into effort estimation phase. *It means that people have to code each listed task in the effort estimation document with standard task IDs, such as ADM (refer to administration) and COD (refer to coding). When project manager register the hours used for each task in the time registration system, they must use the same unique (in this project) task IDs as found in the effort estimation document to refer to the task.*

When estimating a project, one should create matching tasks for registering info in the time registration system. For example, the project P34 could have the task Dev44, which would be unique to the project P34. The project task P34.Dev44 would then have an estimate in the effort estimation, have effort spent in the time registration system, and could be used in reports. Also the identifier of the task should say something about what kind of task it is. Then people can easily get all effort spent on administration for the tasks ProjectXX.AdmNN to ProjectXX.AdmYY.

The possible benefits of giving standard task ID in the effort estimation phase and referring these IDs in the time registration system are:

- Setting up unique task IDs in the effort estimation will make it easier to automatically generate reports during project progress. Automatic report generation will save a lot of time compared to manually updating.
- This will also create a connection between the effort estimation and the finished project, which again make it easier for estimator to compare the initial estimate with the actual effort of each task.
- Be able to check if there is some relations between the different task categories. This could give a pinpoint if the estimate is a bit accurate or not. Let's say that administration is 20% of each project, and then this could help to control the estimate accuracy.

After going through several project reports, the similar and different ways to document both effort and other economical data were identified. It seems that for all projects the following data should be included:

- Budget
- Budget accumulated
- Budget in percent
- Real
- Real accumulated
- Remaining (estimated)
- Prognosis (Real accumulated + remaining)
- Degree of consumption (%)
- Degree of completeness (%)

Options could be:

- Have Budget, Budget accumulated, Real and Real accumulated in kr if there is set a price per hour.
- If it is an external project it could include earnings accumulated. This could also be done for internal project if they use internal invoicing.
- Travel costs if it involves travels.
- Other costs, like licensees or hiring of personnel from other companies. This should be done as budget, real and deviation.
- If the project could have changes in the specification while the project is ongoing it should include a request for changes.

Although we did not observe the process of generating monthly/final economic report of the project, we can get the feeling that project managers have to fill in the number of the report manually.

Much of this data could be automatically generated if each registration of hour used has some corresponding task ID for the project and activity. When creating a link between activities in the time registration system and the monthly reports project managers may generate the figures automatically. This could also be the case for the end report. The figures for the reports should be generated on data in the time registration system. This could possibly save a lot of work for the managers when updating and creating reports.

The table 25 below is taken from one of the project reports. This shows that there have been thoughts in the same direction as the improvements we are suggesting in our Excel template

SubProject	Element	Jan	Feb	Mar	Apr	May
Adm/test	Budget hours					
Adm	Accumulated hours					
Adm	Estimated remaining hours					
Adm	Budget travel 1000 kr					
Adm	Accumulated travel 1000 kr.					
Adm	Budget other costs1000 kr.					
Adm	Accumulated other costs 1000 kr.					
SubProject	Element					
Office	Budget hours					
Office	Accumulated hours					
Office	Estimated remaining hours					
Office	Budget travel 1000 kr					
Office	Accumulated travel 1000 kr.					
Office	Budget other costs1000 kr.					
Office	Accumulated other costs 1000 kr.					
SubProject	Element					
Selfservice	Budget hours					
Selfservice	Accumulated hours					
Selfservice	Estimated remaining hours					
Selfservice	Budget travel 1000 kr					
Selfservice	Accumulated travel 1000 kr.					
Selfservice	Budget other costs1000 kr.					
Selfservice	Accumulated other costs 1000 kr.					
Total	Element					
Total	Budget hours					
Total	Accumulated hours					
Total	Estimated remaining hours					
Total	Budget travel 1000 kr					
Total	Accumulated travel 1000 kr.					
Total	Budget other costs1000 kr.					
Total	Accumulated other costs 1000 kr.					
Total	Budget hours - month 1000 kr					
Total	Accumulated hours - month 1000- kr.					
Total	Total budget month 1000 kr.					
Total	Totalt accumulated month1000 kr.					
Total	Total budget so far 1000kr					
Total	Total accumulated so far 1000 kr					

[Table 25] One available report with task IDs

4.2.4 Proposals for I2

We have not been able to identify any risk guidelines. The risks involved in an estimate are set using expert judgement of the estimator(s). To be surer that these risks are reasonable one should have some sort of guidelines that tell something about expected risks. This could be in the form of:

- New development tools , 10%
- New development domain , 15 %
- Inexperienced workers, 10 %
- Similar tasks have not been carried out before. 5 %
- Uncertain specification, 10% - 25%

In the future one might look further into the field Software risk management to better assess risks. These are the general risks we identified:

1. Requirements may not be defined precisely
2. Requirements may change
3. Key personnel may have too many task assignments in parallel
4. Key personnel may quit during the project
5. Key personnel may have narrow knowledge span on each task
6. Key personnel may not work during public holidays
7. Documentation of existing/reusable parts are lacking or wrong
8. Customer or 3. party may not have adequate resources
9. 3 party may not finish their tasks in time
10. Project may have dependencies towards other projects
11. Customer may not follow the initial plan
12. Test environment will not be available on time
13. Test environment may be different from the production environment

4.2.5 Proposals for I3

This step was not included in the template and remains to be done as future work. We did not have enough knowledge on the reports as to know which tasks that are always conducted for a project.

4.2.6 Proposals for I4.

Although the general process of effort estimation is similar (i.e., based on the WBS), people are using different effort estimation templates. There are some differences between projects on what they estimate in cases like risk, maximum, minimum and probably. Some even don't include all of them. The first process on estimating the project should use the same template, no matter which department the effort estimation was done. This will make it a lot easier to build an effort estimation database and for departments to assess estimations done by another department. The main reasons to use a common template are:

- Serve as a checklist and make sure all information on effort estimation is included.
- Make it easier to build an effort estimation database.
- Make it easier for departments to assess estimations done by another department.

By looking on the different effort estimation parameters we have the created a suggestion for a standard template. (See Excel template)

- Tasks: this will be more thoroughly described below.
- Estimated by: The person responsible for the estimates.
- Not to be performed: In case a task should not be performed.
- Minimum: Best effort possible.
- Maximum: Worst effort possible.
- Probable: Most probable effort.
- Risk: Adjustments for risk could be done for the entire estimate or one or more tasks.
- Optional Medium:
- Optional Standard deviation: Deviation from the medium.
- Optional Variance: Dispersion
- Resources: Are the estimates depended on any resources; this could be internal/external people or other resources.
- Comments:

Tasks:

All tasks are setup by the project manager. The tasks should have a prefix telling what kind of category they belong to. Since projects with different context may need different task checklist, we have analyzed the common activities between projects and the differences.

The common activities/tasks that we have found are:

- Administration: Project administration and leadership, meetings, travel, estimation, technical reviews, other general project tasks.
- Design: Requirement specification, analysis, design of data models, etc.
- Development: The actual development of the different functions.
- Test: Establish test environments, system tests, acceptance tests, create/update documentation, etc.
- Bugfixing: Fixing bugs. This might be part of the test category if there is no reason to place it as a separate task.

The variations are:

- Optional Pilot: Tasks related to pilots like install, separate documentation, follow up pilots, etc.
- Optional System administration: Establish a working environment, support and bugfixing in warranty period, test and installation of updates.
- Optional Training: Training of internal and external users. Increase internal knowledge to solve the tasks.

4.2.7 Proposals for I5

With respect to **I5** (i.e., the correlations between related items in the activity checklist should be summarized, so that estimators can easily estimate the effort of one activity based on the effort estimation of another activity), the current process also brings difficulties to summarize the correlations of effort between related activities. The reason is that people use free text (or different terms) to describe the activity. In order to find out the effort correlations between different activities, people have to manually convert different terms being used into standard codes, and use these codes as variables for further

analysis. If there are many documents need to be analyzed, it may require a lot of work.

The table below shows a comparison between actual effort spent and the different task categories. We were not able to determine any obvious patterns at this point.

Project number	design specification	Development	System test	Administration /PM	Deployment	converting	Expension / modification	Tool	Total
1		2835	1254	779		794			5662
2	104	1832	1074	651					3661
3	55,5	810,5	695,5	563,5					2125
4	398	370	641	422	57		210		2098
5	583	817	265	514					2179
6	2189	5508,5	1476,5	2324	135		142	183,5	11958

Project number	design specification	Development	System test	Administration /PM	Deployment	converting	expension/ modification	Tool	
1	0 %	50 %	22 %	14 %	0 %	14 %	0 %	0 %	100 %
2	3 %	50 %	29 %	18 %	0 %	0 %	0 %	0 %	100 %
3	3 %	38 %	33 %	27 %	0 %	0 %	0 %	0 %	100 %
4	19 %	18 %	31 %	20 %	3 %	0 %	10 %	0 %	100 %
5	27 %	37 %	12 %	24 %	0 %	0 %	0 %	0 %	100 %
6	18 %	46 %	12 %	19 %	1 %	0 %	1 %	2 %	100 %

[Table 26] Comparing actual effort and task categories

4.2.8 Proposals for I6

When it comes to the use case points effort estimation method it showed some results which could seem promising. The problem using this method was whether or not to include alternative flows when determining the complexity for the use case. Project A was 19 % off when counting the alternative flows and 30 % off when not counting the alternative flows. Expert estimates for project A was 5 % off. Project B however was opposite and was 5 % off when counting the alternative flows and 2 % when not counting the alternative flows. Expert estimates for project B was 4 % off.

This method is however a top down effort estimation method that they are planning to use as an early effort estimation. The accuracies on re-estimation with expert estimates might be more accurate, since the estimator has more information available. In these two examples both effort estimation proposals could be accounted to be adequate.

By conducting a comparison of use case points against actual effort and expert estimates we found results that were quite close. There are however some uncertainties on this step. We only had two projects available to compare with. The template includes UCP estimation method.

4.3 Results from step 3

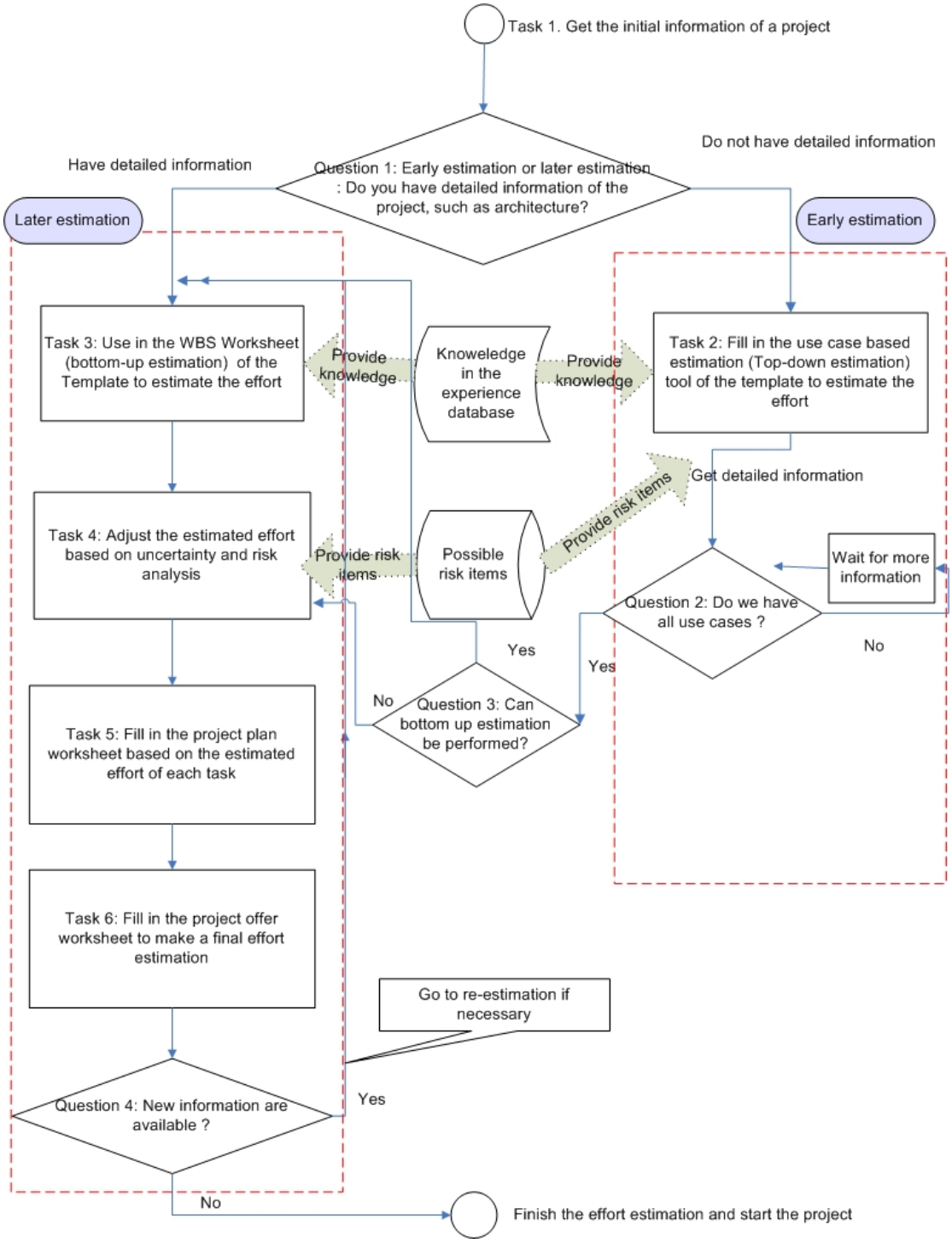
Based on the results from step 2 and discussions by phone and email we proposed an Excel template for the company. Issues from table 24 and how they are handled are included in the examples from this template below.

4.3.1 Using the effort estimation template

The effort estimation template contains the following worksheets:

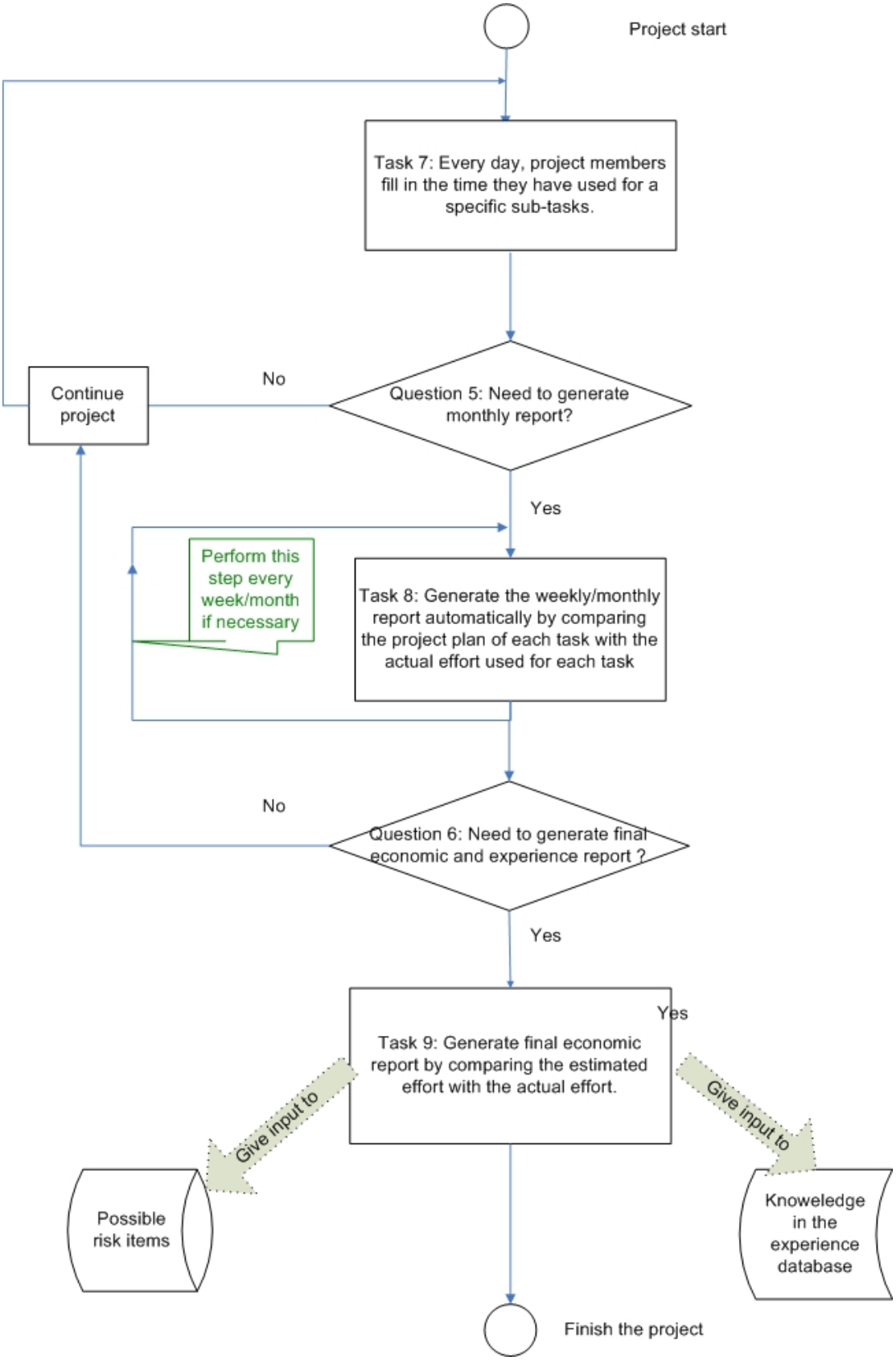
- Offer: With overall cost and project information
- UCP: Use case points effort estimation method that should be used for early estimations only. Solves **I6**
- Project tasks: Here you can estimate tasks based on predefined cost factors.
- Effort estimation: The sheet for registering tasks and estimated effort.
- Project plan: Plan to enter when the tasks should be carried out. Solves **I1**.
- Detailed month report: Shows each tasks and effort spent up to the date you enter. Solves **I1**.
- Month report: Generated month reports based on estimate and time system. Solves **I1**.
- Final report: Generated final report based on the month reports.. Solves **I1**.
- Risks and basis: Risk assessments and other specific project info. Solves **I2**.
- Cost factors: Here you can specify cost factors for different components
- Data types: This is a registry for the cost factors.
- Time registration: Simulation of time registration entries
- Time registration system: Simulation of the data source for the time registration system

The different initial tasks for effort estimation using the template can be seen in figure 9. These tasks describe the process before any formal project has been started. This process will give input to find out if the project should be started or terminated.



[Figure 9] New initial estimation process based on the template

Figure 10 describes the process after the initial effort estimation.



[Figure 10] New project process based on the template

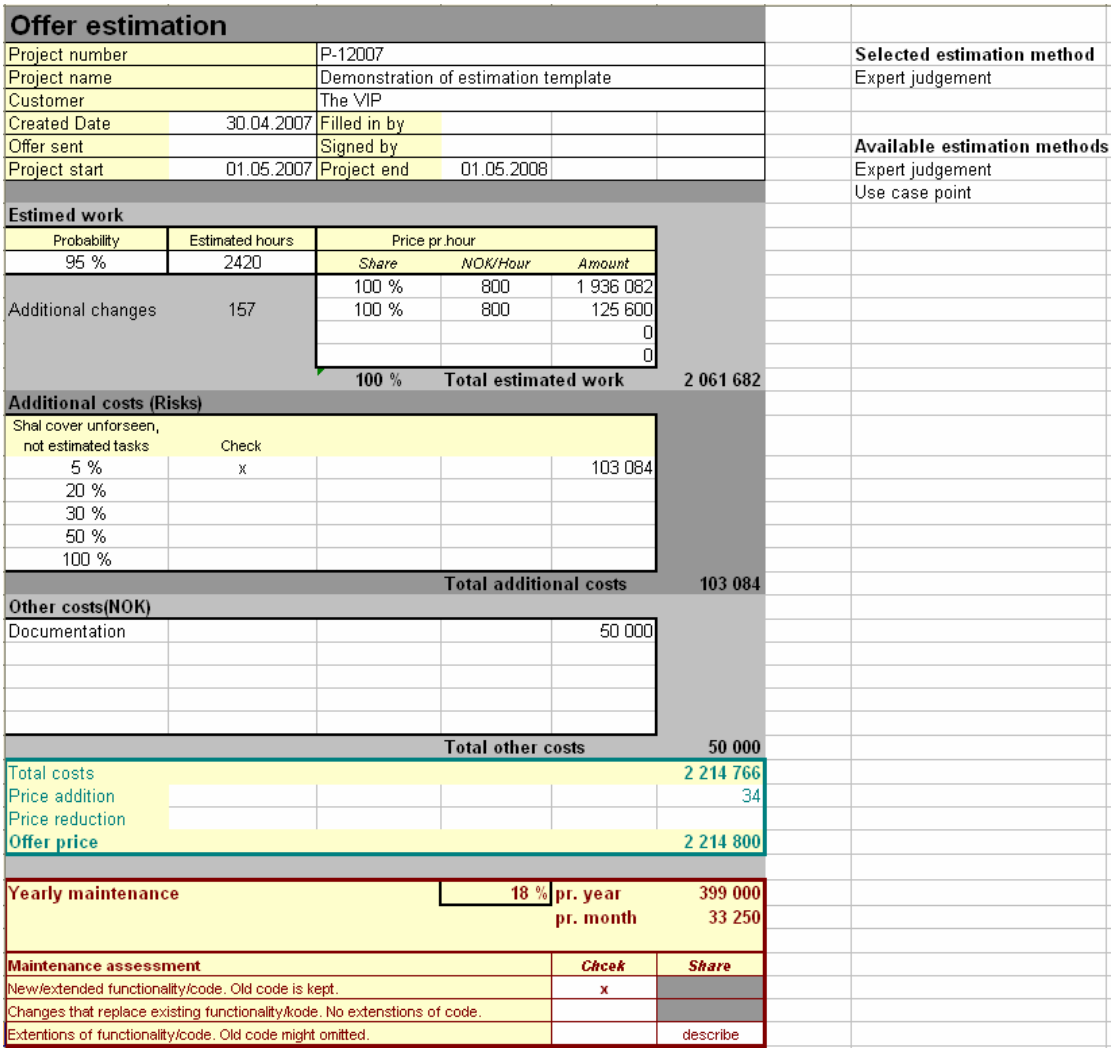
Task 1. Get the initial project information

The first or last task when using the estimation template is to fill in relevant information in the offer sheet.

In this worksheet the user should fill in a project number, name and customer. The user must also fill in project start and project end dates. The fields for offer sent, filled in by and signed by are optional.

The estimated work part is generated based on the effort estimation worksheet or UCP. The user must fill in a price pr hour and share. Additional work might also be inserted here. You must select whether or not to use expert estimates and values from the effort estimation sheet, or Use case points from the UCP sheet. The UCP should only be used for early estimations, when you have little knowledge on the tasks.

Additional costs will increase the effort based on the risk percentage that is chosen. Other costs might be included in the other costs part. The total costs have a rounding mechanism either up or down. It is also possible to fill in a yearly maintenance part.

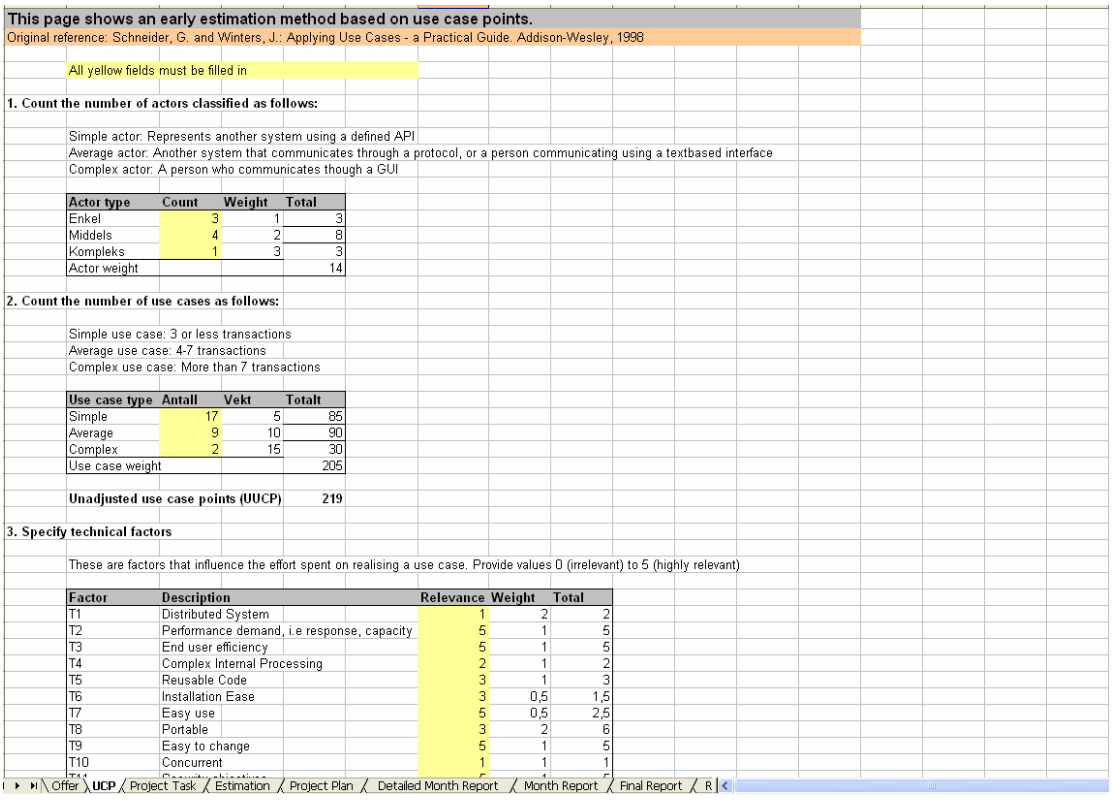


Offer estimation							
Project number		P-12007					Selected estimation method
Project name		Demonstration of estimation template					Expert judgement
Customer		The VIP					
Created Date	30.04.2007	Filled in by					Available estimation methods
Offer sent		Signed by					Expert judgement
Project start	01.05.2007	Project end	01.05.2008				Use case point
Estimed work							
Probability	Estimated hours	Price pr.hour					
95 %	2420	*Share*	*NOK/Hour*	*Amount*			
		100 %	800	1 936 082			
Additional changes	157	100 %	800	125 600			
				0			
				0			
		100 %	**Total estimated work**				2 061 682
Additional costs (Risks)							
Shal cover unforseen, not estimated tasks	Check						
5 %	x			103 084			
20 %							
30 %							
50 %							
100 %							
			Total additional costs				103 084
Other costs(NOK)							
Documentation				50 000			
			Total other costs				50 000
Total costs							2 214 766
Price addition							34
Price reduction							
Offer price							2 214 800
Yearly maintenance			18 %	**pr. year**			399 000
				pr. month			33 250
Maintenance assessment					***Check***		***Share***
New/extended functionality/code. Old code is kept.					x		
Changes that replace existing functionality/kode. No extenstions of code.							
Extentions of functionality/code. Old code might omitted.							describe

[Figure 11] Screenshot from total offer sheet

Task 2. Early estimation : UCP

This is an optional sheet if the project needs an early estimate. Typically this is done for projects which require a bidding phase or need some other kind of quick estimate on costs. Before you can use this sheet you need to have use cases available. You have to fill in complexity of actors and use cases, environment and technical factors and give an estimate of PHperUCP. Be sure to select this method on the offer sheet if you want this estimate to be shown. This solves **I6**.



This page shows an early estimation method based on use case points.
Original reference: Schneider, G. and Winters, J.: Applying Use Cases - a Practical Guide. Addison-Wesley, 1998

All yellow fields must be filled in

1. Count the number of actors classified as follows:

Simple actor: Represents another system using a defined API
Average actor: Another system that communicates through a protocol, or a person communicating using a textbased interface
Complex actor: A person who communicates though a GUI

Actor type	Count	Weight	Total
Enkel	3	1	3
Middels	4	2	8
Kompleks	1	3	3
Actor weight			14

2. Count the number of use cases as follows:

Simple use case: 3 or less transactions
Average use case: 4-7 transactions
Complex use case: More than 7 transactions

Use case type	Antall	Vekt	Totalt
Simple	17	5	85
Average	9	10	90
Complex	2	15	30
Use case weight			205

Unadjusted use case points (UUCP) 219

3. Specify technical factors

These are factors that influence the effort spent on realising a use case. Provide values 0 (irrelevant) to 5 (highly relevant)

Factor	Description	Relevance	Weight	Total
T1	Distributed System	1	2	2
T2	Performance demand, i.e response, capacity	5	1	5
T3	End user efficiency	5	1	5
T4	Complex Internal Processing	2	1	2
T5	Reusable Code	3	1	3
T6	Installation Ease	3	0,5	1,5
T7	Easy use	5	0,5	2,5
T8	Portable	3	2	6
T9	Easy to change	5	1	5
T10	Concurrent	1	1	1

Offer | UCP | Project Task | Estimation | Project Plan | Detailed Month Report | Month Report | Final Report | R

[Figure 12] Screenshot from UCP effort estimation

Task 3. Expert estimation

This step should be conducted when you don't need an early estimate. Typically when you have good information on the project and do not need quick results. The template has currently two ways in creating estimations for tasks. One is based on cost factors and the other is based on expert estimation. The cost factors are more of an example on how things can be done if you have a good knowledge database or have previous estimation information on the tasks available.

Task 3a1. Data Types

This sheet contains information relevant to cost factors and project tasks. Here you need to fill inn the types for life cycle, technology and complexity that are used in the cost factors. This could be connected to a knowledge database in the future.

	A	B	C	D	E	F	G	H	I
1									
2									
3									
4									
5		**Component types**		**Technology types**		**Complexity**		**Life Cycle**	
6		Window		Java		Low		New development	
7		Business logic component		.Net		Medium		Enhancement	
8		External interface		Visual Basic		High			
9		Database connection		Cobol					
10		Database entity							
11		Batch routine							
12		Report							
13		Use case							
14									
15									
16									
17									

[Figure 13] Screenshot from data types sheet

Task 3a2. Cost factors

This sheet contains data that are a simulated projects knowledge base. When a project is finished, real effort from that project should be classified and entered in the knowledge base. The database will then contain information about component types, technology types, complexity and life cycle stages. Combining this information could provide a useful foundation for early effort estimation.

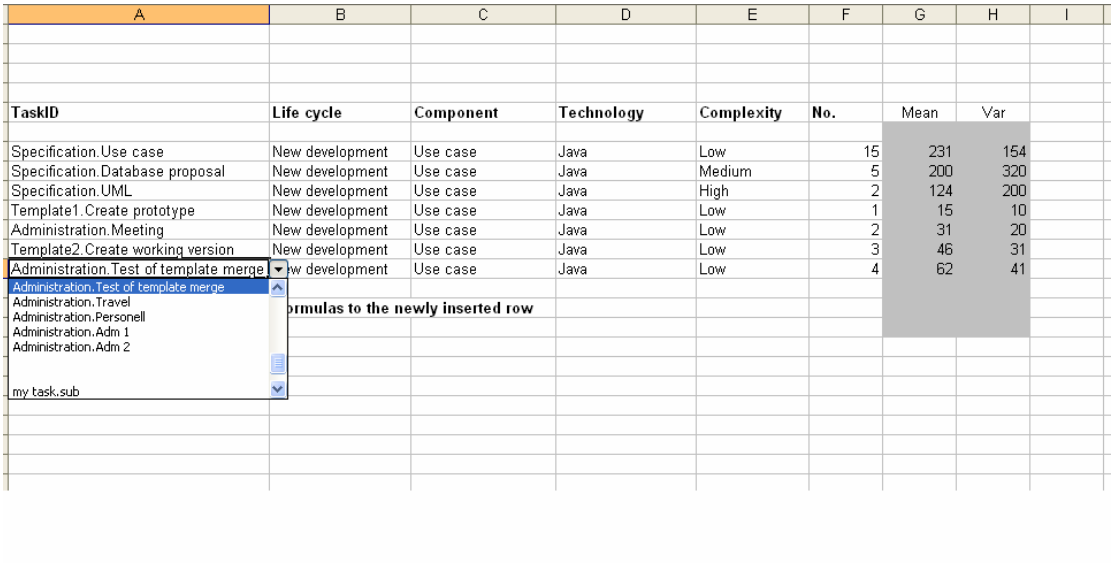
					Analysis	Analysis	Analysis	Analysis	Analysis	Design	Design	Design	Design	Design	Code+UT	Code+UT	Code+UT
Key	Life cycle	Component	Technology	Complexity	L	M	H	Mean	Var	L	M	H	Mean	Var	L	M	H
New developmentUse caseJava	New development	Use case	Java	Low	8	15	24	15,4	10,2	10	15	25	16	9	48	66	9
New developmentUse caseJava	New development	Use case	Java	Medium	20	40	60	40	64	20	35	50	35	36	94	127	18
New developmentUse caseJava	New development	Use case	Java	High	40	60	90	62	100	35	55	90	58	121	156	202	32
								0	0				0	0			
New developmentWindowJavaL	New development	Window	Java	Low				0	0				0	0			
New developmentWindowJavaM	New development	Window	Java	Medium				0	0				0	0			
New developmentWindowJavaH	New development	Window	Java	High				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	Low				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	Medium				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	High				0	0				0	0			
New developmentExternal inter	New development	External interface	Java	Low	8	15	24	15,4	10,2	10	15	25	16	9	48	66	9
New developmentExternal inter	New development	External interface	Java	Medium	20	40	60	40	64	20	35	50	35	36	94	127	18
New developmentExternal inter	New development	External interface	Java	High	40	60	90	62	100	35	55	90	58	121	156	202	32
New developmentDatabase con	New development	Database connection	Java	Low				0	0				0	0			
New developmentDatabase con	New development	Database connection	Java	Medium				0	0				0	0			
New developmentDatabase con	New development	Database connection	Java	High				0	0				0	0			
New developmentReportJavaLo	New development	Report	Java	Low				0	0				0	0			
New developmentReportJavaMe	New development	Report	Java	Medium				0	0				0	0			
New developmentReportJavaHi	New development	Report	Java	High				0	0				0	0			

[Figure 14] Screenshot from cost factors

Task 3a3. Project Task

In this worksheet one should specify tasks with the unique taskID, life cycle, component, technology, complexity and the number of times the component is used. E.g. A task with the Use Case component and No. 15 specifies that this task has 15 use cases attached.

The values are now fetched from cost factors sheet, but should be fetched from a projects knowledge database which contains data for the different selections.



[Figure 15] Screenshot from project tasks based on cost factors

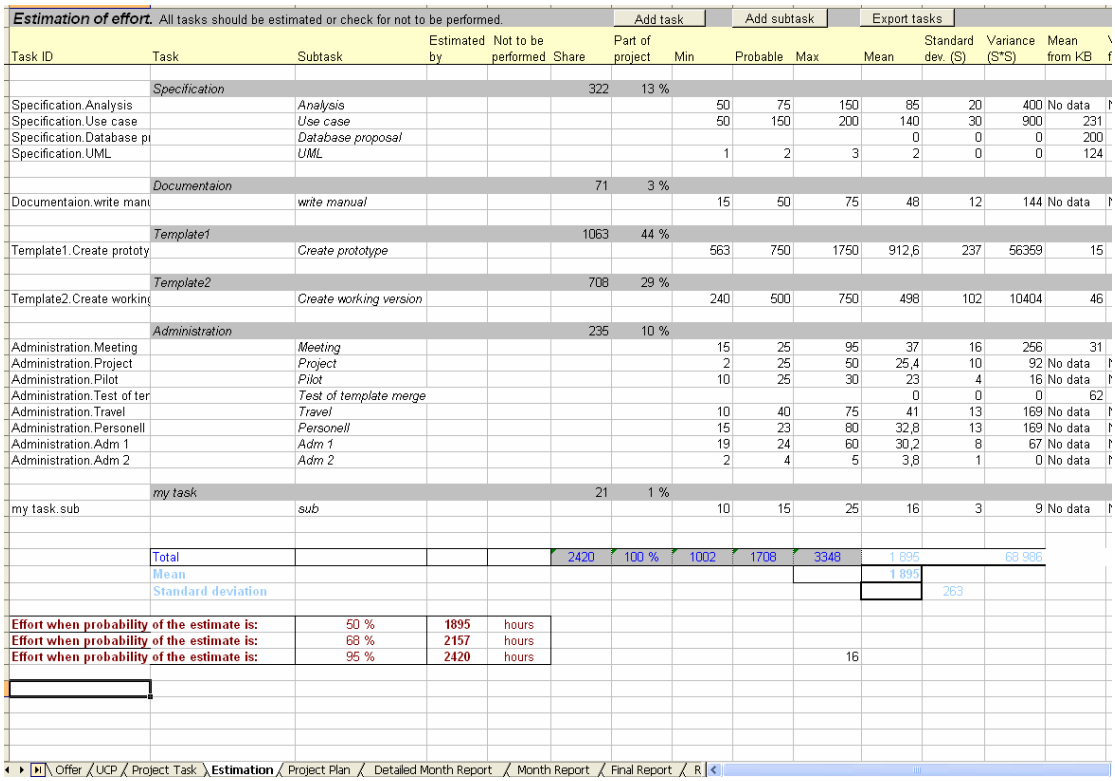
Task 3b. Effort estimation

This is the worksheet were all estimated effort should be provided. This sheet has some buttons that must be used to add tasks and subtasks A task id is generated based on the task and subtask. A task is just a category which has a share of the project in hours, and a percentage part of the project. To add a task one must click the add task button. You should only change the name of a task and nothing more.

To add a subtask, click the cell underneath a task and click add subtask button. This will create a new subtask with the correct formulae. You should only change the name of the task and provide information on min, probable and max estimated effort for the subtask.

If you have specified a project task in the project task worksheet variance and mean values are suggested in the rows Mean from KB and Variance from KB. The subtasks will be aggregated along with effort for the different certainty levels. The template uses the value for 95% probability.

Export tasks button will export the tasks to the time registration sheet. This is done as a simulation as a time registration system. The tasks should be exported into the real time registration system once the project is going to be started.



Estimation of effort. All tasks should be estimated or check for not to be performed. | Add task | Add subtask | Export tasks

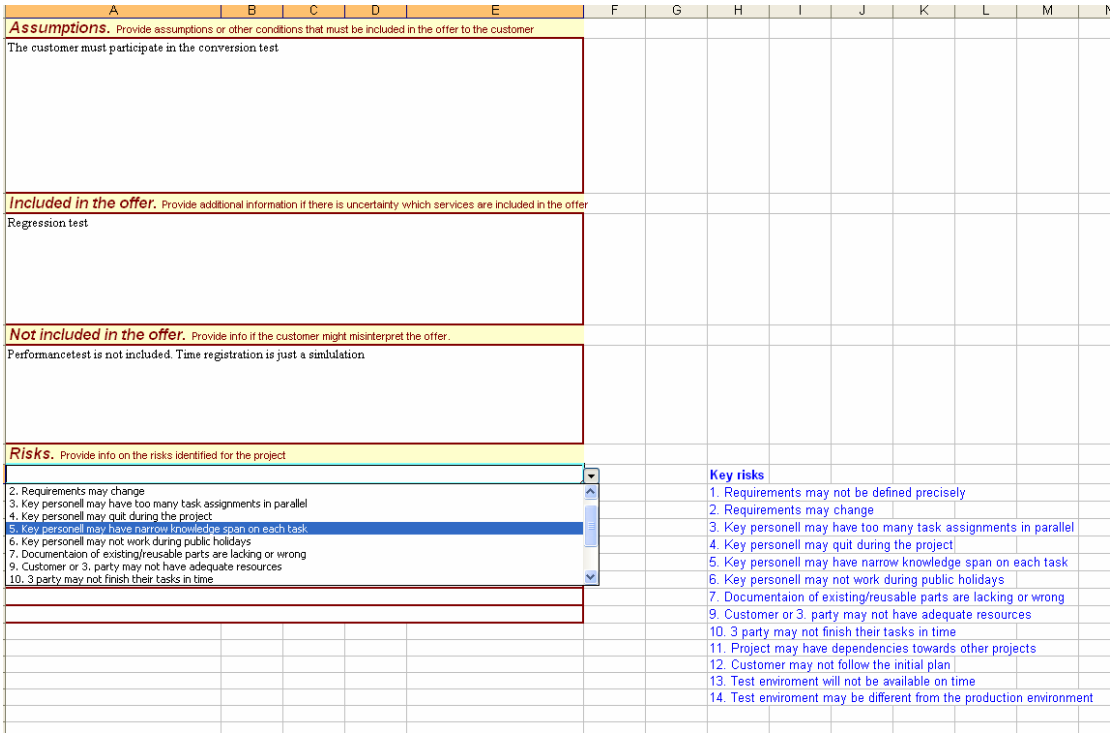
Task ID	Task	Subtask	Estimated by	Not to be performed	Share	Part of project	Min	Probable	Max	Mean	Standard dev. (S)	Variance (S*S)	Mean from KB
	Specification				322	13 %							
Specification.Analysis		*Analysis*					50	75	150	85	20	400	No data
Specification.Use case		*Use case*					50	150	200	140	30	900	231
Specification.Database pı		*Database proposal*								0	0	0	200
Specification.UML		*UML*					1	2	3	2	0	0	124
	Documentaion				71	3 %							
Documentaion.write manı		*write manual*					15	50	75	48	12	144	No data
	Template1				1063	44 %							
Template1.Create prototy		*Create prototype*					563	750	1750	912,6	237	56359	15
	Template2				708	29 %							
Template2.Create workinı		*Create working version*					240	500	750	498	102	10404	46
	Administration				235	10 %							
Administration.Meeting		*Meeting*					15	25	95	37	16	256	31
Administration.Project		*Project*					2	25	50	25,4	10	92	No data
Administration.Pilot		*Pilot*					10	25	30	23	4	16	No data
Administration.Test of ter		*Test of template merge*								0	0	0	62
Administration.Travel		*Travel*					10	40	75	41	13	169	No data
Administration.Personell		*Personell*					15	23	80	32,8	13	169	No data
Administration.Adm 1		*Adm 1*					19	24	60	30,2	8	67	No data
Administration.Adm 2		*Adm 2*					2	4	5	3,8	1	0	No data
	my task				21	1 %							
my task.sub		*sub*					10	15	25	16	3	9	No data
	Total				2420	100 %	1002	1708	3348	1 895		68 986	
	Mean									1 895			
	Standard deviation										263		
Effort when probability of the estimate is:		50 %	**1895**	hours									
Effort when probability of the estimate is:		68 %	**2157**	hours									
Effort when probability of the estimate is:		95 %	**2420**	hours						16			

Offer | UCP | Project Task | **Estimation** | Project Plan | Detailed Month Report | Month Report | Final Report | R

[Figure 16] Screenshot from effort estimation of tasks

Task 4. Risks and basis

This is a sheet where the user should specify, if needed, risks, assumptions or other parts that should be communicated regarding the offer. The offer sheet must also be updated with the appropriate risk and risk percentage. This also serves as a risk checklist with solves **I2.**



[Figure 17] Screenshot from identifying risks

Task 5. Project plan

This is a generated template for a project plan. Pressing the generate project plan button will fill inn all tasks that are estimated for the project. It will also generate an entry for each month, represented by the first date for that month. The user should enter how many hours one estimates for each tasks for each month. This makes it possible to budget tasks for the entire project and thus makes the users able to compare them on a later stage. This is necessary to be able to solve **I1**.

Projectno	P-12007	Project name	Demonstration of estimation ter										
TaskID	**Task**	**Subtask**	**Effort estimated**	**Remaining**	01.10.2007	01.11.2007	01.12.2007	01.01.2008	01.02.2008	01.03.2008	01.04.2008	01.05.2008	01.06.2008
Generate project plan				0									
	Specification			0									
Specification.Anal		*Analysis*	75	0	1	1	1	1	1	1	1	2	1
Specification.Use		*Use case*	150	0	15	20	20	20					
Specification.Data		*Database proposal*	5	0	1	1		1					
Specification.UML		*UML*	2	0				2					
				0									
	Documentaion			0									
Documentaion.writ		*write manual*	50	0	15	1	2	3	4	4	6		
				0									
	Template1			0									
Template1.Create		*Create prototype*	750	0		128	200	100	45	75	62	75	65
				0									
	Template2			0									
Template2.Create		*Create working version*	500	0	50	50	50	100	100	150			
				0									
	Administration			0									
Administration.Me		*Meeting*	25	0	5	5	5	5					
Administration.Pro		*Project*	25	0	2	3	2	3	2				
Administration.Pilo		*Pilot*	25	0	4	4	4	4	5				
Administration.Tra		*Travel*	40	0				2	30	5	3		
Administration.Per		*Personell*	23	0								23	
Administration.Adr		*Adm 1*	24	0							24		
Administration.Adr		*Adm 2*	4	0									4
				0									
	my task			0									
my task.sub		*sub*	15	-15									
				0									
				0									
				0									
				0									

[Figure 18] Screenshot from project plan

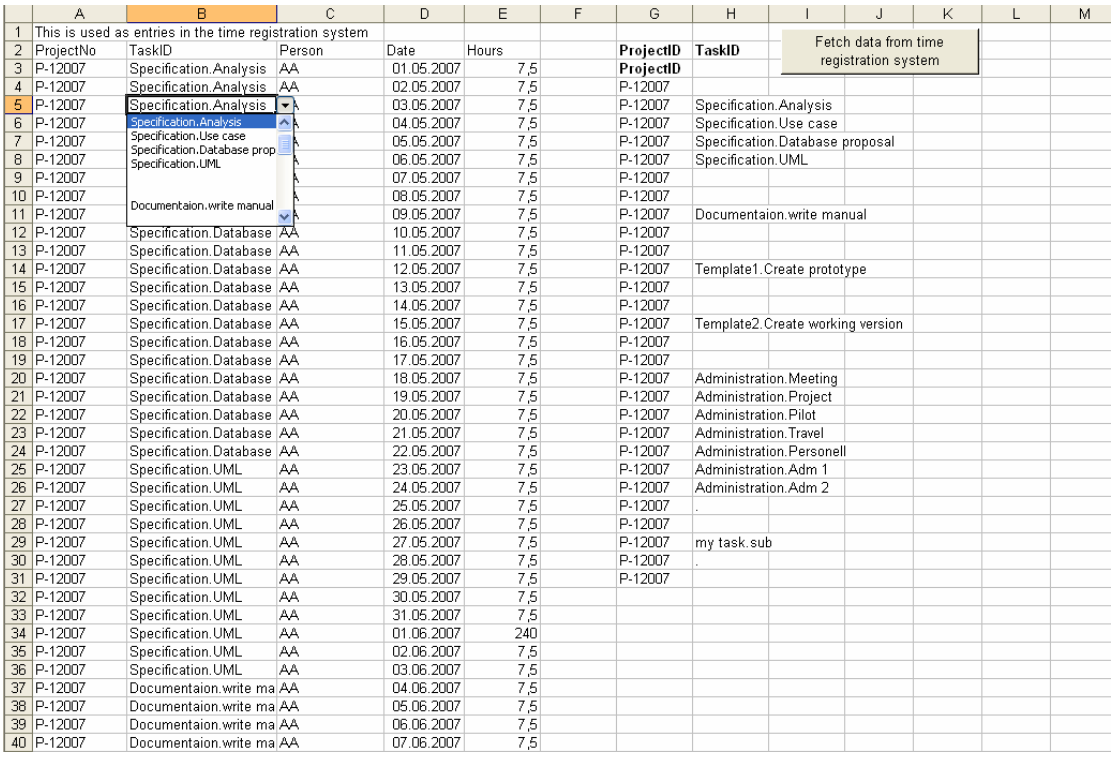
Task 7. Update time registration system

Before personnel starts to work on the project the time registration system must be updated with the new project tasks. The integration with the company's time registration system is currently not available in the template, therefore this functionality is mimicked in the time registration system sheet. When you click export tasks in the estimation sheet the data are exported to the time registration system sheet.

	A	B	C	D	E	F	G	H	I	J
1	The data below should be exported into the time registration system, this sheet is just used as a demonstration									
2	**Project no**	**TaskID**								
3	P-12007									
4	P-12007									
5	P-12007	Specification.Analysis								
6	P-12007	Specification.Use case								
7	P-12007	Specification.Database proposal								
8	P-12007	Specification.UML								
9	P-12007									
10	P-12007									
11	P-12007	Documentaion.write manual								
12	P-12007									
13	P-12007									
14	P-12007	Template1.Create prototype								
15	P-12007									
16	P-12007									
17	P-12007	Template2.Create working version								
18	P-12007									
19	P-12007									
20	P-12007	Administration.Meeting								
21	P-12007	Administration.Project								
22	P-12007	Administration.Pilot								
23	P-12007	Administration.Travel								
24	P-12007	Administration.Personell								
25	P-12007	Administration.Adm 1								
26	P-12007	Administration.Adm 2								
27	P-12007									
28	P-12007									
29	P-12007	my task.sub								

[Figure 19] Screenshot from time registration system sheet

Each day personnel that are involved in the project need to fill in hours they have spent for each subtask. Since the template is not integrated with the time registration system it is mimicked in the time registration sheet. To use this sheet you have to fetch tasks from the time registration system. Then it is possible to register project number, taskID, person, date and hours spent on the task.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	This is used as entries in the time registration system												
2	ProjectNo	TaskID	Person	Date	Hours		**ProjectID**	**TaskID**	Fetch data from time registration system				
3	P-12007	Specification.Analysis	AA	01.05.2007	7,5		**ProjectID**						
4	P-12007	Specification.Analysis	AA	02.05.2007	7,5		P-12007						
5	P-12007	Specification.Analysis	A	03.05.2007	7,5		P-12007	Specification.Analysis					
6	P-12007	Specification.Analysis	A	04.05.2007	7,5		P-12007	Specification.Use case					
7	P-12007	Specification.Use case	A	05.05.2007	7,5		P-12007	Specification.Database proposal					
8	P-12007	Specification.Database prop	A	06.05.2007	7,5		P-12007	Specification.UML					
9	P-12007	Specification.UML	A	07.05.2007	7,5		P-12007						
10	P-12007		A	08.05.2007	7,5		P-12007						
11	P-12007	Documentaion.write manual	A	09.05.2007	7,5		P-12007	Documentaion.write manual					
12	P-12007	Specification.Database	AA	10.05.2007	7,5		P-12007						
13	P-12007	Specification.Database	AA	11.05.2007	7,5		P-12007						
14	P-12007	Specification.Database	AA	12.05.2007	7,5		P-12007	Template1.Create prototype					
15	P-12007	Specification.Database	AA	13.05.2007	7,5		P-12007						
16	P-12007	Specification.Database	AA	14.05.2007	7,5		P-12007						
17	P-12007	Specification.Database	AA	15.05.2007	7,5		P-12007	Template2.Create working version					
18	P-12007	Specification.Database	AA	16.05.2007	7,5		P-12007						
19	P-12007	Specification.Database	AA	17.05.2007	7,5		P-12007						
20	P-12007	Specification.Database	AA	18.05.2007	7,5		P-12007	Administration.Meeting					
21	P-12007	Specification.Database	AA	19.05.2007	7,5		P-12007	Administration.Project					
22	P-12007	Specification.Database	AA	20.05.2007	7,5		P-12007	Administration.Pilot					
23	P-12007	Specification.Database	AA	21.05.2007	7,5		P-12007	Administration.Travel					
24	P-12007	Specification.Database	AA	22.05.2007	7,5		P-12007	Administration.Personell					
25	P-12007	Specification.UML	AA	23.05.2007	7,5		P-12007	Administration.Adm 1					
26	P-12007	Specification.UML	AA	24.05.2007	7,5		P-12007	Administration.Adm 2					
27	P-12007	Specification.UML	AA	25.05.2007	7,5		P-12007	.					
28	P-12007	Specification.UML	AA	26.05.2007	7,5		P-12007						
29	P-12007	Specification.UML	AA	27.05.2007	7,5		P-12007	my task.sub					
30	P-12007	Specification.UML	AA	28.05.2007	7,5		P-12007	.					
31	P-12007	Specification.UML	AA	29.05.2007	7,5		P-12007						
32	P-12007	Specification.UML	AA	30.05.2007	7,5								
33	P-12007	Specification.UML	AA	31.05.2007	7,5								
34	P-12007	Specification.UML	AA	01.06.2007	240								
35	P-12007	Specification.UML	AA	02.06.2007	7,5								
36	P-12007	Specification.UML	AA	03.06.2007	7,5								
37	P-12007	Documentaion.write ma	AA	04.06.2007	7,5								
38	P-12007	Documentaion.write ma	AA	05.06.2007	7,5								
39	P-12007	Documentaion.write ma	AA	06.06.2007	7,5								
40	P-12007	Documentaion.write ma	AA	07.06.2007	7,5								

[Figure 20] Screenshot from time registration sheet

Task 8. Compare actual and estimated effort.

There are currently three main sheets for comparing estimated effort and actual effort, a monthly report, a detailed monthly report and the final report. These reports solve **I1.**

The detailed report for all tasks shows progress until the entered date in the date cell. Pressing update will update the tasks and figures. This makes the project managers able to see which tasks are over or under the estimate.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Project no**	P-12007	Project name	Demonstration of estimation template				Update				
2	**Date**	01.09.2007										
3				Budget Acc	Real Acc	Remaining	Prognosis	Consumption(%)	Completeness(%)	Budget Acc (NOK)	Real Acc (NOK)	
4		*Specification*										
5	Specification.Analysis		*Analysis*	65	30	10,0	40,0	46,15	75,00	52000	24000	
6	Specification.Use case		*Use case*	75	30	75,0	105,0	40,00	28,57	60000	24000	
7	Specification.Database pr		*Database proposal*	2	105	3,0	108,0	5250,00	97,22	1600	84000	
8	Specification.UML		*UML*	0	322,5	2,0	324,5	no budget	99,38	0	258000	
9												
10		*Documentaion*										
11	Documentaion.write manu		*write manual*	15	165	35,0	200,0	1100,00	82,50	12000	132000	
12												
13		*Template1*										
14	Template1.Create prototyp		*Create prototype*	0	150	750,0	900,0	no budget	16,67	0	120000	
15												
16		*Template2*										
17	Template2.Create working		*Create working version*	0	232,5	500,0	732,5	no budget	31,74	0	186000	
18												
19		*Administration*										
20	Administration.Meeting		*Meeting*	5	30	20,0	50,0	600,00	60,00	4000	24000	
21	Administration.Project		*Project*	13	22,5	12,0	34,5	173,08	65,22	10400	18000	
22	Administration.Pilot		*Pilot*	4	7,5	21,0	28,5	187,50	26,32	3200	6000	
23	Administration.Travel		*Travel*	0	7,5	40,0	47,5	no budget	15,79	0	6000	
24	Administration.Personell		*Personell*	0	7,5	23,0	30,5	no budget	24,59	0	6000	
25	Administration.Adm 1		*Adm 1*	0	7,5	24,0	31,5	no budget	23,81	0	6000	
26	Administration.Adm 2		*Adm 2*	0	37,5	4,0	41,5	no budget	90,36	0	30000	
27												
28		*my task*										
29	my task.sub		*sub*	-15	0	0,0	0,0	no budget	no budget	-12000	0	
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												

[Figure 21] Screenshot from detailed month report

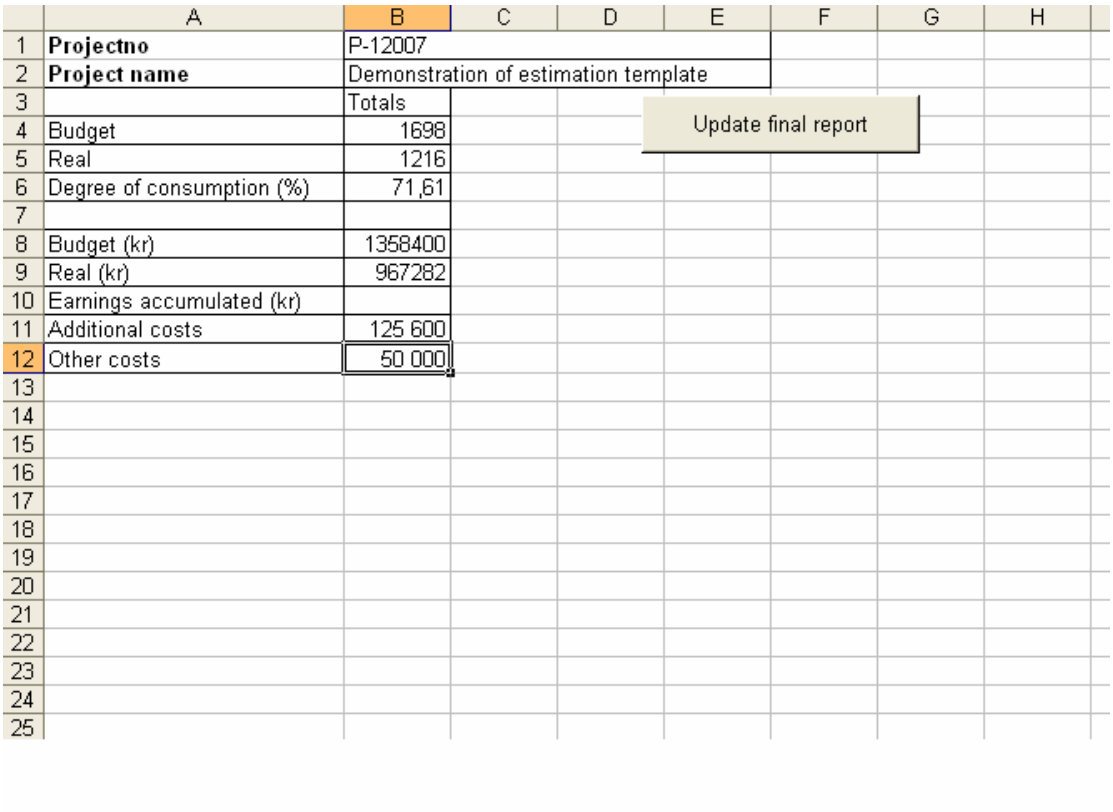
Pressing the update month report will updated the template with month reports for the entire project. Data is filled in based on the information in some fake time registration entries in the time registration sheet.

Projectno	P-12007	Update month report												
Project name	Demonstration of estimation template													
	01.05.2007	01.06.2007	01.07.2007	01.08.2007	01.09.2007	01.10.2007	01.11.2007	01.12.2007	01.01.2008	01.02.2008	01.03.2008	01.04.2008	01.0	
Budget	19	18	68	28	46	93	213	284	241	187	235	96		
Budget accumulated	19	37	105	133	179	272	485	769	1010	1197	1432	1528		
Budget in percent	1	2	6	8	11	16	29	45	59	70	84	90		
Real	233	458	233	233	0	0	0	0	0	0	0	0		
Real accumulated	233	690	923	1155	1155	1155	1155	1155	1155	1155	1155	1155		
Remaining (estimated)	2188	1730	1498	1265	1265	1265	1265	1265	1265	1265	1265	1265		
Prognosis (Real accumulated + remaining)	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420		
Degree of consumption (%)	1224	2542	342	830	0	0	0	0	0	0	0	0		
Degree of completeness (%)	10	29	38	48	48	48	48	48	48	48	48	48		
Budget (kr)	15200	14400	54400	22400	36800	74400	170400	227200	192800	149600	188000	76800		
Budget accumulated (kr)	15200	29600	84000	106400	143200	217600	388000	615200	808000	957600	1145600	1222400	1	
Real (kr)	186000	552000	738000	924000	924000	924000	924000	924000	924000	924000	924000	924000		
Real accumulated (kr)	1750082	1384082	1198082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1	
Earnings accumulated (kr)														
Additional costs	125600													
Other costs	50000													
Price per hour	800													

[Figure 22] Screenshot from month report

Task 9. Generate final report data.

When a project is finished data for the final report is automatically generated based on the final monthly report when the user presses the update final report button. It is also important that new risk items are updated for the template, and that relevant information is inputted in the knowledge database.



	A	B	C	D	E	F	G	H
1	**Projectno**	P-12007						
2	**Project name**	Demonstration of estimation template						
3		Totals						
4	Budget	1698						
5	Real	1216						
6	Degree of consumption (%)	71,61						
7								
8	Budget (kr)	1358400						
9	Real (kr)	967282						
10	Earnings accumulated (kr)							
11	Additional costs	125 600						
12	Other costs	50 000						
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

[Figure 23] Screenshot from final report

Time registration and time registration system

Since the time registration system today is on a somewhat complicated mainframe system we have no direct access from the template. The company are currently changing this system and some integration should be available in the future. Then the template should have direct access to the time registration system to fetch necessary data. These sheets are just fake sheets that simulate integration with the time registration system.

Issues not solved.

For **I3** we did not have enough background information as to provide a set of standard tasks for all projects. These tasks could vary from the different project types and should be seen into consideration with **I4**.

For **I4** we did not categorize the different projects in this thesis. We had however several reports from different types of projects and this should be further analysed as a part of future work.

For **I5** we simply did not see any relation between the different types of activities. More investigation is needed on this point and remains as future work.

4.3.2 Initial evaluation of the estimation template

By implementing a common template as suggested, the company could get several benefits. The common process with tools and templates facilitates reporting and measurement (for management), and also is a basis for training and contextualizing experience.

The main reasons to use a common template are:

- Serve as a checklist and make sure all information on effort estimation is included.
- Make it easier to build an effort estimation database.
- Make it easier for departments to assess estimations done by another department.

Our proposed template makes it possible to get the needed figures automatically, both in linking the time registration system with the project reports and calculating the report data.

4.4 Results from step 4

This step was not included in this thesis and remains as future work. At present the proposals have not been implemented in the effort estimation process for projects and no data is available.

5. Discussion

In this section, we first summarize the current practice, the lessons learned, and experience of the effort estimation study in the company. Based on this information, we then propose several possible improvements.

5.1 Comparison with related work

Today the company have some difficulties related to the estimation process. These difficulties are related to best practice and how the estimation process is carried out, mainly on how they use the estimation tool. Our proposals will help the company improve their state of practice.

Our proposed template does not include reusability in the estimation method. Mohagheghi et al. have adapted the use case points method to take into account reusability [Moha05]. Similar types of projects with reusability and iterative development are common in software projects today. It might be that this method proves to be more suitable for the company as en early estimation method.

The same paper from Mohagheghi et al. also states that accuracy with 20% are quite good results for early estimation. Our findings using early estimation with UCP in this thesis had the worst case on 30% accuracy. This indicates that you should always count alternative flows when determining the complexity. When counting the alternative flows the worst case was 19%. This is a quite promising result for this type of effort estimation method. But one should have in mind that we only had two reports available which might not represent a valid representation of projects.

It is also possible to discuss if another method of effort estimation might be more accurate. As noted earlier Jørgensen [Jørg04b] found no evidence that estimation models are superior to expert estimation. This paper states this for general software projects, but there might be special projects that have the characteristics that would benefit from a certain estimation model. Most models can be calibrated to suit ones needs and thus might perform adequately. Then the issue for improving the estimation might be in the form of constantly evaluating and reviewing the estimation process. Companies use different effort estimation models and techniques. Many companies seem to use a mix of both expert effort estimation and formal models. The process of improving the estimation is a living process that needs to be constantly maintained.

Our template does not have any specific suggestions on how to create a knowledge database or what to input in the database. We did not find any relation between the different activity types in our study. When creating a new knowledge database one should decide which parameters are important. For the beginning one should rather register, and reduce the number when one is sure which parameters are important. The main reason with a knowledge database is to make it easier to learn from previous experience and don't do the same mistakes again. It is also vital that this knowledge base is easy to use both to fill in data and retrieve them. Such a knowledge database can easily become a black hole with knowledge that no one uses.

5.2 Methodology issues

To conduct a similar study one has to know something about the starting point. There are two major resources that are investigated in this study, project managers and project reports.

Project managers can provide information on the processes and how they conduct the effort estimation and project process. The best way of getting this information is to conduct a structured interview. This interview should contain questions on which estimation methods they use, their accuracy, and how they are using the best practices proposed by Jørgensen [Jørg04b]. These practices may be valuable for both expert effort estimation and effort estimation using formal models.

Project reports may provide information on the things that went well, problems that occurred, and figures for estimated and actual effort. If this information is not available one should create a standard set of project reports that includes the necessary information, and then do the survey when they are available. By investigating the problems that occurred, one can get a overview of which risks that may occur in the projects, and if they manage to learn from them. Issues that went well might provide input to a knowledge base on e.g. risk handling or other specific issues. The figures for actual and estimated effort can give a good overview of the accuracy.

One of the important steps to assessing the state of practice in this thesis was to compare the current estimation practice with 12 best practices proposed by Jørgensen. These proposals of 12 best practices are quite new, but have shown to point out and increased the awareness of both positive and negative issues in the estimation process.

Creating good interview questions to project managers and compare them against the best practices have proven to be very valuable. A lot of information was also found in the project reports. To get a state of practice on effort estimation in a company these two methods help to pinpoint which issues that works good and which doesn't.

5.3 Possible validity issues

Wohlin et al. [Wohl00] define four categories of validity threats:

- **Conclusion validity** (for statistical analysis) - "right analysis": this validity is concerned with the relationship between the treatment (the independent variable in a study) and outcome (the dependent variable). We want to make sure that there is a statistical relationship of significance. Threats are related to choice of statistical tests, sample sizes, reliability of measures etc.

- **Internal validity** (for explanatory and causal studies, not for exploratory or descriptive studies) - "right data": we must make sure that there is a causal relationship between treatment and outcome and that is not a result of factors that are not measured. Threats are related to history, maturation, selection of subjects, unpredicted events and interactions, ambiguity about the direction of causal influence etc.
- **Construct validity** "right metrics": we must ensure that the treatment reflects the cause and the outcome reflects the effect. Threats are mono-operation bias (a single case may not reflect the constructs), mono-method bias (a single type of measure may be misleading), hypothesis guessing etc.
- **External validity** "right context": this validity is concerned with generalization of results outside the scope of a study. Three types of interactions with the treatment may happen: people (the subjects are not representative for the population), place (the setting is not representative), and time (the experiment is conducted in a special time for example right after a big software crash).

5.3.1 Possible validity issues of step 1.

The study is a state-of-the-practice study, the possible limitations of the study are:

Construct validity:

- Most data from the interviews represent subjective options from interviewees. Since people tend to present positive aspects and avoid negative aspects in interviews, some reasons of wrong effort estimation may be skipped by the interviewees. In addition, most projects were finished projects. The interviewees may have forgotten certain details of the project.

External validity:

- The investigated projects may not reflect the representative projects in the company, because we can only select project with available information and interviewees with willingness to participate.
- The investigated reports in the study where quite few. It could be that the reports did not represent the average. When doing the study with use case points there were only two reports available, this is too few in order to make a finite conclusion.
- The investigated reports might need to be categorized further. There can be differences in a project that is in-house, compared to an external customer or other third parties. This might change the risks involved and other parameters. One should consider categorizing projects further and doing a comparison again.

5.3.2 Possible validity issues of step 2.

Construct validity:

- There did not seem to be guidelines that described how a use case should be created. Some of the reports contained all effort related to a project, while some only contained the development part. This indicates that some projects might not have all the effort included in the reports.

External validity:

- The investigated projects may not reflect the representative projects in the company, because we can only select project with available information and interviewees with willingness to participate.
- The investigated reports in the study where quite few. It could be that the reports did not represent the average. When doing the study with use case points there were only two reports available, this is too few in order to make a finite conclusion.

5.3.3 Possible validity issues of step 3.

External validity:

- The template and the process of finishing it, was only discussed with the senior manager. The senior manager might not have insight in all of the issues in the current project process and may not represent the general opinion.

6. Conclusions and future work

This thesis has studied a state of practice in a large company. Many of their projects span to several thousand person hours in effort. To determine problems related to processes in the company one have to do a systematically investigation. It will also take time to change the processes in such a large organization. In order to implement the proposals, one need to do that in cooperation with the company's internal project management learning team or leave that to the company entirely.

6.1 Conclusions

This thesis presents the state-of-the-practices of effort estimation in different departments of the company. The data from five structural interviews with senior project managers from the company are collected. The experience and lessons learned of estimating effort are summarized. Suggestions for future improvement are proposed.

The first step was to determine the state of practice by conducting interviews and comparing the answers against 12 best practices. It also gave information on which estimation method and tools they used. To get more insight in the effort estimation process we also look at project reports to see how the information from the effort estimate was handled.

The main conclusion on the first step is that the effort estimation process is good. However, the process of creating and using the information from the effort estimation has some severe lacks which could be solved using a common effort estimation template.

The second step concentrated on a study of use case points method to see if that could be used as an early estimation. Since the first step of the research revealed that they did not have an early estimation we wanted to merge this into the common template.

The results from the use case points study showed quite promising results. There are some uncertainties on the guidelines for use cases, but all who uses the estimation template should be able to create early estimates based on the use case points method.

The third step was to implement the proposals. This was done by creating a common estimation template. As the previous steps pointed out implementing such a template may be able to solve some of the issues the company has experienced in their effort estimation.

The finished template was created in Excel with functions to provide a more powerful way of automatically generating data for reports. The estimation template will not add extra work load for the project managers, and in fact may reduce the work load. The project manager may now see tasks with deviations at an earlier stage and take actions to minimize possible problems. Estimators will also have a easier way to share their knowledge throughout the organization. Sharing knowledge and handle deviations at an earlier stage may greatly improve the knowledge of the estimators.

Measuring the results of our proposals and improvements can not be done before they are implemented and some projects following these guidelines are completed.

6.2 Future work

The further work of the effort estimation improvement in the company is to discuss and decide the improvement proposals with their project managers. The first step is to organize a pre-seminar with person of the project office. The purpose is to get their comments and feedbacks on the content of this report. The second step is to revise the report to make final proposals based on the results of the pre-seminar. The next step is to organize a seminar with project managers in the company to discuss the feasibility of the final proposals. After that, the final proposals will be implemented, and then evaluated.

On the template and effort estimation part one should do more investigation on the reports and try to get an ever broader range of reports. This selection of reports should also be categorized if possible to see any connections related to the type of project. The template should also have a default setup where tasks that are common for all projects should be present.

Functions point or another effort estimation model might be included in the template. This could help to determine if there are cases where another effort estimation model might be more beneficial than expert estimates.

A revision of the knowledge base on effort estimation and actual effort to work with the template should be done. The knowledge base can support the effort estimation process by providing additional information on previous projects.

This thesis focuses on the total estimation effort or a main task effort. If the company manages to implement a better template and knowledge base, one might be better able to investigate specific subtasks and not just a task or total effort.

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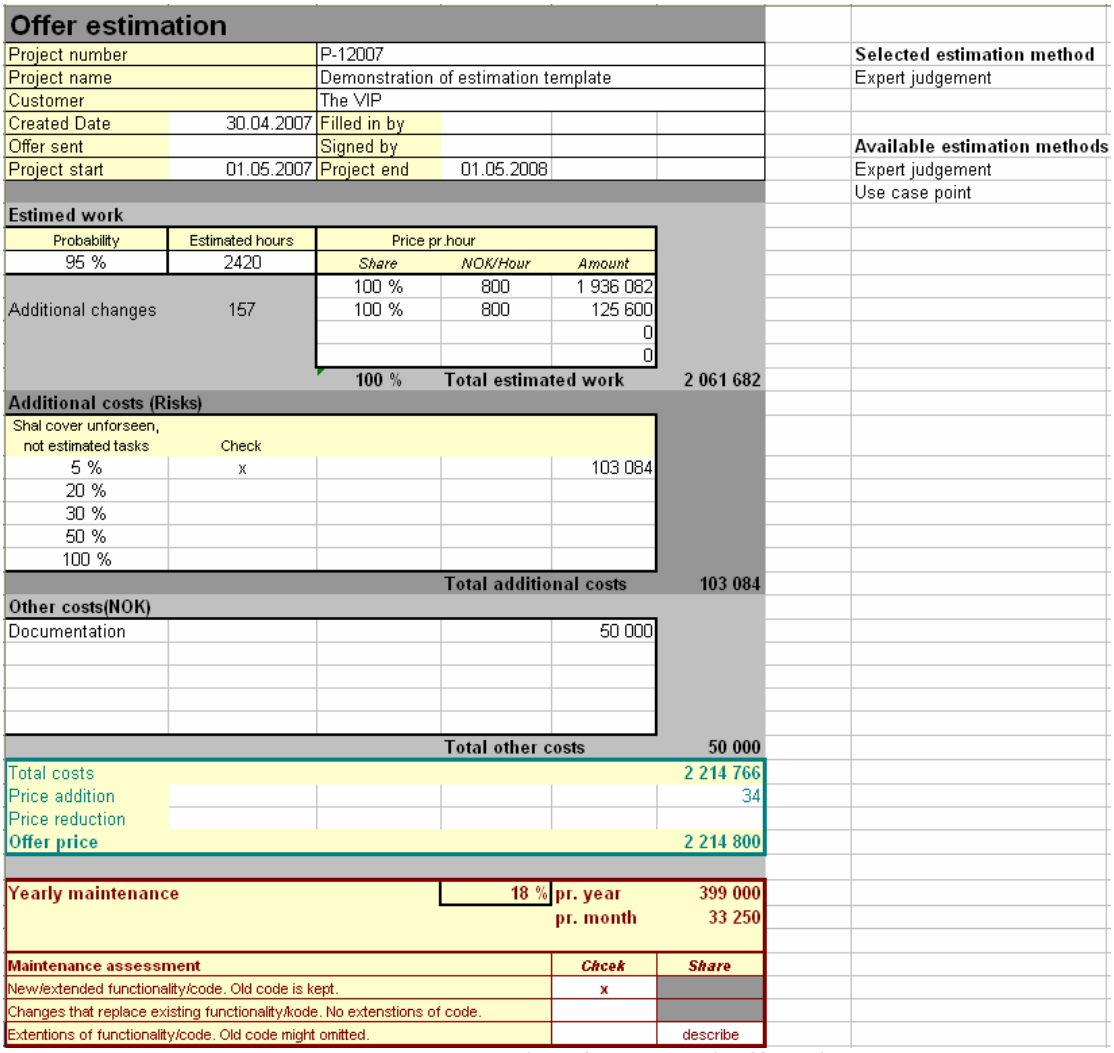
Appendix A. Template macro code

```
' Note .Select selects the actual cell.
' ActiveCell.FormulaR1C1 = enters a new formula to the selected cell
' RC is the current cell R[-1]C is the cell on the row above, RC[-1] is the cell on
the column to the left
' Offset moves to the cell the number of rows and columns specified
' More information available in the VBA docs:
' http://www.microsoft.com/downloads/details.aspx?familyid=0447c5a0-5e58-4e69-b90e-
c42ec7dbf887&displaylang=en
```

Task 1. Get the initial project information

This part contains no code, just a logic test where to get the estimated effort.



Offer estimation

Project number		P-12007				
Project name		Demonstration of estimation template				
Customer		The VIP				
Created Date	30.04.2007	Filled in by				
Offer sent		Signed by				
Project start	01.05.2007	Project end	01.05.2008			

Selected estimation method
Expert judgement

Available estimation methods
Expert judgement
Use case point

Estimed work

Probability	Estimated hours	Price pr.hour			
95 %	2420	*Share*	*NOK/Hour*	*Amount*	
		100 %	800	1 936 082	
Additional changes	157	100 %	800	125 600	
				0	
				0	
		100 %	**Total estimated work**		2 061 682

Additional costs (Risks)

Shal cover unforseen, not estimated tasks	Check				
5 %	x			103 084	
20 %					
30 %					
50 %					
100 %					
			Total additional costs		103 084

Other costs(NOK)

Documentation				50 000	
			Total other costs		50 000

Total costs					2 214 766
Price addition					34
Price reduction					
Offer price					2 214 800

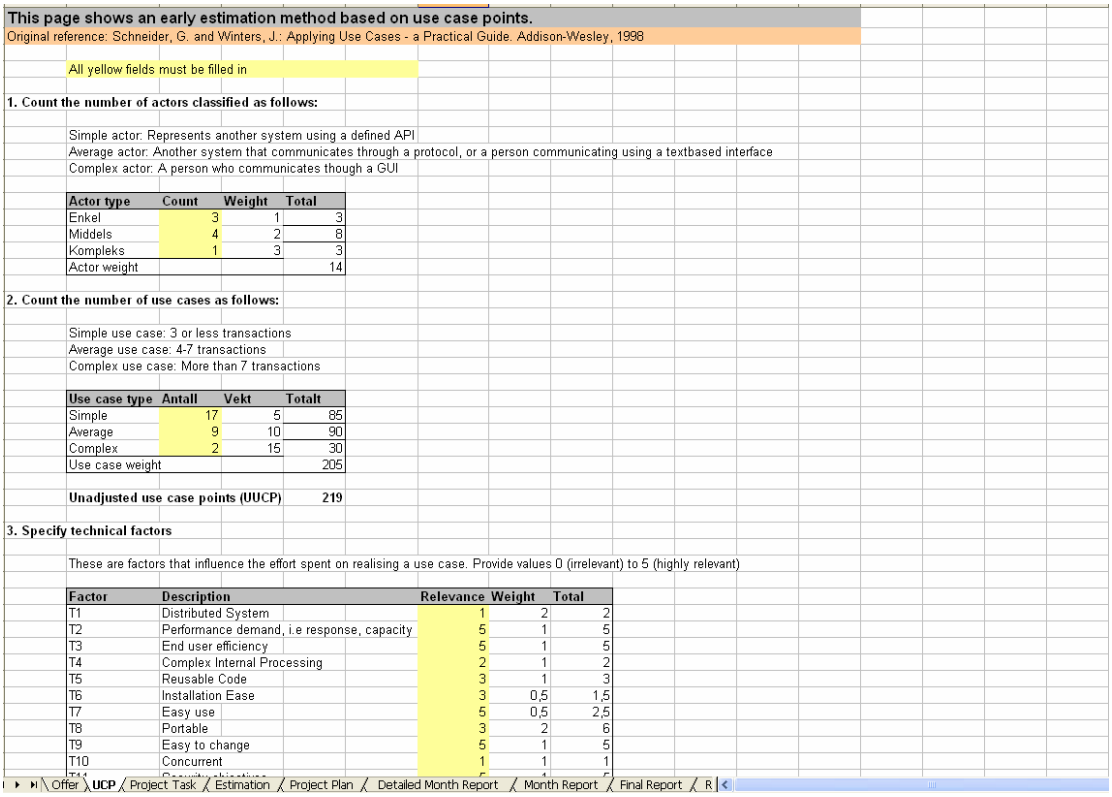
Yearly maintenance	18 %	**pr. year**	399 000
		pr. month	33 250

Maintenance assessment	*Check*	*Share*
New/extended functionality/code. Old code is kept.	x	
Changes that replace existing functionality/kode. No extenstions of code.		
Extentions of functionality/code. Old code might omitted.		describe

[Figure 24A] Screenshot from total offer sheet

Task 2. Early estimation : UCP

This sheet contains no code just logic to calculate UCP effort estimation.



This page shows an early estimation method based on use case points.
Original reference: Schneider, G. and Winters, J.: Applying Use Cases - a Practical Guide. Addison-Wesley, 1998

All yellow fields must be filled in

1. Count the number of actors classified as follows:

Simple actor: Represents another system using a defined API
Average actor: Another system that communicates through a protocol, or a person communicating using a textbased interface
Complex actor: A person who communicates though a GUI

Actor type	Count	Weight	Total
Enkel	3	1	3
Middels	4	2	8
Kompleks	1	3	3
Actor weight			14

2. Count the number of use cases as follows:

Simple use case: 3 or less transactions
Average use case: 4-7 transactions
Complex use case: More than 7 transactions

Use case type	Antall	Vekt	Totalt
Simple	17	5	85
Average	9	10	90
Complex	2	15	30
Use case weight			205

Unadjusted use case points (UUCP) 219

3. Specify technical factors

These are factors that influence the effort spent on realising a use case. Provide values 0 (irrelevant) to 5 (highly relevant)

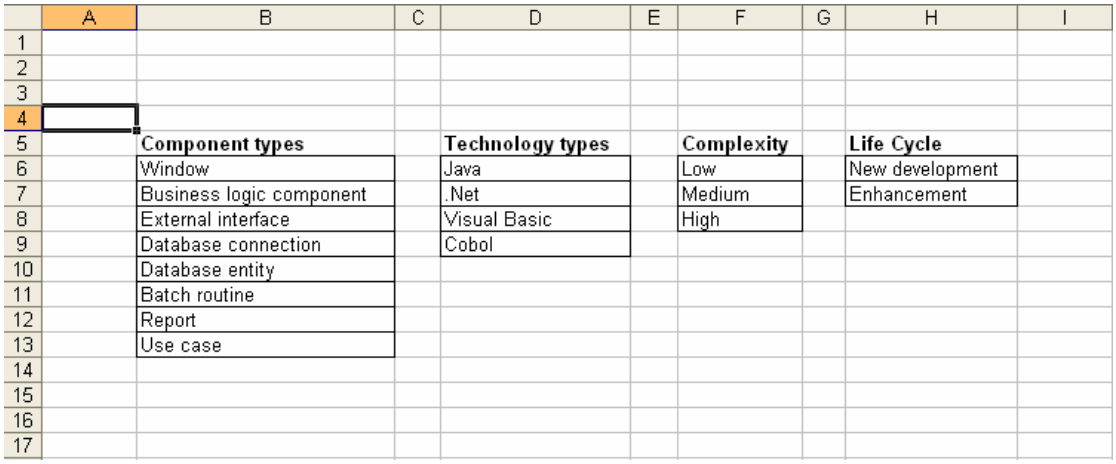
Factor	Description	Relevance	Weight	Total
T1	Distributed System	1	2	2
T2	Performance demand, i.e response, capacity	5	1	5
T3	End user efficiency	5	1	5
T4	Complex Internal Processing	2	1	2
T5	Reusable Code	3	1	3
T6	Installation Ease	3	0,5	1,5
T7	Easy use	5	0,5	2,5
T8	Portable	3	2	6
T9	Easy to change	5	1	5
T10	Concurrent	1	1	1

Offer | UCP | Project Task | Estimation | Project Plan | Detailed Month Report | Month Report | Final Report | R

[Figure 25A] Screenshot from UCP effort estimation

Task 3a1. Data Types

This sheet contains no code. This is used as a data source for cost factors.



	Component types	Technology types	Complexity	Life Cycle
6	Window	Java	Low	New development
7	Business logic component	.Net	Medium	Enhancement
8	External interface	Visual Basic	High	
9	Database connection	Cobol		
10	Database entity			
11	Batch routine			
12	Report			
13	Use case			

[Figure 26A] Screenshot from data types sheet

Task 3a2. Cost factors

This sheet contains no code. Just used as a data source for project tasks.

					Analysis	Analysis	Analysis	Analysis	Analysis	Design	Design	Design	Design	Design	Code+UT	Code+UT	Code+UT
Key	Life cycle	Component	Technology	Complexity	L	M	H	Mean	Var	L	M	H	Mean	Var	L	M	H
New developmentUse caseJava	New development	Use case	Java	Low	8	15	24	15,4	10,2	10	15	25	16	9	48	66	9
New developmentUse caseJava	New development	Use case	Java	Medium	20	40	60	40	64	20	35	50	35	36	94	127	18
New developmentUse caseJava	New development	Use case	Java	High	40	60	90	62	100	35	55	90	58	121	156	202	32
								0	0				0	0			
New developmentWindowJavaL	New development	Window	Java	Low				0	0				0	0			
New developmentWindowJavaM	New development	Window	Java	Medium				0	0				0	0			
New developmentWindowJavaH	New development	Window	Java	High				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	Low				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	Medium				0	0				0	0			
New developmentBusiness log	New development	Business logic component	Java	High				0	0				0	0			
New developmentExternal inter	New development	External interface	Java	Low	8	15	24	15,4	10,2	10	15	25	16	9	48	66	9
New developmentExternal inter	New development	External interface	Java	Medium	20	40	60	40	64	20	35	50	35	36	94	127	18
New developmentExternal inter	New development	External interface	Java	High	40	60	90	62	100	35	55	90	58	121	156	202	32
New developmentDatabase cor	New development	Database connection	Java	Low				0	0				0	0			
New developmentDatabase cor	New development	Database connection	Java	Medium				0	0				0	0			
New developmentDatabase cor	New development	Database connection	Java	High				0	0				0	0			
New developmentReportJavaLo	New development	Report	Java	Low				0	0				0	0			
New developmentReportJavaMe	New development	Report	Java	Medium				0	0				0	0			
New developmentReportJavaHi	New development	Report	Java	High				0	0				0	0			

[Figure 27A] Screenshot from cost factors

Task 3a3. Project Task

This sheet contains no code. Just used as a data source to the estimation sheet.

	A	B	C	D	E	F	G	H	I
	TaskID	Life cycle	Component	Technology	Complexity	No.	Mean	Var	
	Specification.Use case	New development	Use case	Java	Low	15	231	154	
	Specification.Database proposal	New development	Use case	Java	Medium	5	200	320	
	Specification.UML	New development	Use case	Java	High	2	124	200	
	Template1.Create prototype	New development	Use case	Java	Low	1	15	10	
	Administration.Meeting	New development	Use case	Java	Low	2	31	20	
	Template2.Create working version	New development	Use case	Java	Low	3	46	31	
	Administration.Test of template merge	w development	Use case	Java	Low	4	62	41	
	Administration.Test of template merge								
	Administration.Travel								
	Administration.Personell								
	Administration.Adm 1								
	Administration.Adm 2								
	my task.sub								

rmulas to the newly inserted row

[Figure 28A] Screenshot from project tasks based on cost factors

Task 3b. Effort estimation

Code to add a task:

```
Sub AddTask() ' Adds a new task in the estimation sheed
'
'
'Select the row to add a task
    Rows("4:4").Select
    Selection.Insert Shift:=xlDown
    Selection.Insert Shift:=xlDown
    Range("B4").Select
    Selection.Font.Italic = True
    'Create a default task name
    ActiveCell.FormulaR1C1 = "enter task name"
    Range("G4").Select
    'Create formulae for the task
    ActiveCell.FormulaR1C1 = "=SUM(RC[2]:R[1]C[2])/total_probable"
    Range("F4").Select
    ActiveCell.FormulaR1C1 = "=RC[1]*hours95"
    Range("B4:Q4").Select
    'This just adds a background color
    With Selection.Interior
        .ColorIndex = 15
        .Pattern = xlSolid
    End With
    Range("F5").Select
End Sub
```

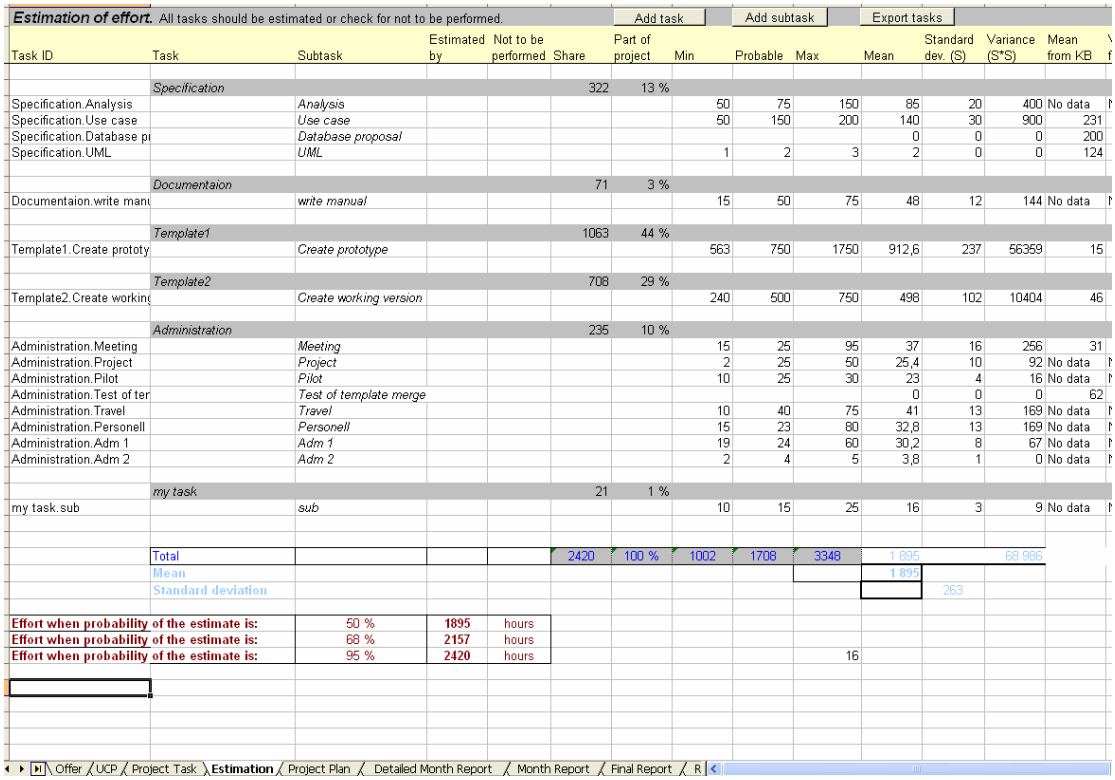
Code to add a subtask:

```
Sub AddSubTask() ' Adds a new subtask under a task in the estimation sheet

    ActiveCell.EntireRow.Select
    Dim row As String
    row = ActiveCell.row
    Selection.Insert Shift:=xlDown
    'create task name for the subtask and hide it with white color
    Range("B" & row).Select
    ActiveCell.FormulaR1C1 = "=R[-1]C"
    Range("B" & row).Select
    Selection.Font.ColorIndex = 2
    Range("C" & row).Select
    'create a default subtask name
    ActiveCell.FormulaR1C1 = "enter subtask name"
    With ActiveCell.Characters(start:=1, Length:=18).Font
        .Name = "Arial"
        .FontStyle = "Italic"
        .Size = 10
        .Strikethrough = False
```

```
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlUnderlineStyleNone
        .ColorIndex = xlAutomatic
    End With
    Range("A" & row).Select
    'create formuale to create taskID
    ActiveCell.FormulaR1C1 = "=CONCATENATE(Estimation!RC2,""."",Estimation!RC3)"
    'insert calculation formuales
    Range("K" & row).Select
    ActiveCell.FormulaR1C1 = "=(RC[-3]+(3*RC[-2])+RC[-1])/5"
    Range("L" & row).Select
    ActiveCell.FormulaR1C1 = "=(RC[-2]-RC[-4])/5"
    Range("M" & row).Select
    ActiveCell.FormulaR1C1 = "=RC[-1]*RC[-1]"
    Range("N" & row).Select
    'create formuales that fetches information from project tasks if they are defined
    ActiveCell.FormulaR1C1 = "=IF(ISERROR(VLOOKUP(RC[-13],project_tasks,7,FALSE)),""No
data"",VLOOKUP(RC[-13],project_tasks,7,FALSE))"
    Range("O" & row).Select
    ActiveCell.FormulaR1C1 = "=IF(ISERROR(VLOOKUP(RC[-14],project_tasks,8,FALSE)),""No
data"",VLOOKUP(RC[-14],project_tasks,8,FALSE))"
    Range("B" & row & ":Q" & row).Select
    With Selection.Interior
        .ColorIndex = xlNone
    End With
    Range("C" & row).Select
End Sub
```

Code to export tasks:

```
Sub ExportToTimeSystem()' Fake export, now only exports to the time registration sheet
    'This function should be replaced with a function that actually expert the data to
the time system
    Range("start:end").Select
    Selection.Copy
    Sheets("Time registration system").Select
    Range("B3").Select
    ActiveSheet.Paste
    Range("D16").Select
    Sheets("Estimation").Select
    Range("A9").Select

End Sub
```



Estimation of effort. All tasks should be estimated or check for not to be performed. Add task | Add subtask | Export tasks

Task ID	Task	Subtask	Estimated by	Not to be performed	Share	Part of project	Min	Probable	Max	Mean	Standard dev. (S)	Variance (S*S)	Mean from KB
	Specification				322	13 %							
Specification.Analysis		*Analysis*					50	75	150	85	20	400	No data
Specification.Use case		*Use case*					50	150	200	140	30	900	231
Specification.Database pr		*Database proposal*								0	0	0	200
Specification.UML		*UML*					1	2	3	2	0	0	124
	Documentaion				71	3 %							
Documentaion.write manu		*write manual*					15	50	75	48	12	144	No data
	Template1				1063	44 %							
Template1.Create prototy		*Create prototype*					563	750	1750	912,6	237	56359	15
	Template2				708	29 %							
Template2.Create working		*Create working version*					240	500	750	498	102	10404	46
	Administration				235	10 %							
Administration.Meeting		*Meeting*					15	25	95	37	16	256	31
Administration.Project		*Project*					2	25	50	25,4	10	92	No data
Administration.Pilot		*Pilot*					10	25	30	23	4	16	No data
Administration.Test of ter		*Test of template merge*								0	0	0	62
Administration.Travel		*Travel*					10	40	75	41	13	169	No data
Administration.Personell		*Personell*					15	23	80	32,8	13	169	No data
Administration.Adm 1		*Adm 1*					19	24	60	30,2	8	67	No data
Administration.Adm 2		*Adm 2*					2	4	5	3,8	1	0	No data
	my task				21	1 %							
my task.sub		*sub*					10	15	25	16	3	9	No data
	Total				2420	100 %	1002	1708	3348	1 895		68 986	
	Mean									1 895			
	Standard deviation										263		

Effort when probability of the estimate is:	50 %	**1895**	hours
Effort when probability of the estimate is:	68 %	**2157**	hours
Effort when probability of the estimate is:	95 %	**2420**	hours

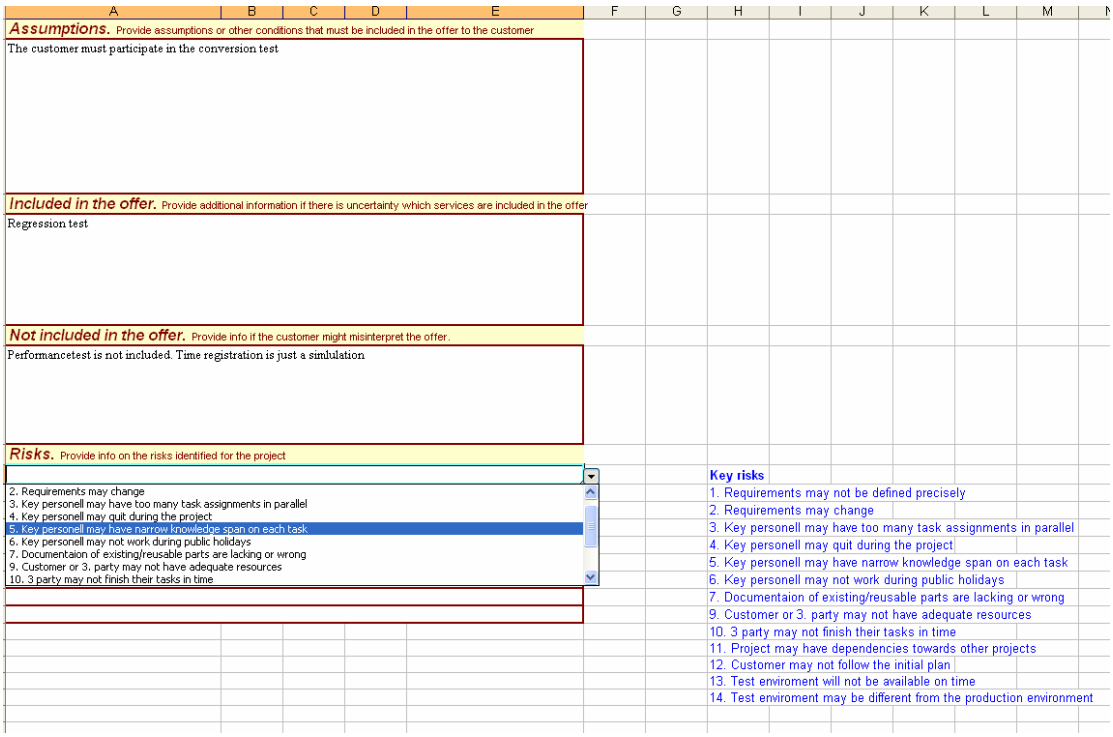
16

Offer | UCP | Project Task | **Estimation** | Project Plan | Detailed Month Report | Month Report | Final Report | R

[Figure 29A] Screenshot from effort estimation of tasks

Task 4. Risks and basis

This sheet contains no code. Just used as a checklist for risks.



Assumptions. Provide assumptions or other conditions that must be included in the offer to the customer

The customer must participate in the conversion test

Included in the offer. Provide additional information if there is uncertainty which services are included in the offer

Regression test

Not included in the offer. Provide info if the customer might misinterpret the offer.

Performancetest is not included. Time registration is just a simulation

Risks. Provide info on the risks identified for the project

2. Requirements may change
3. Key personell may have too many task assignments in parallel
4. Key personell may quit during the project
5. Key personell may have narrow knowledge span on each task
6. Key personell may not work during public holidays
7. Documentaion of existing/reusable parts are lacking or wrong
9. Customer or 3. party may not have adequate resources
10. 3 party may not finish their tasks in time

Key risks

1. Requirements may not be defined precisely
2. Requirements may change
3. Key personell may have too many task assignments in parallel
4. Key personell may quit during the project
5. Key personell may have narrow knowledge span on each task
6. Key personell may not work during public holidays
7. Documentaion of existing/reusable parts are lacking or wrong
9. Customer or 3. party may not have adequate resources
10. 3 party may not finish their tasks in time
11. Project may have dependencies towards other projects
12. Customer may not follow the initial plan
13. Test enviroment will not be available on time
14. Test enviroment may be different from the production environment

[Figure 30A] Screenshot from identifying risks

Task 5. Project plan

This sheet is used as a data source for budget data. The following code generates the project plan:

```
Sub CreateProjectPlan()' Creates a default project plan
    Sheets("Offer").Select
    Dim startDate As Date
    Dim endDate As Date
    Dim m As Integer
    Dim y As Integer
    startDate = Range("B7").Value
    endDate = Range("D7").Value
    m = month(startDate)
    y = year(startDate)
    Sheets("Project Plan").Select
    Range("F2").Select
    'enter the dates in the cells
    While (startDate <= endDate)
        startDate = DateSerial(y, m, 1)
        ActiveCell.FormulaR1C1 = startDate
        Selection.Columns.AutoFit
        ActiveCell.Offset(0, 1).Select
        m = m + 1
    Wend

    'Copy the tasks from the estimation sheet into the project plan.
    Sheets("Estimation").Select
    Range("start:end").Select
    Selection.Copy
    Sheets("Project Plan").Select
    Range("A3").Select
    ActiveSheet.Paste
    Sheets("Estimation").Select
    ActiveWindow.SmallScroll Down:=0
    Range("startTask:endTask").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Project Plan").Select
    Range("B3").Select
    ActiveSheet.Paste
    Sheets("Estimation").Select
    Range("startSubtask:endSubtask").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Project Plan").Select
    Range("C3").Select
    ActiveSheet.Paste
    Sheets("Estimation").Select
    Range("startProbable:endProbable").Select
```

```
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Project Plan").Select
    Range("D3").Select
    ActiveSheet.Paste
    Range("E3").Select
    Sheets("Offer").Select
    Range("C2").Select
    Selection.Copy
    Sheets("Project Plan").Select
    Range("B1").Select
    ActiveSheet.Paste
    Selection.UnMerge
    Sheets("Offer").Select
    Range("C3").Select
    Selection.Copy
    Sheets("Project Plan").Select
    Range("D1").Select
    ActiveSheet.Paste
    Selection.UnMerge
    Range("C1").Select
    ActiveCell.FormulaR1C1 = "Project name"
End Sub
```

Projectno	P-12007	Project name	Demonstration of estimation ter										
TaskID	**Task**	**Subtask**	**Effort estimated**	**Remaining**	01.10.2007	01.11.2007	01.12.2007	01.01.2008	01.02.2008	01.03.2008	01.04.2008	01.05.2008	01.06.2008
Generate project plan				0									
	Specification			0									
Specification.Anal		*Analysis*	75	0	1	1	1	1	1	1	1	2	1
Specification.Use		*Use case*	150	0	15	20	20	20					
Specification.Data		*Database proposal*	5	0	1	1		1					
Specification.UML		*UML*	2	0				2					
				0									
	Documentaion			0									
Documentaion.writ		*write manual*	50	0	15	1	2	3	4	4	6		
				0									
	Template1			0									
Template1.Create		*Create prototype*	750	0		128	200	100	45	75	62	75	65
				0									
	Template2			0									
Template2.Create		*Create working version*	500	0	50	50	50	100	100	150			
				0									
	Administration			0									
Administration.Me		*Meeting*	25	0	5	5	5	5					
Administration.Pro		*Project*	25	0	2	3	2	3	2				
Administration.Pilo		*Pilot*	25	0	4	4	4	4	5				
Administration.Tra		*Travel*	40	0	1			2	30	5	3		
Administration.Per		*Personell*	23	0								23	
Administration.Adı		*Adm 1*	24	0							24		
Administration.Adı		*Adm 2*	4	0									4
				0									
	my task			0									
my task.sub		*sub*	15	-15									
				0									
				0									
				0									
				0									

[Figure 31A] Screenshot from project plan

Task 7. Update time registration system

The time registration system sheet contains no code. Just used as a data source for time registration sheet. The tasks here are exported from the estimation sheet.

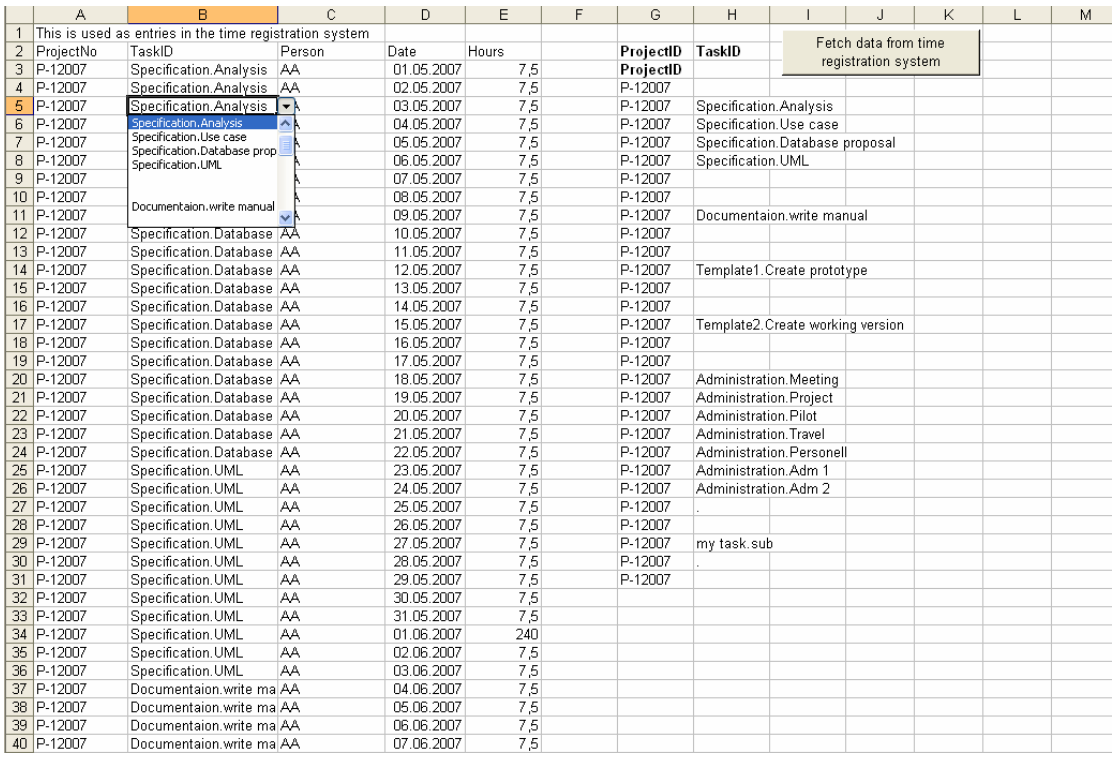
	A	B	C	D	E	F	G	H	I	J
1	The data below should be exported into the time registration system, this sheet is just used as a demonstration									
2	**Project no**	**TaskID**								
3	P-12007									
4	P-12007									
5	P-12007	Specification.Analysis								
6	P-12007	Specification.Use case								
7	P-12007	Specification.Database proposal								
8	P-12007	Specification.UML								
9	P-12007									
10	P-12007									
11	P-12007	Documentaion.write manual								
12	P-12007									
13	P-12007									
14	P-12007	Template1.Create prototype								
15	P-12007									
16	P-12007									
17	P-12007	Template2.Create working version								
18	P-12007									
19	P-12007									
20	P-12007	Administration.Meeting								
21	P-12007	Administration.Project								
22	P-12007	Administration.Pilot								
23	P-12007	Administration.Travel								
24	P-12007	Administration.Personell								
25	P-12007	Administration.Adm 1								
26	P-12007	Administration.Adm 2								
27	P-12007									
28	P-12007									
29	P-12007	my task.sub								

[Figure 32A] Screenshot from time registration system sheet

The time registration sheet contains code to fetch data from the time registration system sheet.

```
Sub FetchTimeData()' Fetches fake information from the time registration system sheet.

    'This function should be replaced with a function that fetches information
    'from the real time registration system
    Sheets("Time registration system").Select
    Range("B2:B43").Select
    Selection.Copy
    Sheets("Time registration").Select
    Range("H2").Select
    ActiveSheet.Paste
    Range("G2").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "ProjectID"
    With ActiveCell.Characters(start:=1, Length:=9).Font
```

```
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlUnderlineStyleNone
        .ColorIndex = xlAutomatic
    End With
    Range("G4").Select
    Sheets("Offer").Select
    Range("C2:F2").Select
    ActiveCell.FormulaR1C1 = "P-12007"
    Sheets("Time registration").Select

    Selection.AutoFill Destination:=Range("G4:G31"), Type:=xlFillCopy
    Range("G3:G31").Select
    Range("H31").Select
End Sub
```



[Figure 33A] Screenshot from time registration sheet

Task 8. Compare actual and estimated effort.

The detailed month report is generated with the following code:

```
Sub GenerateDetailedMonthReport()' Generates a detailed month report
    Dim startDate As Date
    Dim m As Integer
    Dim y As Integer
    Dim compareDate As Date
    Dim taskRows As Integer
    Dim taskid As String
    Sheets("Offer").Select
    startDate = Range("B7").Value
    Sheets("Detailed Month Report").Select
    Range("B2").Select
    'Get the date you want to generate detailed month reports
    compareDate = ActiveCell.Value
    m = month(compareDate)
    y = year(compareDate)
    m = DateDiff("m", startDate, compareDate)
    'Get the estimation tasks
    Sheets("Estimation").Select
    Range("end").Select
    taskRows = ActiveCell.row
    Range("start").Select
    taskRows = taskRows - ActiveCell.row
    Range("start:end").Select
    Selection.Copy
    Sheets("Detailed Month Report").Select
    Range("A3").Select
    ActiveSheet.Paste
    Sheets("Estimation").Select
    ActiveWindow.SmallScroll Down:=0
    Range("startTask:endTask").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Detailed Month Report").Select
    Range("B3").Select
    ActiveSheet.Paste
    Sheets("Estimation").Select
    Range("startSubtask:endSubtask").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Detailed Month Report").Select
    Range("C3").Select
    ActiveSheet.Paste
    'Get project information
    Sheets("Offer").Select
    Range("C2").Select
    Selection.Copy
    Sheets("Detailed Month Report").Select
```

```
    Range("B1").Select
    ActiveSheet.Paste
    Selection.UnMerge
    Sheets("Offer").Select
    Range("C3").Select
    Selection.Copy
    Sheets("Detailed Month Report").Select
    Range("D1").Select
    ActiveSheet.Paste
    Selection.UnMerge
    Range("C1").Select
    ActiveCell.FormulaR1C1 = "Project name"
    Dim rowno As Integer
    Dim colno As Integer
    Dim hours As Double
    Range("A4").Select
    'Get figures for each task.
    For i = 1 To taskRows
        taskid = ActiveCell.Value
        If (taskid <> "") Then
        ActiveCell.Offset(0, 3).Select
        ActiveCell.FormulaR1C1 = "=SUM('Project Plan'!RC[1]:RC[" & 2 + m & "])"
        ActiveCell.Offset(0, 1).Select
        rowno = ActiveCell.row
        colno = ActiveCell.Column
        'Get the amount of hours for this task
        hours = Module2.HoursForTask(taskid, compareDate)
        Sheets("Detailed Month Report").Select
        Cells(rowno, colno).Select
        ActiveCell.Value = hours
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=SUM('Project Plan'!RC[" & 1 + m & "]:RC[200])"
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=RC[-2] + RC[-1]"
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=IF(RC[-4] > 0 , RC[-3] / RC[-4] * 100, ""no
budget"")"
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=IF(RC[-2] > 0 , RC[-4] / RC[-2] * 100, ""no
budget"")"
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=RC[-6] * priceHour"
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=RC[-6] * priceHour"
        ActiveCell.Offset(0, -10).Select
        End If
        ActiveCell.Offset(1, 0).Select
    Next i
End Sub
```

The code below sums up the hours registered for a task up to a certain date. This code is placed in module 2.

```
Function HoursForTask(taskid As String, compareDate As Date) As Double ' Gets the
total hours for a 'task up to a certain date
Dim m As Integer
Dim dateMonth As Integer
Dim result As Double
Dim selectedDate As Date
Sheets("Time registration").Select
Range("B3").Select
'sum the amount of hours for this task
Do Until (IsEmpty(ActiveCell.Value2) = True)
    If (ActiveCell.Value = taskid) Then
        ActiveCell.Offset(0, 2).Select
        selectedDate = ActiveCell.Value
        If (year(compareDate) > year(selectedDate) Or (year(compareDate) =
year(selectedDate) _
            And month(compareDate) >= month(selectedDate))) Then
            ActiveCell.Offset(0, 1).Select
            result = result + ActiveCell.Value
            ActiveCell.Offset(0, -1).Select
        End If
        ActiveCell.Offset(0, -2).Select

    End If
    ActiveCell.Offset(1, 0).Select
Loop
HoursForTask = result
End Function
```

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Project no**	P-12007	Project name	Demonstration of estimation template				Update				
2	**Date**	01.09.2007										
3				Budget Acc	Real Acc	Remaining	Prognosis	Consumption(%)	Completeness(%)	Budget Acc (NOK)	Real Acc (NOK)	
4		*Specification*										
5	Specification.Analysis		*Analysis*	65	30	10,0	40,0	46,15	75,00	52000	24000	
6	Specification.Use case		*Use case*	75	30	75,0	105,0	40,00	28,57	60000	24000	
7	Specification.Database pr		*Database proposal*	2	105	3,0	108,0	5250,00	97,22	1600	84000	
8	Specification.UML		*UML*	0	322,5	2,0	324,5	no budget	99,38	0	258000	
9												
10		*Documentaion*										
11	Documentaion.write manu		*write manual*	15	165	35,0	200,0	1100,00	82,50	12000	132000	
12												
13		*Template1*										
14	Template1.Create prototyp		*Create prototype*	0	150	750,0	900,0	no budget	16,67	0	120000	
15												
16		*Template2*										
17	Template2.Create working		*Create working version*	0	232,5	500,0	732,5	no budget	31,74	0	186000	
18												
19		*Administration*										
20	Administration.Meeting		*Meeting*	5	30	20,0	50,0	600,00	60,00	4000	24000	
21	Administration.Project		*Project*	13	22,5	12,0	34,5	173,08	65,22	10400	18000	
22	Administration.Pilot		*Pilot*	4	7,5	21,0	28,5	187,50	26,32	3200	6000	
23	Administration.Travel		*Travel*	0	7,5	40,0	47,5	no budget	15,79	0	6000	
24	Administration.Personell		*Personell*	0	7,5	23,0	30,5	no budget	24,59	0	6000	
25	Administration.Adm 1		*Adm 1*	0	7,5	24,0	31,5	no budget	23,81	0	6000	
26	Administration.Adm 2		*Adm 2*	0	37,5	4,0	41,5	no budget	90,36	0	30000	
27												
28		*my task*										
29	my task.sub		*sub*	-15	0	0,0	0,0	no budget	no budget	-12000	0	
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												

[Figure 34A] Screenshot from detailed month report

The month report is generated with the following code:

```
Sub UpdateMonthReport()' Updates the month report with figures
'Insert the project information from the offer sheet
    Sheets("Offer").Select
    Range("C2:F2").Select
    Selection.Copy
    Sheets("Month Report").Select
    Range("B1").Select
    ActiveSheet.Paste
    Sheets("Offer").Select
    Range("C3:F3").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Month Report").Select
    Range("B2").Select
    ActiveSheet.Paste
    Sheets("Offer").Select
    Range("D12").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Month Report").Select
    Range("B23").Select
    ActiveSheet.Paste
    Sheets("Offer").Select
    Range("E13:E15").Select
    Sheets("Month Report").Select
    Range("B19").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "=SUM(Offer!R[-6]C[3]:R[-4]C[3])"
    Range("B20").Select
    ActiveCell.FormulaR1C1 = "=SUM(Offer!R[6]C[3]:R[10]C[3])"
    Range("B21").Select
    Sheets("Offer").Select
    Dim startDate As Date
    Dim endDate As Date
    Dim start As Date
    Dim m As Integer
    Dim y As Integer
    Dim cols As Integer
    cols = 0
    startDate = Range("B7").Value
    start = startDate
    endDate = Range("D7").Value
    m = month(startDate)
    y = year(startDate)
    Sheets("Month Report").Select
    Range("B3").Select
    'Fetch the figures for each month
    While (startDate <= endDate)
        'Insert formuales for each cell and move to the next
        startDate = DateSerial(y, m, 1)
```

```
        ActiveCell.FormulaR1C1 = startDate
        Selection.Columns.AutoFit
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=SUM('Project Plan'!R[-1]C[4]:R[221]C[4])"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=RC[-1]+R[-1]C"
        ActiveCell.Offset(1, 0).Select
        rowno = ActiveCell.row
        colno = ActiveCell.Column
        noHours = Module2.hours(startDate)
        Sheets("Month Report").Select
        Cells(rowno, colno).Select
        ActiveCell.Offset(1, 0).Select
        ActiveCell.Value = noHours
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=RC[-1]+R[-1]C"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=hours95 - R[-1]C"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-2]C + R[-1]C"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=IF(R[-7]C >0 , R[-4]C / R[-7]C * 100, ""no
budget"")"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-4]C / R[-2]C * 100"
        ActiveCell.Offset(2, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-10]C * priceHour "
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-10]C * priceHour "
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-8]C * priceHour "
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "=R[-8]C * priceHour "
        ActiveCell.Offset(-14, 0).Select
        ActiveCell.Offset(0, 1).Select
        m = m + 1
        cols = cols + 1
    Wend
    Range("B5").Select
    ActiveCell.FormulaR1C1 = "=R[-1]C"
    Range("B8").Select
    ActiveCell.FormulaR1C1 = "=R[-1]C"
    Range("B6").Select
    cols = cols - 1
    'Set the percentage of budget value
    ActiveCell.FormulaR1C1 = "=R[-1]C / R[-1]C[" & cols & "] * 100"
    cols = cols - 1
    While (cols > 0)
        ActiveCell.Offset(0, 1).Select
        ActiveCell.FormulaR1C1 = "=R[-1]C / R[-1]C[" & cols & "] * 100"
        cols = cols - 1
```

```
    Wend
    ActiveCell.Offset(0, 1).Select
    ActiveCell.FormulaR1C1 = "=R[-1]C / R[-1]C * 100"
    Range("A1").Select
End Sub
```

The code below sums up the hours registered for a task for a certain month. This code is placed in module 2.

```
Function hours(compareDate As Date) As Double ' Gets the hours for a task in a month
Dim m As Integer
Dim dateMonth As Integer
Dim result As Double
m = month(compareDate)
y = year(compareDate)
Sheets("Time registration").Select
Range("D3").Select
comparedDate = ActiveCell.Value
'sum the amount of hours for this month
Do Until (IsEmpty(ActiveCell.Value2) = True)
    ActiveCell.Offset(0, 1).Select
    If (month(comparedDate) = m And year(comparedDate) = y) Then
        result = result + ActiveCell.Value
    End If
    ActiveCell.Offset(0, -1).Select
    ActiveCell.Offset(1, 0).Select
    comparedDate = ActiveCell.Value
Loop
hours = result
End Function
```

Projectno	P-12007				Update month report								
Project name	Demonstration of estimation template												
	01.05.2007	01.06.2007	01.07.2007	01.08.2007	01.09.2007	01.10.2007	01.11.2007	01.12.2007	01.01.2008	01.02.2008	01.03.2008	01.04.2008	01.0
Budget	19	18	68	28	46	93	213	284	241	187	235	96	
Budget accumulated	19	37	105	133	179	272	485	769	1010	1197	1432	1528	
Budget in percent	1	2	6	8	11	16	29	45	59	70	84	90	
Real	233	458	233	233	0	0	0	0	0	0	0	0	
Real accumulated	233	690	923	1155	1155	1155	1155	1155	1155	1155	1155	1155	
Remaining (estimated)	2188	1730	1498	1265	1265	1265	1265	1265	1265	1265	1265	1265	
Prognosis (Real accumulated + remaining)	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	
Degree of consumption (%)	1224	2542	342	830	0	0	0	0	0	0	0	0	
Degree of completeness (%)	10	29	38	48	48	48	48	48	48	48	48	48	
Budget (kr)	15200	14400	54400	22400	36800	74400	170400	227200	192800	149600	188000	76800	
Budget accumulated (kr)	15200	29600	84000	106400	143200	217600	388000	615200	808000	957600	1145600	1222400	1
Real (kr)	186000	552000	738000	924000	924000	924000	924000	924000	924000	924000	924000	924000	
Real accumulated (kr)	1750082	1384082	1198082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1012082	1
Earnings accumulated (kr)													
Additional costs	125600												
Other costs	50000												
Price per hour	800												

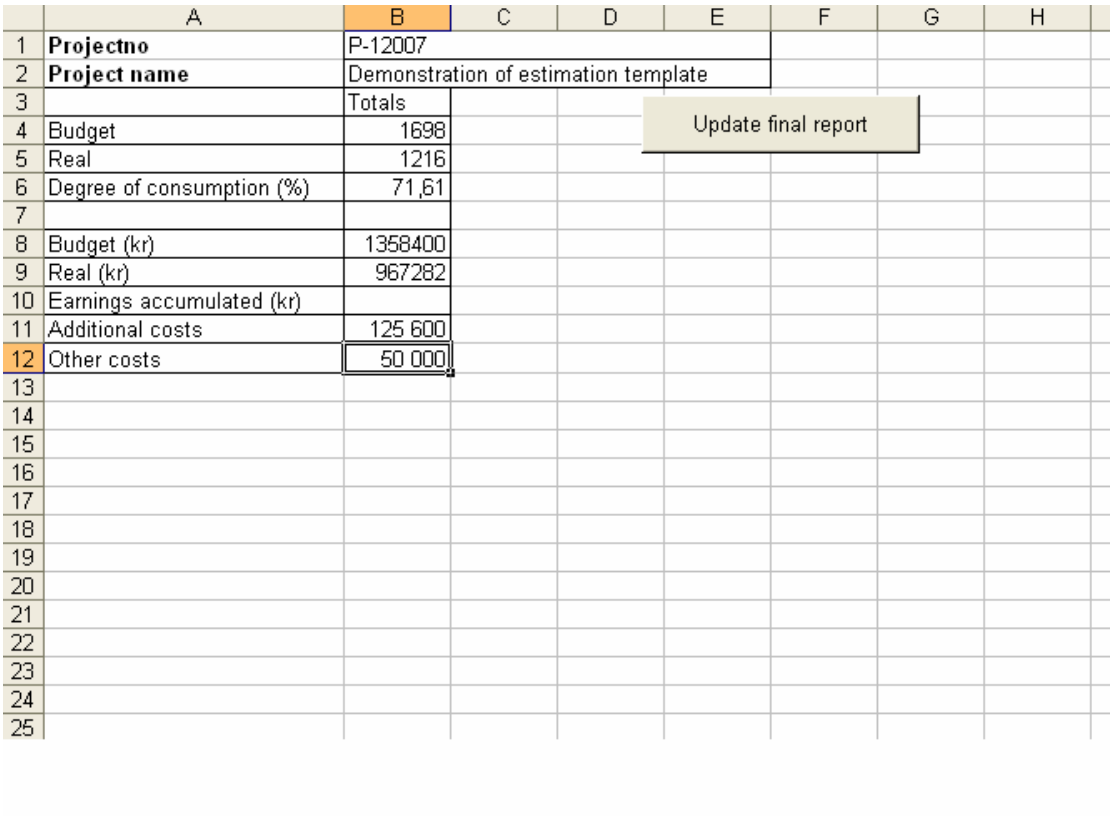
[Figure 35A] Screenshot from month report

Task 9. Generate final report data.

The final report is generated with the following code:

```
Sub UpdateFinalReport()' Updates the final report with figures
    'Get project data from offer sheet
    Sheets("Offer").Select
    Range("C2:F2").Select
    Selection.Copy
    Sheets("Final Report").Select
    Range("B1").Select
    ActiveSheet.Paste
    Sheets("Offer").Select
    Range("C3:F3").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Final Report").Select
    Range("B2").Select
    ActiveSheet.Paste

    Dim budget As Double
    Dim real As Double
    Dim budgetNOK As Double
    Dim realNOK As Double
    'Get total values from month report
    Sheets("Month Report").Select
    Range("B5").Select
    Do Until (IsEmpty(ActiveCell.Value2))
        ActiveCell.Offset(0, 1).Select
    Loop
    ActiveCell.Offset(0, -1).Select
    budget = ActiveCell.Value
    ActiveCell.Offset(3, 0).Select
    real = ActiveCell.Value
    ActiveCell.Offset(7, 0).Select
    budgetNOK = ActiveCell.Value
    ActiveCell.Offset(2, 0).Select
    realNOK = ActiveCell.Value
    'update with additional costs from offer sheet
    Sheets("Final Report").Select
    Range("B11").Select
    ActiveCell.FormulaR1C1 = "=SUM(Offer!R[2]C[3]:R[4]C[3])"
    Range("B12").Select
    ActiveCell.FormulaR1C1 = "=SUM(Offer!R[14]C[3]:R[18]C[3])"
    'insert values found in month report
    Range("B4").Select
    ActiveCell.Value = budget
    Range("B5").Select
    ActiveCell.Value = real
    Range("B6").Select
    ActiveCell.FormulaR1C1 = "=R[-1]C / R[-2]C * 100"
```

```
    Range("B8").Select
    ActiveCell.Value = budgetNOK
    Range("B9").Select
    ActiveCell.Value = realNOK
End Sub
```



	A	B	C	D	E	F	G	H
1	**Projectno**	P-12007						
2	**Project name**	Demonstration of estimation template						
3		Totals						
4	Budget	1698						
5	Real	1216						
6	Degree of consumption (%)	71,61						
7								
8	Budget (kr)	1358400						
9	Real (kr)	967282						
10	Earnings accumulated (kr)							
11	Additional costs	125 600						
12	Other costs	50 000						
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

[Figure 36A] Screenshot from final report

Appendix B. Use case point method

Use Case Points [Karn93][Karn93a]

A use case model defines the functional scope of the system to be developed. The size and complexity of the functionality can be determined by the attributes of the use case model. The use case points (UCP) effort estimation method is an extension of [Symo91] Function points analysis and MK II function points analysis. The weights factors (WF) and formula for each step is borrowed from the Function points method by Albrecht[Albr79]. For environmental factors Karner interviewed experienced personnel and proposed the weights. The formula for environmental factors is based on some effort estimation results.

The UCP method consists of six steps.

- Classify actors and determine the complexity of the actors. The complexity is determined by the type of actors in the use case. This will in turn produce the unadjusted actor weights (UAW).
- Classify the use cases and determine the complexity of them to determine the unadjusted use case weights (UUCW). Use case complexity is determined by the number of transactions in the use case.
- Calculate the unadjusted use case point (UUCP), by adding the two former values.
- Determine technical and environmental factors. Technical factors are related to how difficult it is to build the system, distributed system, reusable code, etc. This is the technical factors when regarding the use case. This step also consists of determining environmental factors, which relates to the efficiency of the project, experience, stable requirements, etc.

The technical complexity factor (TCF) = 0,6 + (0,01 * TFactor) , and the environmental factor (EF) = 1,4 + (-0,03 * EFactor). Each factor is assigned a value between 0 and 5 depending on its assumed influence on the project. A rating of 0 means the factor is irrelevant while 5 mean it is essential.

- The use case points can then be calculated as UCP = UUCP * TCF * EF. In order to estimate effort the method uses person hours per UCP , PHperUCP. PHperUCP is based on previous project experience. Schneider and Winters proposed number of staff hours per Use Case point depends on the environmental factors [Schn98], and to be in the range 20 -36. The number of factors in E1 through E6 that are below 3 are counted and added to the number of factors in E7 through E8 that are above 3. If the total is 2 or less, the general idea is to use twenty hours per UCP; if the total is 3 or 4, use twenty-eight hours per UCP. If the number exceeds 5, it is usually recommended that changes should be made to the project so the number can be adjusted, because in this case, the risk is unacceptably high. Another possibility is to increase the number of hours to thirty-six per Use Case points.

Schneider also proposes to classify the complexity as shown in the tables below. This is also used by Bente Anda et al. in [Anda01]:

Actor type	**Description**	**Weight factor**
Simple	Defined API	1
Average	Interactive or protocol-driven interface	2
Complex	Graphical use interface	3

[Table 27] Use case actors complexity

Use case type	Description	Weight factor
Simple	Up to 3 transactions	5
Average	4 to 7 transactions	10
Complex	More than 7 transactions	15

[Table 28] Use case complexity

Technical factor	Factor description	Weight factor
T1	Must have a distributed solution	2
T2	Must respond to specific performance objectives	2
T3	Must meet end-user efficiency desires	1
T4	Complex internal processing	1
T5	Code must be reusable	1
T6	Must be easy to install	0,5
T7	Must be easy to use	0,5
T8	Must be portable	2
T9	Must be easy to change	1
T10	Must allow concurrent users	1
T11	Includes special security features	1
T12	Must provide direct access for third-parties	1
T13	Requires special user training facilities	1

[Table 29] Technical factors and weights

Environment factor	Factor description	Weight factor
E1	Familiar with software process	1,5
E2	Application experience	0,5
E3	Paradigm experience (OO)	1
E4	Lead analyst capability	0,5
E5	Motivation	1
E6	Stable requirements	2
E7	Part-time workers	-1
E8	Difficulty of programming language	-1

[Table 30] Use case environmental factors

Appendix C. PERT method

Rationale behind the PERT method

Program Evaluation and Review Technique (PERT) is a popular estimation method that includes a notion of probability. The company's estimation template is based on PERT. [NetMBAWeb]
When applying PERT, three time estimates are given for each activity:

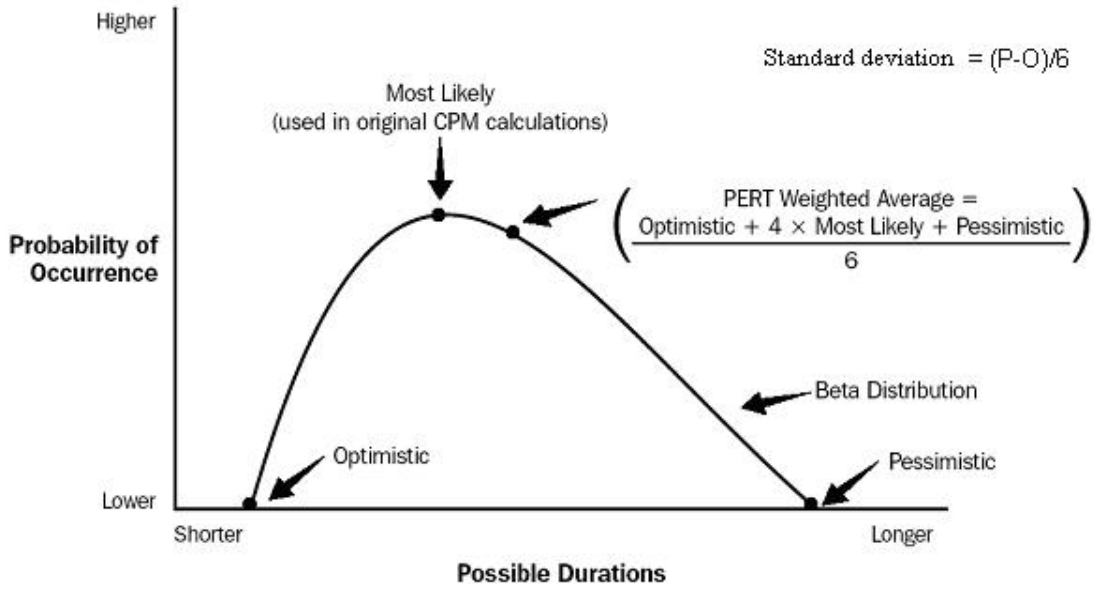
- **Optimistic time**: The shortest time in which the activity can be completed. It is common to specify optimistic times to be three standard deviations from the mean, so that there is approximately a 1% chance that the activity will be completed within the proposed time.
- **Most likely time**: The completion time having the highest probability. Note that this time is different from the *expected* time.
- **Pessimistic time**: The longest time that the activity might require. Three standard deviations from the mean is commonly used for the pessimistic time.

PERT assumes a beta probability distribution for the time estimates. For a beta distribution, the expected time for each activity can be approximated using the following weighted average:

Expected time = (Optimistic + 4 × Most Likely + Pessimistic) / 6

To calculate the variance for each activity completion time, if three standard deviation times were selected for the optimistic and pessimistic times, then there are six standard deviations between them, so the variance is given by:

$$[(\text{Pessimistic} - \text{Optimistic}) / 6]^2$$



[Figure 37C] PERT possible durations

The company assumes the following:

You can select other probability levels for the optimistic/pessimistic times. For example, selecting ±2 standard deviations corresponds to a 5% chance of being within the proposed time, whereas ±2.5 standard deviations correspond to an X% chance. The formulas will have to be modified accordingly.