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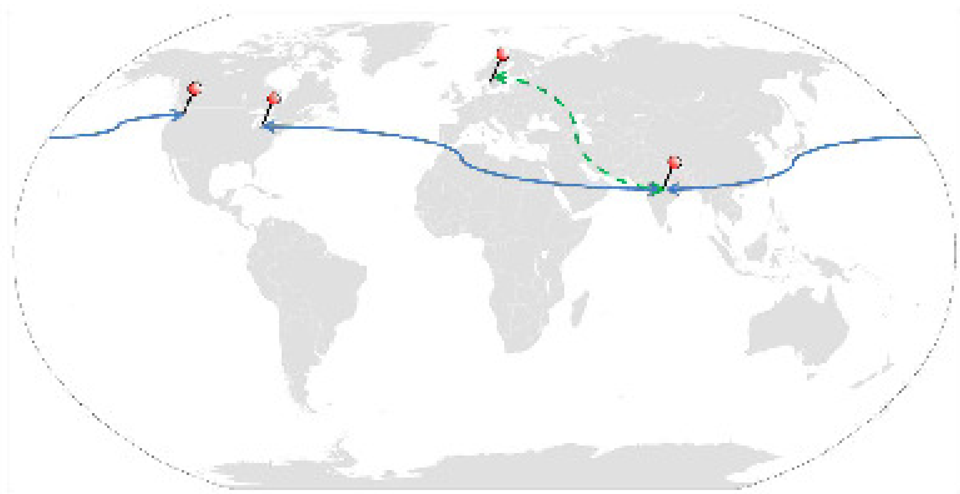

Successful Discrete-Event Simulation Offshoring

Guidelines for an Operative Setting

Master of Science Thesis

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Göteborg, Sweden, 2011

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Cover:
Offshoring

Printed by:
Chalmers Reproservice, Göteborg, Sweden
June 2011

Preface

This report is the result of a Master's thesis project conducted from January 2011 to June 2011. The thesis was conducted at PMC Europe, at their Göteborg office. The Master's thesis project has been the final compulsory part of the Master's degree programme Production Engineering at the department of Product and Production Development at Chalmers University of Technology.

We especially want to thank our examiner Björn Johansson and the supervisor from PMC Peter Schill for their help and encouragement during the project.

When looking at the individuals participating in the case study, we would especially like to thank Nils Andersson who spent an entire day out of his spare time participating in the case study performed during the project and thereby providing very valuable input. We would also like to thank all the other individuals participating in our case study for their interest, input, questions and answers while performing their tasks.

We also want to thank Ravi Lote, Anders Skoogh, Karthik Vasudevan, Nikhil Garge, Marcelo Zottolo for their interview participation and for having taken time out of their often busy schedule to talk to us. Their input has been invaluable for the result of the thesis.

Finally we would like to thank our opponents Andreas Larsson and Henrik Nilsson for the valuable feedback and support received during our presentation.

Göteborg 2011-06-01

Sam Asplund Torbjörn Jakobsson

Abstract

PMC Europe has recently experimented with discrete-event simulation (DES) offshoring. This experimentation highlighted a need for project management guidelines, which could not be found in academic literature. This Master's thesis therefore describes the creation of a knowledge base for DES-offshoring by answering the main question "how to and in which way can parts of or entire DES-projects successfully be offshored?" divided into five separate sub-questions.

The main research methodology consists of literature studies on discrete-event simulation and offshoring respectively, a case study regarded as an emulated DES-offshoring and interviews with professionals on both sending and receiving end of DES-offshoring projects.

The results are presented by giving a background to DES-offshoring by looking at business motivations and the initiation phase, followed by the main results answering each of the five sub-questions for an operative setting one by one. Firstly, the results present a version of Banks model modified for a simulation offshoring setting, showing which steps in a simulation study to be performed onshore, offshore or at both locations.

Secondly, the results state that in theory all projects can be offshored, but in practice projects that due to legislation cannot be offshored and projects with a short timeframe are not offshored.

Thirdly, the results show that the from a communication point-of-view, the model conceptualization step should be performed in cooperation between the onshore and offshore location. It also states that daily updates should occur both in the form of latest model version uploads and in the form of a standardized email template on project progress. To ensure successful project communication, VoIP- and screen sharing communication should also occur at least every two or three days.

Fourthly, a cost model is developed based on percentage of communication between the onshore and offshore location. It shows that if 20 % of the project time is spent communicating, the project is financially beneficial if the hourly cost for the offshored work is lower than 60 % of the hourly cost for the onshored work.

Fifthly, the results show that cultural differences exist and need to be taken into account, but can however be bridged. A practical factor to consider is that simulation training needs to be conducted due to acquiring new software or when hiring new staff.

Definitions

This list contains concept definitions used in the report. *Italic* definitions are non-recognized definitions which are described here as used in the report.

Attribute
Property of an entity.

BaseModel
A model built from a conceptual model describing the *original model*.

Basic layout
The layout from which the *original model* was derived.

Conceptual model
Approximation of a real system containing its essential features together with necessary assumptions.

Conceptual model, the
A conceptual model describing the *original model.*

Communication
Something imparted, interchanged, or transmitted.

Discrete
Something non-continuous, separate, individual.

Discrete-Event Simulation (DES)
Type of simulation that involves time and contains random elements in a modelled system where changes in state variables are made in a discrete manner.

Enterprise Dynamics
The simulation software used in this thesis.

Entity
Component or object that mimics a real world entity.

Event
Occurrence that changes the state of the system instantaneously.

Experiment guide
A document describing how to conduct experiments on the *BaseModel* in the simulation software.

FinalModel
An improved version of the *BaseModel* when from a system performance point-of-view.

Lean Production
Production philosophy that regards any non-value creating expenses for the end customer as waste that can be eliminated.

Model
Abstract representation of a system.

Normalization
Dividing multiple data sets with a common variable to allowing same scale comparisons.

Offshore outsourcing
Combination of outsourcing and offshoring.

Offshoring
Movement to a location in another country of some part of a firm's activity

Onshore
The location from where an offshoring is performed.

Original model
The model created by the researchers as a base for the *conceptual model* in the case study.

Outsourcing
When one company makes an agreement with a second company to provide services that the first could provide, but chooses not to.

Project
A unique, temporary effort to create a product or service.

Project Management
The discipline used to execute a project and achieve its objectives.

Simulation
An imitation of the operation of a real world process or system over time.

Software guide
A document describing how to construct the *BaseModel* in the simulation software.

System
Collection of entities.

System state
Collection of variables that holds information necessary to describe the system at any point in time.

Variable
A name associated with a changeable value.

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1 Introduction

This chapter introduces the Master's thesis.

1.1 Background

Production Modeling Corporation, PMC, is a consultancy firm specialized in, among others, Discrete Event Simulation (DES). PMC was founded in Dearborn, Michigan in 1979. Today PMC has a global presence with offices in Europe, North America and Asia. PMC Europe AB is based in Göteborg, Sweden and was founded in 2007.

PMC Europe has recently experimented with collaborating with the company's Indian office on European DES-projects. This experience highlighted a need for project management guidelines for discrete-event simulation offshoring.

1.2 Purpose

The purpose of this Master's thesis is to understand the process of offshoring discrete-event simulation projects and to create general guidelines for how to perform the process successfully.

1.3 Objective

PMC Europe has previously undertaken projects where they have used the advantages of having offices on three different continents. However they have not been working in a standardized way, which afterwards has highlighted the need for having project management guidelines for working on the same simulation project on different locations.

The master's thesis main question is therefore:

MQ: How to and in which way can parts of or entire DES-projects successfully be offshored?

The following sub-questions will facilitate answering the main question:

SQ1: What cannot be done elsewhere other than on-site or from the local office and why?

SQ2: What type of simulation projects can or cannot be offshored and why?

SQ3: What requirements are there on communication between an onshored and an offshored office and how often should it occur?

SQ4: Which are the limiting factors regarding the profitability of offshoring a simulation project?

SQ5: Which cultural and practical factors need to be taken into account when offshoring?

1.4 Delimitations

In order to make sure the project does not drift out of focus or becomes vague and scattered some delimitations need to be set up. The main delimitations are:

- The type of simulation discussed in this thesis is discrete-event simulation.
- The main focus will be to look at DES-offshoring in the current company setting, i.e. in an operative setting where an offshored office already exists.

- Offshoring destinations discussed in the report are India and China
- Communication theory will briefly be discussed.
- Regarding interviews and a performed case study, the number of participants is regarded as being too low to statistically prove the results.

2 Method

This chapter describes the methods used to gather the material in the research. To the knowledge of the authors, no published material currently exists on offshoring discrete-event simulation projects, which created a need for material to be gathered from both offshoring and discrete-event areas. A specific focus has however been put on finding information from people and projects within the multidisciplinary area. Figure 1 shows the positions of the different research methods in the DES/Offshoring areas.

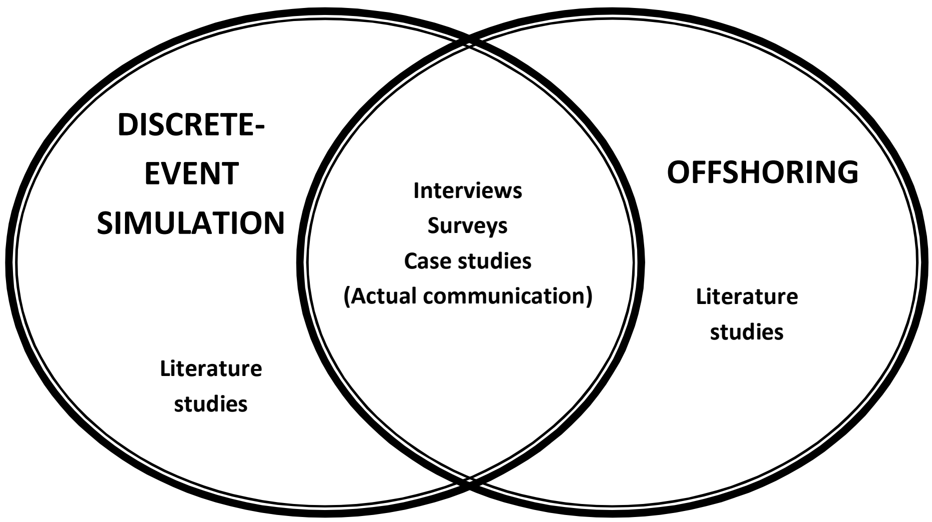


Figure 1 – Research methods by topic

2.1 Interviews

The chosen interview approach in this research is the semi-structured interview. The semi-structured interview is a prepared interview focused on particular topics. This interview form is classified as a qualitative research interview, many times undertaken with prepared questions following an interview guide. The purpose of the qualitative research interview is "to understand themes of the lived daily world from the subjects' own perspectives". (Kvale, 1996)

The interviews conducted within the thesis work have been undertaken by two interviewers, with one of the interviewers having the main responsibility for posing questions and the other being responsible for taking notes. When possible, the interviews have been recorded and after the interviews, with aid from the recordings, the notes have been summarized and sent to the interviewees if requested.

Interviews have been the chosen method used for the following purposes:

- Getting a general understanding on a subject from a practitioner's point-of-view
- Investigating different perspectives within simulation offshoring

2.2 Surveys

The survey is a fast method to collect both qualitative and quantitative data from large groups. The survey methodology starts by identifying the objectives of the survey and then translating them to a questionnaire. This can prove to be a difficult task and a big challenge lies in asking right questions and due to the fact of communication in the survey only being through written text, being clear and getting the point understood. Another important feature in survey making is knowing what to measure and why. (Iarossi and ebrary Inc., 2005)

In this master's thesis, the survey has been used for the following purposes:

- Getting quantitative and qualitative data from individuals with similar experiences or data from individuals not available for interviewing

2.3 Case studies

The case study is an investigative method which often, despite being frequently used, is subjected to criticism claiming that it is a weak method compared to more quantitative scientific methods. According to Yin, this stereotyped view of the case study may be wrong due to looking upon the case study from a faulty perspective and misunderstanding its strengths and weaknesses. (Yin, 2003)

Yin identifies three situations where case studies are the preferred strategy:

- When "how" or "why" questions are being posed
- When the investigator has little control over events
- When the focus is on a contemporary phenomenon within some real-life context.

The case study within the thesis is embedded (Yin, 2003), meaning that within the study several units (four groups) are examined using both similar and different ways of data collection between units.

The performed study is in one way a single case study, as the four studied units are all looked upon individually. In another way, the case study can be looked upon as multiple-case since the four units are comprised of individual groups being studied in the same way. Figure 2 describes the different case study design types.

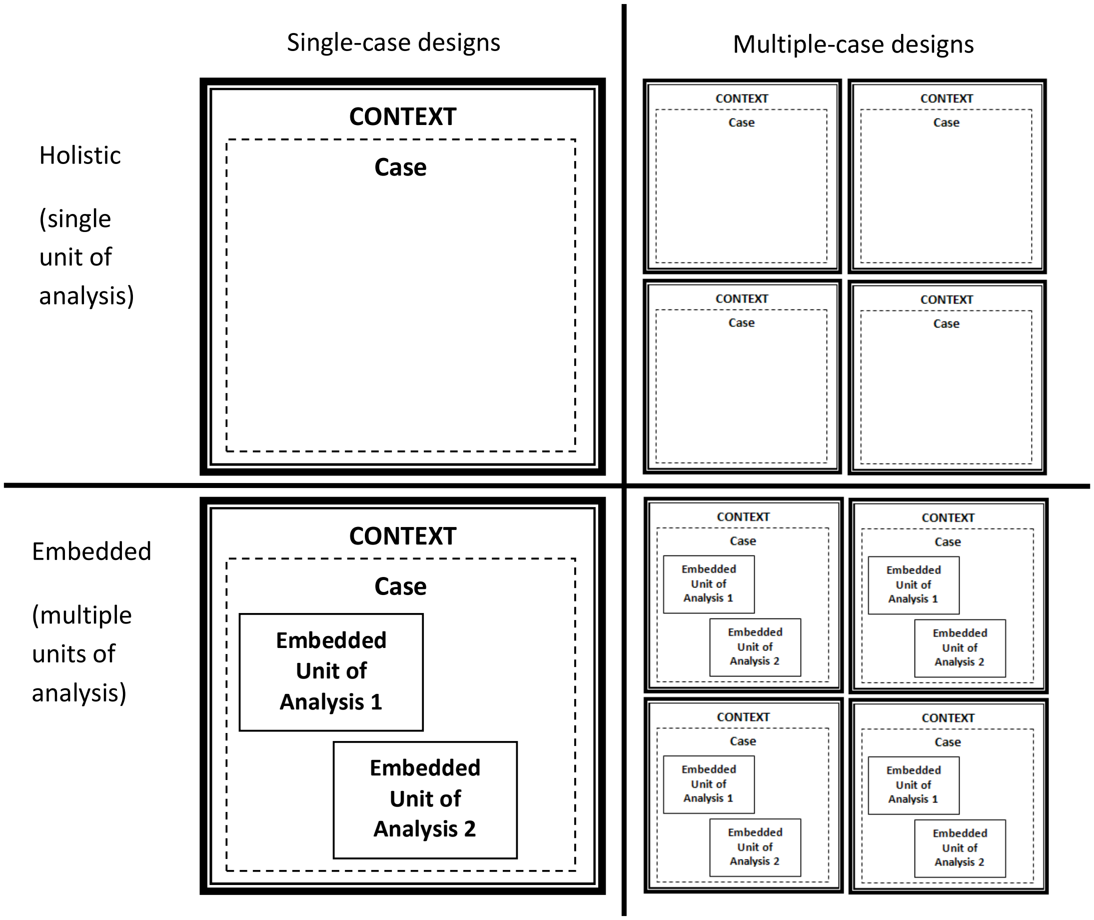


Figure 2 – Basic Types of Design for Case Studies (Yin, 2003)

When possible, a multiple-case design is preferable for several reasons. Firstly having multiple cases is less vulnerable because the study can go on if one study for any reason is terminated. Secondly, and more important, the results from a multiple-case are often more reliable and powerful. Especially if the findings are similar, the analytic conclusions are much more reliable. (Yin, 2003)

In this master's thesis, the case study method has been used for the following purposes:

- Understanding how written information is interpreted
- Comprehending why and where mistakes occur when using written communication
- Investigating whether groups with different prior knowledge skills interpret the same information differently.

In chapter 4.1, the specific methodology (fabrication of material, chosen groups, execution parameters, data collection methodology) used in the actual case study is described in more detail.

2.4 Actual communication

The *actual communication* turned out to be an unrealizable method for this project.

One idea was to be an active part in a real DES offshoring project within the company, either as the onshore part, managing the project or as the offshore part, building the model. However, during the course of the thesis, no such projects came about.

Another idea was to participate in actual DES offshoring-communication between two company offices mainly as non-interacting listeners to find out how communication is handled in practice to gain insights on current work procedures and their advantages/disadvantages. However due to reasons of both confidentiality and lack of time at the company offices involved with offshoring, this turned out to be an option which was not possible.

3 Theoretical framework

This chapter describes the theoretical background in the thesis. The theoretical framework is divided into the three main parts *discrete-event simulation, outsourcing and offshoring* and *communication.*

3.1 Discrete-event simulation

Virtual simulation, offline programming and the digital factory concept are buzzwords often heard in academic environments. Some of them are still mainly visions or concepts while others are tools used daily with great results. Computer simulation has become very popular within manufacturing, production, logistics, service and finance industries during the last 30 years (Salmeron, 2009). Ulgen and Williams list "reduction in cost of computers and simulation software, emergence of more user-friendly and powerful simulation software […], increase in speed of model building and delivery, and acceptance of an established set of guidelines of simulation model building" as some of the reasons an observed 20 year expansion in popularity can be derived from (Ulgen and Williams, 2002). However some sources claim that simulation hasn't developed as good as expected. According to a panel discussion in the 2000 Winter Simulation Conference on the development of simulation since 1990, "[s]imulation did not exactly stand still, but at the same time, we have reached 2000 without the type of widespread permeation through all industries and organizational sizes that many in the community might have hoped would come to pass" (Banks, 2000).

3.1.1 Business motivations for simulation

As mentioned above, reduced equipment costs for both software and hardware combined with better work methods within simulation are two of the reasons contributing to simulation's popularity. These are however not the main incentives for companies to engage in simulation. Five business motivations listed by Ulgen and Williams (2002) are:

- Increase in Global Competition
- Cost Reduction Effort
- Improved Decision-Making
- Effective Problem Diagnosis
- Prediction and Explanation Capabilities

Increase in Global Competition. In his book, "The World Is Flat", Thomas Friedman describes how he after a trip to Bangalore in India reached the conclusion that "the global competitive playing field was being leveled. […] Clearly, it is now possible for more people than ever to collaborate and compete in real time with more other people on more different kinds of work from more different corners of the planet and on a more equal footing than at any previous time in the history of the world" (Friedman, 2006). To run a business in a world where practically any product or service can be produced and transported everywhere puts completely new demands on companies. Increasing competition means among others that companies need to make continuous improvements, be more flexible to changes, decrease setup times, modularize, increase their number of product variants and this leads to systems becoming increasingly complex. Simulation can in this global environment be a tool used to test new solutions before they are implemented. It can also be used to test extreme conditions or as a tool to optimize parameters in order to minimize warm up periods when changing factory layouts or setups.

Cost Reduction Effort. Ulgen and Williams (2002) mention the lean production boom starting during the early 1980s, in particular within manufacturing and supply chain, as a reason for the needs to reduce inventory, equipment and labor costs while at the same time increasing production rates and flexibility. A lean system is fast and flexible, but at the same time more likely to have a lot of variation in the system parameters. Simulation in this context is described as an "essential tool to increase the robustness of the system relative to internal and external disturbances".

Improved Decision-Making. Simulation has proven to be a powerful tool when training managers. By being able to visualize cause-and-effect relationships with the aid of models, management can learn to understand the effects of their decisions. When systems are too complex to grasp, being able to base decisions on model outputs can be very important when trying to make good decisions. (Ulgen and Williams, 2002)

Effective Problem Diagnosis. Problems such as "throughput reduction, large setup times, imbalance in resource utilization, large inventories and waiting times" are most effectively solved with simulation. Using other analytical tools is usually either too complex or requires too many simplistic assumptions. Simulation provides different detail levels and is, especially together with visualizations, a convenient way to explain problems to management. (Ulgen and Williams, 2002)

Prediction and Explanation Capabilities. Simulation can predict system behavior during different scenarios. It can be used to test extreme conditions and it is also a great tool to get an understanding of why the analyzed system acts the way it does. A deeper understanding of the already existing causal relationships is a great managerial aid when making improvement decisions. (Ulgen and Williams, 2002)

3.1.2 Definitions and concepts of discrete-event simulation

Before looking into the basic concepts of discrete-event simulation, the words *discrete*, *event* and *simulation* are defined.

Basic definitions

Discrete can be defined as either something that is "completely separate and unconnected" or in the frame of mathematics as finite, i.e. "describes mathematical elements or variables that are distinct, unrelated, and have a finite number of values" (Encarta, 2009a).

An *event* can be defined as an important incident or occurrence or as in the frame of physics as a single point in space time (Encarta, 2009b). An event in the realms of discrete-event simulation can simply be explained as a significant occurrence, for example the press of a button.

Simulation is a wide term with several definitions. Two of the definitions provided by the Encarta World English Dictionary are as "the imitation or feigning of something" and "an artificial or imitation object" (Encarta, 2009c). However in the case of DES, a more thorough definition is the one of Banks stating that

> *"Simulation is the imitation of the operation of a real world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system and the observation of that artificial history to draw interferences concerning the operating characteristics of a real system"* (Banks, 2005)

A discrete-event simulation model can be defined by the three attributes *stochastic, dynamic* and *discrete-event.* (Leemis and Park, 2004)

Stochastic refers to the fact that a discrete-event simulation model has some system variables that are random (for example when using statistical distributions) while the term *dynamic* relates to the fact that the evolution of time is of importance. *Discrete-event* is, as mentioned earlier, the changes in state variables that occur at discrete points in time. (Leemis and Park, 2004)

To put it simple it can be stated that discrete-event simulation is a type of simulation that involves time and contains random elements in a modelled system where changes in state variables are made in a discrete manner (Banks, 2005).

Concepts of discrete-event simulation

According to Banks, the framework of discrete-event simulation modelling consists of twelve major concepts (Banks, 2005):

- System – The collection of entities, for example operators and/or machines.
- Model – The abstract representation of a system. The model can for example be a representation of a production facility. The model can contain mathematical, structural and logical relationships. These relationships describe the system in terms of its entities, state and their attributes, activities and events.
- System state – Collection of variables that holds information necessary to describe the system at any point in time
- Entity – A component or object that mimics a real world entity, for example an operator or a machine.
- Attribute – The properties of an entity, for example setup time.
- List – A collection of logically ordered associated (temporarily or permanently) entities. The logical order can for example be according to a given principle such as first in, first out.
- Event – An occurrence that changes the state of the system instantaneously.
- Event notice – A record that contains information regarding an event that should occur instantaneously or in the future. The record should at least include what type of event and when it should occur.
- Event list – A list of notices for future events ordered by when the events should occur.
- Activity – A specified amount of time, for example the mean time to failure.
- Delay – An unspecified amount of time. The length of time is unknown until it ends, for example a length of time that depends on future events.
- Clock – The variable representing simulated time. As mentioned above, a discrete-event simulation model is “run” and not solved hence the need to simulate time.

3.1.3 Advantages/disadvantages with discrete-event simulation

Simulation is advantageous as it provides the ability to study and experiment with a complex system. It is also appropriate when there is a need to understand what input to a system will yield what output. Another appropriate scenario is to use simulation for what-if analyses. (Banks, 2005)

Scenarios when simulation is not an appropriate tool include for example when a problem can be solved by common sense, when a problem can be solved by an analytical approach or when it is easier to perform a real-world experiment. (Banks, 2005)

Many of the advantages of discrete-event simulation are derived from its ability to capture the dynamics of a system, a property not found in the same extent within static analysis. (Johansson, 2006)

One of those advantages is that things such as new policies, decision rules and information flows can be looked into without disrupting the real world system. Another advantage is the possibility for feasibility testing of hypotheses concerning why a certain phenomenon occurs. The ability to aid the understanding of how a system behaves instead of guessing how it behaves is also a great advantage. Advantageous is also the possibility to perform what-if analyses when designing a new real world system. (Banks, 2005)

Disadvantages of simulation include things as the fact that building a simulation model requires special training, the difficulty of interpreting results from simulation and also building a simulation model is time consuming and expensive. (Banks, 2005)

3.1.4 The discrete-event simulation study

Each simulation study or creation of a simulation model is unique. This uniqueness makes it natural for the simulation study to be performed in project form. However this uniqueness does not make it impossible to have a structured and well defined methodology in which the study is carried out. There are several well established models or methods to use when carrying out a simulation study. Many of them are similar to each other and are usually characterized by consisting of a number of steps in a flowchart manner where some of the steps are iterative. One of the more widely used models was proposed by Jerry Banks and is referred to as Banks model. Banks model consists of 12 steps (see fig 3).

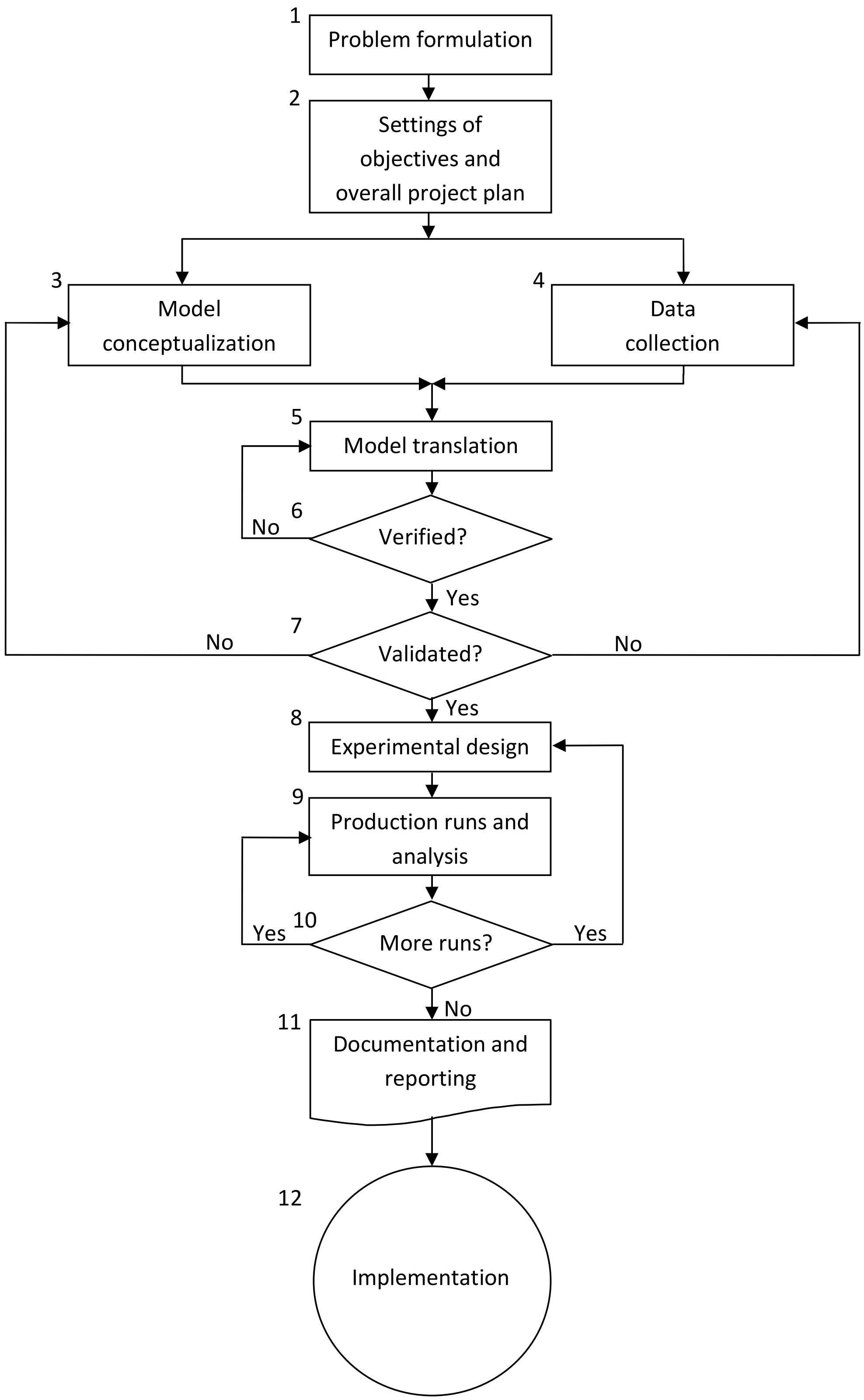


Figure 3 – Steps in a simulation study, also referred to as *Banks model* (Banks, 2005)

Problem formulation. The first step of the study is to determine its scope and to clearly state the problem(s) to solve. What is important here is that the client that has ordered the simulation study and the group or person that is conducting the study (hereafter referred to as "simulation engineers") have a thorough understanding of the problem. (Banks, 2005)

Understanding the problem is especially important due to the fact that the company performing the study is most often not experienced with the system that is the target of the simulation study (Ulgen et al., 1994).

Setting of objectives and overall project plan. Step two is the setting of objectives and the creation of the overall project plan. The objectives are an indication to which questions that are to be answered by the study, for example what the major bottlenecks are in the production system. Here the question whether simulation is the right way to go should also be posed. In some cases common sense, an analytical approach or a direct experiment can be used instead of simulation. Choosing a different approach than simulation can for example be necessary if the cost of the simulation study exceeds the possible savings or if the simulation study takes more time than the time available. (Banks, 2005)

In this step there is also a need to make a cost-benefit analysis of the entire project. A simulation study can be an expensive endeavour and if the cost of the project is very high compared to the possible financial gain there will not be a need for a simulation study at all. A common ratio for the cost benefit can be around one to one-hundred up to one to one-thousand. In other words, the savings or earnings from conducting a simulation study should be one hundred to one thousand times more than the cost of the study. These figures represent the entire life cycle of the system that is modelled. (Ulgen et al., 1994)

The client must be the one to clearly specify the objectives. This is preferably done together with the client's high level management. When forming the project group responsible for the simulation study an engineer from the client's organization is usually assigned to the project group together with a manager/supervisor. From the viewpoint of the simulation engineers it is also preferred to involve an engineer and a project manager to be able to communicate with the client on all levels. (Ulgen et al., 1994)

It is also in this phase that the need for alternate models (which can be different versions of the same system) is decided upon. (Banks, 2005)

The project plan itself involves except the objectives also the number of people involved, the cost of the study, time spent on each part of the study and the results for each part of the study. (Banks, 2005)

Model conceptualization. Step three is the conceptualization of the model. This is the phase in which conceptual construction of the model starts by generating a basic understanding of the actual system. The conceptual model consists of an approximation of the real system containing its essential features together with necessary assumptions. It is important to keep in mind to start with a simple model and incrementally increase the complexity without exceeding the needed level of complexity. A too complex model serves no purpose and will only increase costs and also possibly cause delays in the project. To involve the client in this phase is important in order to enhance the quality and to increase the client's confidence in the model. (Banks, 2005)

The result of this phase is hence the establishing of how to model the real world system in such a way that it minimizes the simulation effort while meeting the set objectives (Ulgen et al., 1994).

This phase includes decisions regarding the level of detail for the entities of the system (for example a machine). For some entities, detailed modelling is necessary, while others can be treated more like "black boxes". (Ulgen et al., 1994)

Concerning the level of involvement from the client, the company must keep in mind that information from one source in the client organization is most often not enough because different parts of the client's organization can have different perceptions of the system. To achieve an accurate conceptualization it is hence important to take in information about the system from several sources in the client's organization. (Ulgen et al., 1994)

Data collection. Step four, the data collection, is carried out alongside the model conceptualization phase. The data collection is the collection of input data (for example attributes such as cycle times) used in the model. The data collection phase consumes a large portion of the simulation study's total time. Due to this, it is important to start with this phase early in the study. The objectives of the study are the deciding factors of what data that is to be collected. (Banks, 2005)

The data collection is of utmost importance because of its impact on getting a good result. A perfect model will return a perfect result only if the data itself also is perfect. If the data is unreliable, so is the result.

The data that is to be collected can be divided into three different categories (Robinson and Bhatia, 1995):

- Available
- Not available but collectable
- Not available and not collectable

Available data can for example be digitalized logs from a machine in an excel sheet. Data that is *not available but collectable* can for example be data that can be collected manually by conducting a time study (Skoogh, 2009). *Not available and not collectable data* is the type of data that can cause problems for the simulation engineer. For that type of data qualified estimations can be made. These estimations must be made in a careful manner since the client will not accept results based on misleading or incorrect data. In this case a sensitivity analysis can be made in order to establish the accuracy of the results that these estimations will produce (Robinson and Bhatia, 1995).

Model translation. Step five is the model translation where the actual construction of a virtual model is started. Due to the wide range of possible DES-projects, a wide range of software exists for different scenarios. It is possible to construct a model in a simulation language, but the complexity of most systems dictates the need for some type of purpose-built simulation software. (Banks, 2005)

Verification. Step six is the verification phase where the constructed model is examined to assure that its input parameters and logical structure are working properly. This step usually contains a large portion of debugging and is therefore an iterative process as seen in fig x.x. (Banks, 2005)

According to Johansson, the verification phase answers the question: "Is the model built correctly?"(Johansson, 2006).

Validation. Step seven is validation, where the model is put under scrutiny in order to make sure that the model mimics the real world system in a satisfactory manner. This can for example be done by using historical data collected from the real world system as input to the model, running the model and checking (validating) that the model behaves in the same way as the real world system did. (Banks, 2005)

One of the most powerful ways to validate the model is to use the above mentioned technique where historical data is used. This method of validation proposed by Law and Kelton is called "The correlated inspection approach". Figure 4 demonstrates this type of comparison between the model and the real world system by the use of historical data.

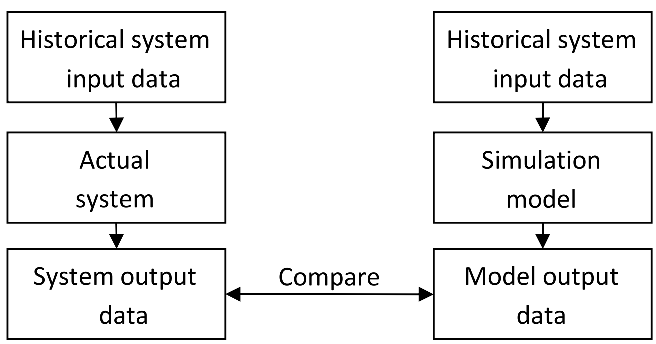


Figure 4 – The correlated inspection approach (Law and Kelton, 2007)

Experimental design. Step eight is the phase where decisions are made concerning what type of experimentation methods to use, how they are to be used and how to analyze their results (Banks, 2005). In this phase, the analysis base for the outcome of the simulation runs is set and in order to conduct the analysis some output parameters have to be set (Johansson, 2006). These output parameters can include such things as the number of replications of each scenario, required simulation time and output parameters from the real system (for example total output or lead time) (Johansson, 2006). Experimental design is commonly referred to as Design of Experiments (DOE).

Design of experiments incorporates the methods to use when conducting experiments. An important aspect of the DOE is to always use a method that will yield the least number of required simulation runs while maintaining a required level of quality (Goupy et al., 2007). One of these methods that are of interest when there is a need to study more that one parameter (for example cycle time or bath sizes) is called a factorial experiment (Law and Kelton, 2007). A factorial experiment refers to a way of conducting experiments with several parameters to understand the effects of their interactions on the result (Bergman and Klefsjö, 2010).

Production runs and analysis. Step nine is where the runs corresponding to the different scenarios of interest that have been decided upon in the previous step are carried out and analyzed.

More runs. Step ten is a check to see if there is vital information missing that was not derived from the production runs and analysis. If more information is needed, changes can be made in the experimental design resulting in more production runs and analyses.

Documentation and reporting. Step eleven regards the documentation and reporting. Banks divides the documentation into two types: program and progress. In the documentation of the program, the model created in the study is sufficiently explained for the end user. This documentation is important, for instance if some parts of the model is to be reused in later simulation studies or if a different simulation engineer needs to understand the model. Another reason can be that the client wants a greater understanding of the model because the client can then have greater use for it. (Banks, 2005)

The progress documentation contains information on the progress made in the simulation study. Reporting by the use of continuous documentation can help keep track on the progress of the project and detect misunderstandings or sudden changes early, before they become a problem. (Banks, 2005)

Another important reason of documentation is the ability to use that information in later simulation studies which can decrease the risk of repeating passed mistakes.

A final report that has documented the entire project in detail can also work as a form of certificate that can add to the credibility of the model. (Banks, 2005)

Implementation. The twelfth step is very straight forward; it deals with how the model is used after the completion of the project. The success of this phase is dependent on how well the previous eleven steps have been performed (Johansson, 2006). The implementation can range from the model being disregarded after all required analyses are finished to being used as an experimentation tool for a longer period of time.

3.1.5 Successful discrete-event simulation

To succeed with managing discrete-event simulation projects, there are several guidelines and critical success factors that need to be considered. When simulation is initially introduced within a company the first step, according to Ulgen and Williams, is to get management support and understanding. The understanding should include a basic knowledge of how simulation works and which results that can be expected with proper usage. Furthermore, management also has to understand the limitations of simulation and what kind of investments that are needed within simulation. (Ulgen and Williams, 2002)

In the 1996 article "Pitfalls of simulation modeling and how to avoid them by using a robust simulation methodology" Ulgen et al. list possible pitfalls within the simulation modeling and divides them into the three categories "*process, model and people related pitfalls"* as seen in table 1. (Ulgen et al., 1996)

Table 1 – Pitfalls of simulation (Ulgen et al., 1996)

Process related pitfalls

1. Unclear project objectives
2. Keeping the customer uninformed
3. Not establishing a base for comparison
4. Unrealistic expectations from the study
5. Too much faith in the input data
6. Infrequent reporting and lack of documentation
7. Infrequent customer interaction
8. Inadequate selling of project successes
9. Frequent scope changes
10. Too much faith in the simulation output
11. Inadequate review of the project while it is ongoing
12. Spending more time on the model rather than the problem
13. Not knowing when to stop

Model related pitfalls

1. Model assumptions not validated
2. Starting with an overly complex model
3. Losing sight of the implementation issues
4. Using the model sparingly
5. Not understanding the model's limits

People related pitfalls

1. Lack of teamwork
2. Not involving the key decision makers in the project
3. Not knowing and/or listening to the customer
4. Providing a small list of alternatives to the customer
5. Being afraid of advocating change

One of the main observations Ulgen et al. make regarding the pitfalls is that a large number of them are related to project management and further state that by "incorporating the proper simulation project management planning, scheduling, reporting, and control techniques as a part of the simulation methodology, one may increase the success of simulation significantly".

3.2 Outsourcing and offshoring

In his book, "The World is Flat", Thomas Friedman lists ten reasons, "flatteners", to why he believes that the global competition field had been "leveled" in 2005 when the first edition of his book was released. As the first flattener, Friedman mentions the fall of the Berlin Wall in 1989 when countries and people behind the iron curtain could join the economic mainstream arena and play by the same rules as western countries. This chapter focuses on flattener five and six in the book: the concepts *outsourcing* and *offshoring*. (Friedman, 2006)

Outsourcing refers to taking a process previously done in-house, such as accounting, and giving it away to a specialized company. The theory behind outsourcing basically states that if there is another company, focused only around one particular task, the likelihood is high that that particular company can perform that particular task for your company with at least the same quality, but at a lower price compared to the cost of doing it yourself. (Friedman, 2006)

As with many management terms there are several, sometimes even contradictive, definitions of outsourcing. The definition used in this thesis is the definition of Holtsnider and Jaffe in "The IT Managers Handbook" which defines *outsourcing* as (Holtsnider and Jaffe, 2007):

> *"When one company makes an agreement with a second company to provide services that the first could provide, but chooses not to."*

Offshoring, as described by Friedman, is the process of moving your main business activity, such as a complete factory (in contrast to outsourcing for instance back office activities), to another country where the same main activity can be performed in the same way, only under better competitive conditions such as "cheaper labor, lower taxes, subsidized energy, and lower health-care costs". (Friedman, 2006)

As with outsourcing, several definitions exist for offshoring. The usage of the word *offshoring* in this thesis follows the definition by Deardorff's Glossary of International Economics (Deardorff, 2010):

> *"Movement to a location in another country of some part of a firm's activity, usually a part of its production process or, frequently, various back office functions."*

Many of the outsourcing examples in the text are examples of *offshore outsourcing*, which logically means that another company in another country is performing the mentioned activity.

3.2.1 Background and requirements for outsourcing and offshoring

So why have outsourcing and offshoring become possible and popular? In the book, "Outsourcing to India: The offshore advantage" Mark Kobayashi-Hillary lists four basic drivers of outsourcing becoming an interesting alternative for businesses (Kobayashi-Hillary, 2005):

- Government policy and political stimulation
- Globalisation and the Knowledge Economy
- Technology
- Corporate strategy

Government policy and political stimulation. When the global economy is becoming more and more knowledge centered, it is important for nations that their governments adopt positive policies towards outsourcing for their national companies to be able to compete on the international market. There is often opposition from unions regarding low-skilled labor outsourcing. Kobayashi-Hillary mentions the British Communication Workers Union (CWU) being opposed to call-center outsourcing and orchestrating the “Pink Elephant campaign” which highlighted the issue of jobs being outsourced to India. The position of the UK government however, is that it is up to companies to decide where they want to locate their call centers. This position has led the CWU to the conclusion that if they can’t compete on cost they will have to compete on providing better service quality. (Kobayashi-Hillary, 2005)

Another political issue mentioned is the aging population in the developed world and how future lack of workforce due to decreasing birth rates only can be tackled by either workforce immigration or labor migration. (Kobayashi-Hillary, 2005)

Globalization and the Knowledge Economy. Kobayashi-Hillary quotes the former chief executive of Coca Cola, Robert Goizueta saying: “We used to be an American company with a large international business. Now we’re a large international company with a sizeable American business.” Globalization creates competition by allowing companies to choose any supplier based on any criteria which creates both better and cheaper products for the end consumer. (Kobayashi-Hillary, 2005)

The effects of globalization are becoming more obvious and can for instance be seen in the text printed on the Apple iPod: “Designed by Apple in California Assembled in China”.

This statement however does not tell all about the effect of globalization on the components in the product. The more than 400 components of the most expensive 3rd-generation iPod in 2005 were studied and among the 10 most costly components (together adding up 85% of the component cost), only two components, together creating 9% of the part cost, were made by companies with US located headquarters. And only one of them, the CPU maker Portal Player, has manufacturing located in the US. (Linden et al., 2007)

When talking about the future workers in the flat world, Friedman categorizes people in *special people, specialized people, anchored people* and *adaptable people*. Special people are “superstars” like Bill Gates or Michael Jordan. Specialized people are experts within a very narrow field which cannot be replaced because of possessing knowledge no one else has. Anchored people are performing work that has to be done on-site face-to-face and have professions such as barbers, waitresses, plumbers etc. Finally, adaptable people use constant learning to be able to survive in the knowledge economy. According to Friedman, “if you cannot be special or specialized, you don't want to count on being anchored so you won't be outsourced. You actually want to become really adaptable. You want constantly to acquire new skills, knowledge, and expertise that enable you constantly to be able to create value”. (Friedman, 2006)

Technology. Predicting the future is usually a difficult task and many predictions about the future are afterwards ridiculed due to being completely wrong. One of the oldest predictions about the future that still today is true is the famous prediction referred to as *Moore’s law*, first formulated in 1965 by Intel co-founder Gordon Moore regarding the number of components on an integrated circuit with the minimum component cost. Moore noted that the number of components was increasing “at a rate of roughly a factor of two per year” and that “there is no reason to believe it [the rate] will not remain nearly constant for at least 10 years” (Moore, 1965). Ten years later, in 1975, Moore updated his projection to a doubling every two years (Moore, 1975) – a statement which is still true and according to Pat Gelsinger, SVP and co-GM of Intel's Digital Enterprise Group, will remain true until, at least, 2029 (Geelan, 2008).

Moore’s law basically means that computing power is becoming faster and cheaper at a very fast rate. This fact has been one of the main reasons of the development of today’s information society. The other big things enabling work in offshore locations are of course the Internet and telecommunication technologies allowing almost instantaneous communication and fast information transfers despite great geographical distances. (Kobayashi-Hillary, 2005)

Corporate strategy. Kobayashi-Hillary gives credit to Michael E. Porter and Charles Handy for popularizing outsourcing as a competitive concept for businesses. Porter is famous for the value chain-model developed in 1985 making managers understand what type of work that adds value to their product or service. Handy divided the people within the organization into *core workers*, *contract employees* and *flexible workers*. The core workers perform “essential and managerial tasks”. The contract employees are hired for “specific, time-bound projects” and the flexible labor is used “for maintenance, sorting the mail and cleaning the office”. What Porter and Handy had in common was that their theories supported a focus on the companies’ core competencies. Kobayashi-Hillary therefore makes the managerial suggestion to “[l]ook into your value chain and focus on what you are good at. Let the experts worry about the remaining tasks”. (Kobayashi-Hillary, 2005)

3.2.2 Business motivations for offshoring

“Every morning in Africa, a gazelle wakes up.
It knows it must run faster than the fastest lion or it will be killed.
Every morning in Africa, a lion wakes up.
It knows it must outrun the slowest gazelle or it will starve to death.
It doesn't matter whether you are a lion or a gazelle.
When the sun comes up, you better start running.”

-African proverb

The main argument and business motivation for offshoring and offshore outsourcing (hereafter both offshoring and offshore outsourcing are referred to only as *offshoring* unless otherwise stated) is most often the fact that money can be made when offshoring is properly performed. This is supported by the fact that in for example India the typical salary for an IT-worker is 25 - 30 % of the European equivalent (Kobayashi-Hillary, 2005). It is common that an offshored IT-project can demonstrate an Internal Rate of Return of over 100 % compared to an IRR below 70 % when done onshore (Gold, 2005).

However some old myths regarding offshoring still live on. One of the thought mistakes exemplified by Friedman is the illusion that there exists a “fixed lump of labor in the world” and that it, from a nationalistic perspective, should be preferable to have as much as possible of that lump inside your country. The faulty conclusion here is of course not thinking about that “sending away” jobs to new locations makes the global lump of labor grow. The salaries being paid create more wants which of course creates more needs and thus expands markets. Also making more people work in knowledge intensive jobs boosts innovation which then, of course, creates even more jobs. (Friedman, 2006)

The globalist view of making the world a better place for more people and by doing so expanding markets globally might not be a completely obvious worldview from a business perspective where many times a long term financial gain is neglected where fast and "safe" short term money can be gained. The possibility for short term financial gain, however, is of course true in offshoring as well. If the same work can be performed with the same quality at a fraction of the cost in the same amount of time, the reason for businesses to get involved with offshoring is obvious.

Since in this day and age where globalization is a fact, for many companies, going offshore is not just an option but something that is imperative in order to stay competitive. (Gold, 2005)

The financial gain is however not the only advantage with offshoring. Two other advantages are:

Creative use of time zones provides the possibility to use more hours of each day. When operating under large time differences offshoring can provide a possibility to use more hours of each workday since the offshored organization can sleep while the onshored organization works and vice versa. This can of course lead to a substantial increase in productivity. (Gold, 2005)

Bridge cultural differences. Today many large corporations are committed to diversity, but in reality sometimes have a homogenous staff at least in certain fields. Offshoring can be a valuable real-life opportunity providing understanding of the positive organizational effects derived from cultural diversity. Gold gives a vivid example of how a group dressed in saris walking through the corporate halls acts as "a breath of fresh air, a new way of looking at the world for employees". (Gold, 2005)

There are of course not only advantages with offshoring. Some of the disadvantages include:

- Initially a steep cost curve
- Cultural differences
- Natural limits

Initially a steep cost curve. The overhead costs of the initial phase of offshoring can be very high and must be taken into consideration. It will take some time before the offshored organization has ramped up to a profitable level. (Holtsnider and Jaffe, 2007)

Cultural differences. Even though the staff in the country that is the target for offshoring speaks the same language as the onshore company there are still cultural differences to take into considerations, otherwise problems can arise. One of many examples is the fact that national holidays in for example Europe and India differ a lot from each other and usually no one wants to work during a big holiday. Both sides must be comfortable with the arrangement for the offshoring to be successful. (Holtsnider and Jaffe, 2007)

In chapter 3.3.4 Cultural aspects, some further cultural dimensions are discussed.

Natural limits. There is also the obvious issue of natural limits due to geographical distances in offshoring, for instance in time differences, not being able to meet physically or visiting clients and their facilities. Time differences can be used to one's advantage but can at the same time also be a disadvantage. This since direct communication (eg having a telephone conference) will be more difficult. One example of this is when for example the time difference is fairly large (say 12 hours) which will mean that if there is a need to have direct communication, either the onshore or the offshored organization will have to communicate outside normal office hours.

3.2.3 India and China

One of the reasons for the recent outsourcing and offshoring popularity is the development of India and China. India became a serious option for information technology outsourcing in 1999, when the fear of the Y2K software bug was widespread and the workload associated with securing information systems was unbearable for western computer engineers. (Friedman, 2006)

Friedman identifies three reasons to why India was chosen as a knowledge industry outsourcing location:

- Broadband Internet connection
- Expertise
- English proficiency

Broadband Internet connection. After the dot-com bubble burst in 1999, prices dropped dramatically on broadband Internet connection in India. This was due to the fact that a lot of fiber-optic cable already existed in the country due to investments made by risk capitalists believing in an endless expansion of the digital world. This of course provided India with very cheap and good Internet connection towards the USA and the rest of the world.

Expertise. The Indian Institutes of Technology (IITs) provide a very high level of education within computer sciences, management and engineering.

English proficiency. Being an old British colony and a large nation, India houses the second largest English speaking population in the world.

When China joined the World Trade Organization in 2001, they quickly became an attractive market for manufacturing offshoring. According to Friedman, this made international companies feel safer regarding operating in China and the new more capitalistic ruling of the nation opened up a completely new market with more than a billion potential customers. (Friedman, 2006)

While India became a centre for knowledge outsourcing, China was in 2001 primarily regarded as a destination for production offshoring. However this initial focus has broadened as the Chinese are becoming more skilled. According to official Chinese numbers, around 15,000 Ph.D. degrees, more than 100,000 master’s degrees and more than 700,000 bachelor’s degrees in engineering were awarded in 2009 (Wang et al., 2010). For comparison, 78,000 bachelor’s degrees were awarded in the US in 2008 (Wang et al., 2010). Some researchers claim that the Chinese numbers are overstated (Davidson, 2006), but nevertheless their dimensions are in such magnitudes that regarding China as a country only equipped with cheap low-skilled labor is a both ignorant and obsolete world view.

Friedman states that “[b]ecause China can amass so many low-wage workers at the unskilled, semiskilled, and skilled levels, because it has such a voracious appetite for factory, equipment and knowledge jobs to keep its people employed and because it has such a massive and burgeoning consumer market, it has become an unparalleled zone for offshoring”. (Friedman, 2006)

3.2.4 Cultural aspects

Cultural differences between countries concerning business have been studied by professor Geert Hofstede who has developed a model referred to as Hofstede's five Cultural Dimensions. The dimensions give a quantified and comparable view on cultural differences and gives a possibility to compare countries to each other under five dimensions to understand what is similar between the their cultures and what is not. (Hofstede, 2009b)

The dimensions are:

- Power Distance Index (PDI)
- Individualism (IDV)
- Masculinity (MAS)
- Uncertainty Avoidance Index (UAI)
- Long-Term Orientation (LTO)

Power Distance Index (PDI). The power distance index refers to “the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally”. This can be exemplified by the difference in how an employee can approach an executive. In some cultures it is accepted for the employee to question an executive’s decision but in other cultures it is not. (Hofstede, 2009b)

Individualism (IDV). The individualism-measurement refers to “the degree to which individuals are integrated into groups”. In a culture with a high level of individualism, individuals are expected to look after themselves and their immediate family. The opposite of individualism is collectivism, referring to “societies in which people from birth onwards are integrated into strong, cohesive in-groups, often extended families (with uncles, aunts and grandparents) which continue protecting them in exchange for unquestioning loyalty”. (Hofstede, 2009b)

Masculinity (MAS). Masculinity concerns “the distribution of roles between the genders”. In masculine societies the role of men are signified as being much more assertive and competitive compared to women. In feminine societies the difference in roles are less significant. (Hofstede, 2009b)

Uncertainty Avoidance Index (UAI). The uncertainty avoidance index “deals with a society's tolerance for uncertainty and ambiguity; it ultimately refers to man's search for Truth.” A society with a high level of UAI “programs” its people with the notion that things that are out of the ordinary and that conflict with what is considered to be the general truth should be avoided by for example laws and security measures. On the other hand, a society that has a low level UAI accepts to much higher degree things that can differ from the general truth and allows to a higher extent opinions that differ from what they are used to. A society that is not uncertainty avoiding is also to a lesser extent expected to express emotions. (Hofstede, 2009b)

Long-Term Orientation (LTO). Long-term orientation and its opposite short-term orientation refer to how a society looks upon life. Long-term orientation can be explained by characterizing values such as “thrift and perseverance” while short-term orientation is characterized by values such as respect for tradition and fulfilment of social obligations. (Hofstede, 2009b)

Figure 5 compares the countries Sweden, USA, India and China under Hofstede's five Cultural Dimensions.

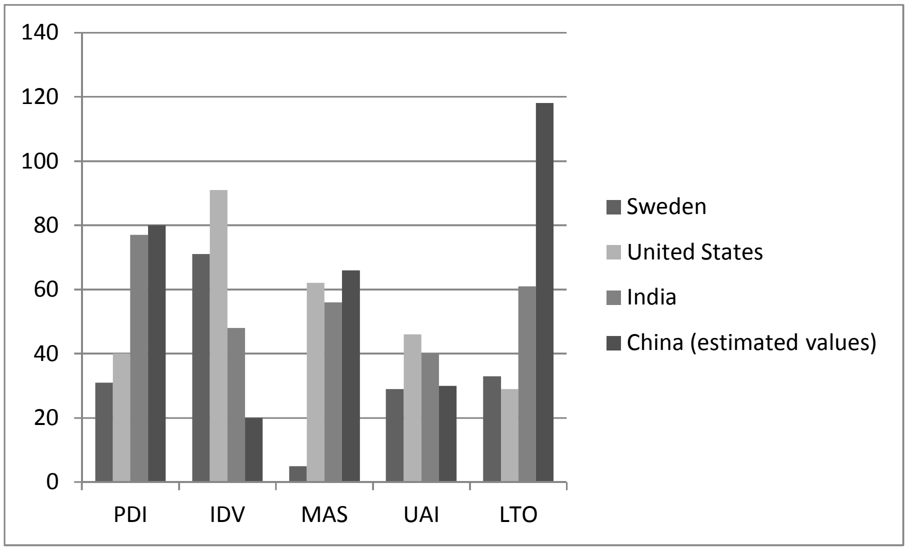


Figure 5 – Hofstede's five cultural dimensions (Hofstede, 2009a)

As seen in the figure there are substantial differences between Sweden, India, USA and China when looking at the five cultural dimensions, but there are also similiarities. Looking for example at the power distance index (PDI) the levels are similar between India and China and between Sweden and USA. This indicates that within the two mentioned pairs they are similar to each other regarding for example how an employee can and cannot question an executive. While looking at for example the masculinity (MAS) index of Sweden it can be seen that is substantially lower than the other three countries, indicating that in Sweden the distibution of roles between genders are more equal than for the other three countries. The reasons to the differences and similarites are many and sometimes complex.

3.2.5 Successful offshoring/outsourcing

Offshoring is an interesting part of a company's business strategy, becoming more and more important in the flatter world. However, in order to perform successful offshoring there are certain pitfalls to consider. Dr. Wendell Jones mentions ten pitfalls (and puts emphasis on the first six) within offshore outsourcing (Jones, 2003), as seen in table 2:

Table 2 - Pitfalls in offshore outsourcing

1. Difficulty of face-to-face interaction and communication
2. Overestimating cost savings
3. Cultural mismatches
4. Potential effect on staff not directly involved in the outsourcing agreement
5. Adverse publicity from misunderstanding of offshoring motives and benefits of globalization.
6. Failure to develop a detailed plan
7. Failure to retain certain critical skills inhouse
8. Failure to locate 20-30 % of the offshore supplier's development staff on-site

9. Failure to create an equally treated joint team
10. Failure to take care of the remaining inhouse team

Difficulty in face-to face communication will lead to some tasks being difficult or impossible to perform offshore. *Overstating the possibility of cost savings* can be caused by the assumption that all work can be offshored which can lead to lower cost savings than projected. *Cultural differences* are important to be aware of, which does not only refer to cultural differences concerning for example local traditions but also differences in business and corporate cultures. (Jones, 2003)

Inadequate communication from management to the staff regarding the effect of the offshoring process on their work tasks can typically cause worry or even dysfunctional behaviour. In other words, people might be worried what will happen to their own jobs if some parts of the organization is being offshored. Issues concerning *publicity* are important, even such an insignificant thing as a rumour saying that jobs are getting shipped overseas can cause large publicity issues. *A detailed plan* that is anchored in the organization is important in order for the offshoring to be successful. (Jones, 2003)

Gold states in "Outsourcing Software Development Offshore" that the key to success lies in executive support and communications (Gold, 2005). To have a strong support from management is crucial due to the inherent difficulties in making big changes to an organization, which is common in the realms of offshoring. Jones summarizes this type of change management by stating that "[f]irst and foremost, successful offshoring is about managing change across organizations, borders, and cultures" (Jones, 2003).

Executive support must also be present to deal with issues concerning the fact that offshoring is controversial due to for example misconceptions regarding globalization and to mitigate these possible problems. With executive support comes the importance of communication. It is imperative to keep the staff in the organization up to speed on what is going on. Gold sums this up saying that "[i]deally, part of the general message from the executive team will be to lay out the total strategy in terms of what work is affected (in terms of roles, not individuals), and what the organization is planning on doing in terms of supporting individuals who can be retrained to other roles within the organization". (Gold, 2005)

3.3 Communication

When interacting with someone on an offshore location, it is important to look into *communication.* Two of the many definitions given by Random House College Dictionary are (Random House College Dictionary, 2010):

> *"something imparted, interchanged, or transmitted"*

and

> *"means of sending messages, orders, etc., including telephone, telegraph, radio, and television"*

When discussing communication overall, one might focus on more practical aspects such as by which means messages should be relayed (email, telephone etc). These practical aspects are of course important but what can sometimes be missed is the importance of theory concerning communication.

3.3.1 Communication theory

It can easily be concluded that language is of importance when communicating, but this does not just mean that that as long as both a sender and receiver speaks the same language they will automatically understand each other at all times. It is a little more complex than that.

As Bertil Gustafsson states in his dissertation "Worklife – viewed through the lens of an interventionist theory of knowledge", concepts (in the realm of simulation, one example can be "entity") belongs to what is called a paradigm. This means that the meaning of a concept is controlled by a more general notion, that a concept belongs to an overall understanding. A simple example can be that the concept of "process" can be interpreted in a number of ways depending on what paradigm it might belong to. Concepts work as means to create order and context in our way of thinking. (Gustafsson, 2008)

What is referred to as discourse is something that is determined by the paradigm. A discourse can be likened to discussion with the exception that the discourse is limited to a certain context and that that context has reached a level of recognition thus leading to the discourse becoming institutionalized. It is the paradigm and the discourse that both limits and determines how we perceive our surroundings. (Gustafsson, 2008)

3.3.2 Shannon and Weaver's Model of Communication

When it comes to the more practical aspects of human communication, a famous model created by Shannon and Weaver visualizes the aspects of communication sent between two destinations. The linear mathematical model was originally created to depict how information is sent in the realms of electronics, but has later been generalized to describe human communication as well. The Shannon-Weaver model is shown in fig 6. (Griffin, 2009)

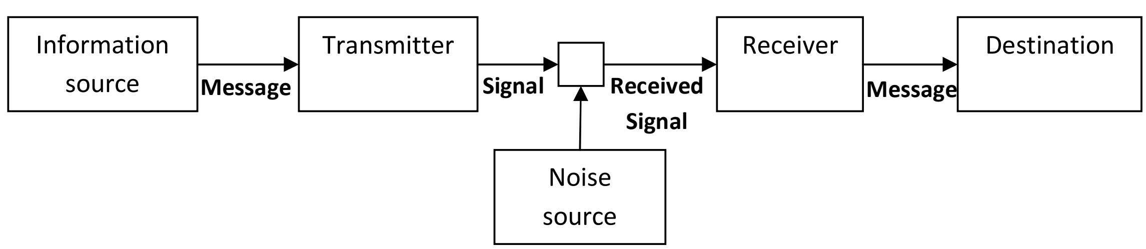


Figure 6 – Shannon and Weaver's Model of Communication (Griffin, 2009)

The Shannon-Weaver model consists of six parts:

- The information source
- The transmitter
- Noise
- Receiver
- Destination

The information source. The information source, in the Shannon-Weaver model, is the origin from which a message is sent. In the realms of electronics, the information source can be represented by a computer. In human communication this can for example be represented by an idea thought up by a person. (Griffin, 2009)

The transmitter. The transmitter receives the message and transforms it to a signal. In the realm of electronics this is for instance represented by the modem. This can in human communication be represented by the voice of the person transforming the electrical impulses from the brain into sound waves. (Griffin, 2009)

Noise. Disturbances will always exist in communication. In the Shannon-Weaver model this is defined as noise. The noise affects the signal so that another signal is received. Noise can for example be signal noise over a telephone wire or the background sounds in a loud environment during a verbal conversation. (Griffin, 2009)

The receiver. The receiver receives the signal and transforms it back to a message. In electronic communication, this can for example be the receiving modem. Between humans this can be the parts of the inner ear transforming the sound waves into electrical impulses for the brain. (Griffin, 2009)

Destination. The destination is the place where the message is intended to arrive. In electronic communication, this can be depicted by the fax machine printing the message to a paper whereas in human communication, this can be the mind of the person receiving the message. (Griffin, 2009)

3.3.3 Difficulties in communication

Communication is not by any means easy. This is exemplified by a series of “laws” stated by Professor Osmo A. Wiio, famous for his research in human communication. Wiio’s laws are not stated as undeniably valid but give a humorously formulated way of describing difficulties in communication. There is a clear relationship between Wiio’s laws and the famous ”Murphy’s law” stating that ”anything that can go wrong, will go wrong”. (Korpela, 2010)

A selection of Wiio’s laws include:

- If communication can fail, it will
- If communication cannot fail, it still most usually fails
- If communication seems to succeed in the intended way, there is a misunderstanding
- If you are content with your message, communication certainly fails

These laws can be seen as entertaining but quite pessimistic, by they are put forward to highlight the difficulties with communicating in order to be able to avoid problems, or at least diminish their effect. (Korpela, 2010)

There are many reasons to why communication fails such as language differences, cultural differences and personal differences. (Korpela, 2010)

A simple example of the difficulty can be shown by using a basic statistical assumption. Say that for each step in the Shannon-Weaver model there is a five percent chance that the information conveyed will be distorted to the extent of not being able to be used. This would mean that when the information from the *information source* reaches the *destination* there is almost a 19% chance that the information is lost and this is without taken consideration to *noise*.

4 Research approach

This chapter describes the research approach. It is divided into two main parts:

- DES-offshoring case study
- Professional DES-offshoring

The first part, the offshoring case study, describes the creation process and conceptualization of a DES-model of a fictional factory producing chairs. The conceptual model is later used, together with a written software guide for Enterprise Dynamics, as handout material in an embedded case study on offshoring of Discrete-Event Simulation-projects. The case study consists of four differently sized units divided with respect to their internal differences regarding simulation and work experience. The units were studied similarly where applicable, differently where not applicable. A limitation on the study was that the main purpose for the members of the two largest units was not to participate in the study, but rather to receive training in Enterprise Dynamics and DES-modeling.

The second part, the professional offshoring, is focused on understanding how DES-offshoring is performed in practice. It describes topics, interviewees and methodology used in the semi-structured interviews with DES-professionals.

4.1 DES-offshoring case study

This chapter describes the approach for the performed DES-offshoring case study.

4.1.1 Introduction

As mentioned in the method (chapter 2), to the researchers' knowledge no available written theory existed on offshoring of DES-projects. Therefore, in order to derive information of interest on offshoring of DES-projects a case study was chosen to be performed.

Purpose

The purpose of the study was to create a knowledge base for offshoring of a DES-project in a real-life setting.

To fulfil the purpose it was decided to emulate an offshoring of a DES-project. In the emulated offshoring the studied persons and groups were divided into units that were to participate in a small simulation study on a fictional production facility. The units were to play the roles of offshored simulation engineers while the researchers acted as onshored project managers of the simulation project, mainly providing the units with written material.

In other words the intention was to imitate an offshoring of a simulation study.

Objectives

From a practitioner's point-of-view, the main thing differentiating an offshored project from a non-offshored project is the simple fact that the simulation engineer cannot be physically present at the site where the object that is to be modelled is located. Due to this, the communication quality between the offshored engineer and the onshored manager plays a crucial role for the success of the simulation project. Therefore the following objectives were set up for the case study:

- To investigate how an offshored simulation engineer interprets information depending on individual level of simulation skills and prior work experience.
- To investigate where common problem areas lie when an offshored simulation engineer interprets information from an onshored location.
- To investigate what means and what frequencies of communication that is needed between offshored and onshored locations.

Delimitations

There were mainly four delimitations in this case study:

- The purpose of the two largest units participating in the study not being participation in the study for the study itself
- Not being able to influence time and occasions
- Not being able to choose unit participants
- Not being familiar with the simulation software

The purpose of the two largest units participating in the study not being participation in the study for the study itself. The two largest units in the case study were not mainly participating in the study as a part of the research but first and foremost in order to get training on DES in Enterprise Dynamics. This limited what parts of the simulation study to emulate. Because of this, it was decided that the first four steps in Banks model (*the problem formulation*, *the setting of objectives and overall project plan*, *model conceptualization*, *data collection*) were not to be emulated. In other words, from the units that conducted the case study's point of view, the first fours steps (in Banks model) were already completed.

Another reason for choosing to not emulate the first four steps was assumptions concerning what can be offshored during the first four steps. One example is that an offshored simulation engineer is very unlikely to be physically present, if there for example is a need to visit a production facility for data collection.

This led to the delimitation that the task for the units was to immediately start with the *model translation step* (step five in Banks model).

Not being able to influence time and occasions. Stemming from the fact that the thesis work is performed in cooperation with a company, the time and occasions available for the case study were in large parts not possible to be influenced by the researchers. One effect from this is that the number of occasions, their length in time and the intervals between them differed between units, leading to units performing the case study under different conditions. Another effect from this delimitation was that the first occasion was placed at an early point in time both seen from a thesis lifetime perspective and from a case preparatory perspective.

Not being able to choose unit participants. Stemming from the same fact as the previous delimitation, it was not regarded as possible for the researchers to affect the number of participants in some of the units and their preconditions.

Not being familiar with the simulation software. Due to the external circumstances of the first two units doing the case mainly for DES training purposes which regarded a specific simulation software

(Enterprise Dynamics) which the authors had no prior experience with, a substantial amount of time was spent getting familiar with the software in question. The researchers' lack of prior knowledge in the simulation software was regarded as a possible delimitation on both results and performed work.

Method

Before deciding on how to conduct the case study the categorization of the units was decided. The categorization was made with regard to the real life setting where people being on the receiving end of an offshored simulation study have different work and/or simulation experience. The categorization was made with respect to the fact that the first and second unit consisted of two of the company's clients that had ordered training on DES in Enterprise Dynamics. In addition to the first two units, two other units were determined to be part of the study. The units were categorized in such a way that they were to represent a spectrum of people that could be on the receiving end of an offshoring of a DES-project. The units were categorized as such:

1. People with no simulation experience and no work experience.
2. People with no simulation experience and work experience.
3. People with simulation experience and work experience.
4. An expert panel consisting of people with both work and academic experience in simulation.

The objectives of the study were oriented around understanding requirements on communication from the onshore to the offshore location. The information gathered during the initial steps in a simulation study can be summarized within the third step, the *model conceptualization*. Therefore emphasis was put on the understanding of how people interpret conceptual models in which data from the *data collection* step also is available, when given the task to complete the *model translation* step (i.e. building a model).

After establishing the unit categorization and delimitations for the study, a methodology for meeting the set objectives was created. The methodology was divided into three parts:

- Case material creation
- Case execution
- Data collection

Below follows a short description of the three parts of the methodology which are more thoroughly described in section 4.1.2-4.1.4.

Case material creation. Material that was needed in order to conduct the study was produced. The material consisted of two main parts:

- A model (from now on referred to as the *original model*) of a fictitious production facility created in Enterprise Dynamics.
- Three documents describing the *original model*.
    - A model description (from now on referred to as the *conceptual model*, viewable in appendix A).
    - A guide on how to build the model in Enterprise Dynamics (from now on referred to as the *software guide*).
    - A guide on how to conduct experiments in Enterprise Dynamics (from now on referred to as the *experiment guide*).

The *software guide* and *experiment guide* were solely created to enable unit 1 and unit 2 to work with Enterprise Dynamics.

Case execution. The case study was not only executed in order to meet the objectives of the study, but also in order to give unit 1 and unit 2 training in model building. The work performed by these units was divided into two main tasks: Firstly to reproduce the *original model* (referred to as the creation of the *BaseModel)* and secondly to improve its performance and thereby creating the *FinalModel*. This execution procedure was chosen for two reasons. The first was to increase the units members' knowledge of Enterprise Dynamics and model building in general by the means of "learning by doing". The second was to increase the possibility for additional gathering of data concerning the *model translation step* and the steps in Banks model concerning experimentation (step 8-10).

Before improvements of the *BaseModel* were allowed to start, the model builders were required to get an approval from the researchers by *verification* and *validation* (step six and seven in Banks model, fig 3) of their *BaseModel.* From the viewpoint of unit 1 and unit 2, the improvement goal for the *FinalModel* was to increase the output of the fictional production facility.

The members of unit 3 were for different purposes provided with different material and only constructed the *BaseModel*. Unit 4 did not perform any model building at all, but some of its members were instructed to study the *conceptual model* and provide the researchers with their views, remarks and feedback. The other members of unit 4 were sent a survey concerning their previous participation as supervisors in a simulation course.

Data collection. Depending on the context the units were studied under, the methods for data collection differed for two reasons.. The first reason was that it was not simply possible to utilize all ways of data collection on all units. For example it was not possible to interview all the participants in the case study from a time perspective. The second reason was that the use of several ways of collecting data would increase the possibility to collect more data.

The case study methodology is shown graphically in figure 7.

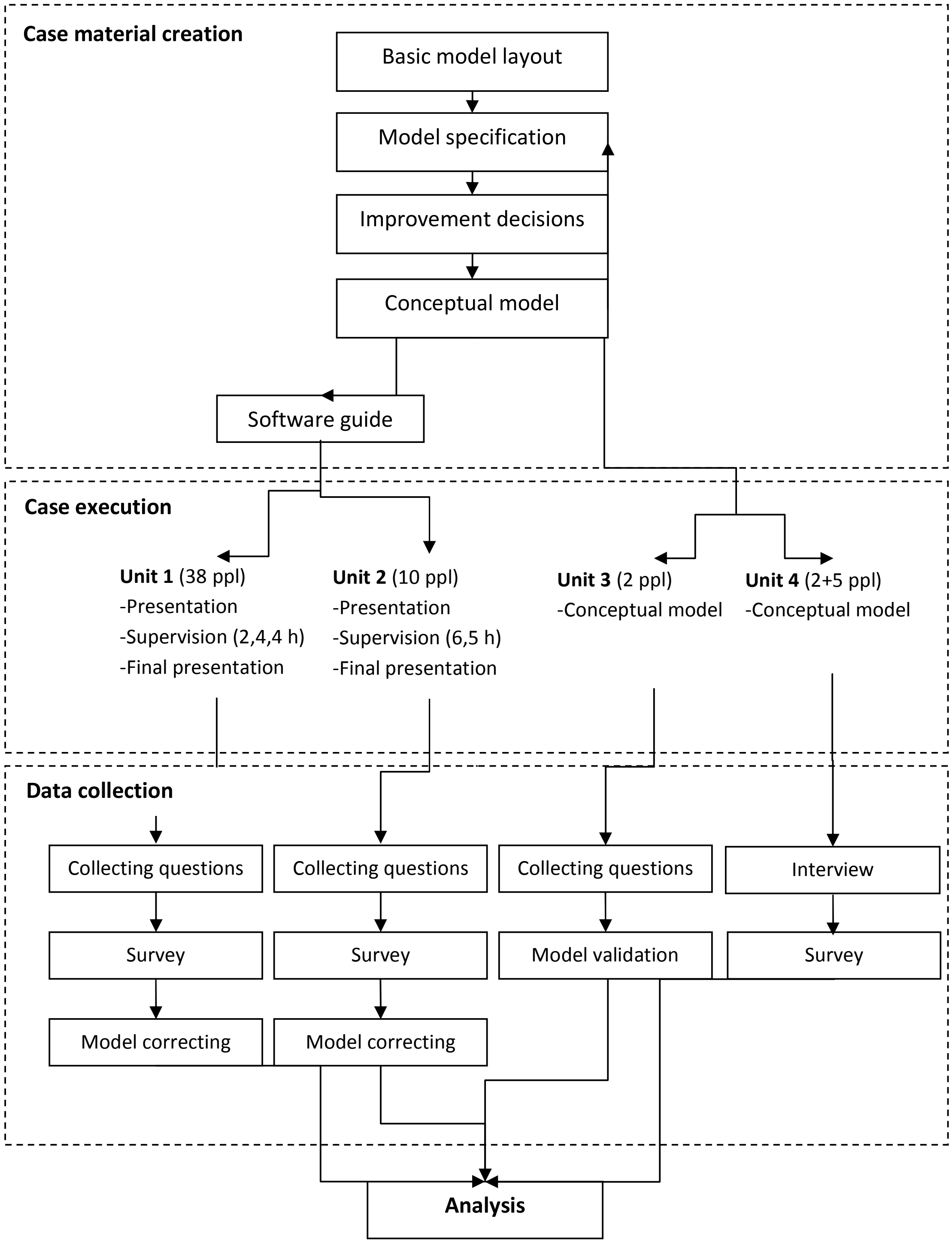


Figure 7 – Case study methodology

4.1.2 Case material creation

The case material creation chapter describes the construction of the *original model* and the development of the documents *the conceptual model, the software guide and the experiment guide*. The phases in the case material creation are shown in fig 8.

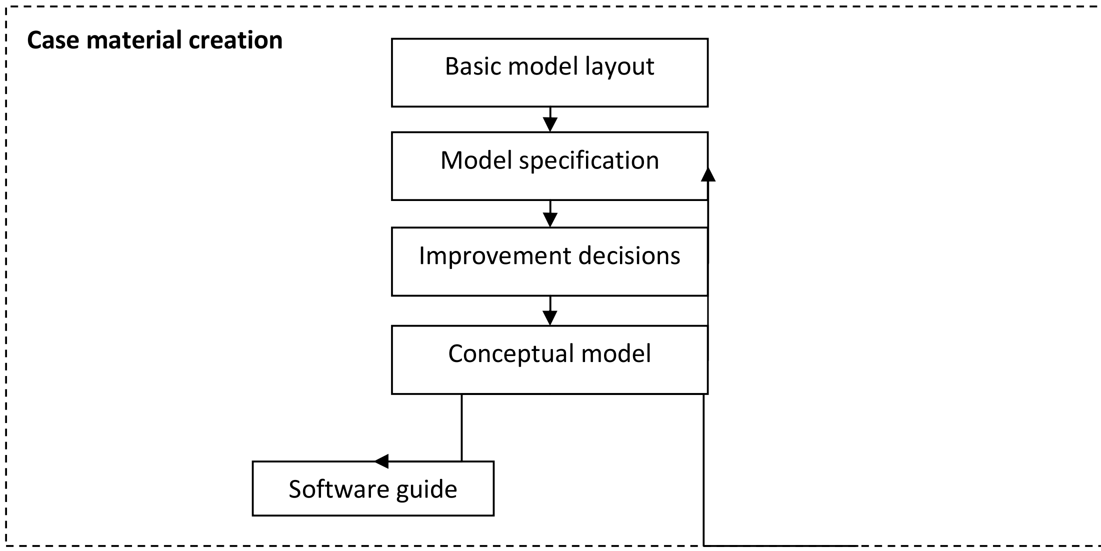


Figure 8 – Case material creation

Basic layout. The case material creation started by developing a basic layout of a fictional production facility which was later translated to a model in Enterprise Dynamics (serving as the basis for the *original model*). Due to the fact that two units primarily participated in the study for ED-training purposes, material that the company previously had used with other clients was used as inspiration for the layout.

The main thought when designing the layout was that the production flow should be simple to understand and relatively easy to model, but still contain a variety of the entities featured in the software. To show the benefits of simulation, a central thought was to create a system in need of improvements where one identified and exploited bottleneck would create a new exploitable bottleneck thus making the improvement process complex, if not impossible, unless performed in an iterative manner.

It was also desired that when modelling the *BaseModel,* the units would encounter an increasing level of difficulty both for training purposes and for the ability to see how the level of difficulty affected the units from the researchers' perspective. In other words the *basic layout* as seen in fig 9 was designed to be increasingly difficult to model if the model is built from left to right.

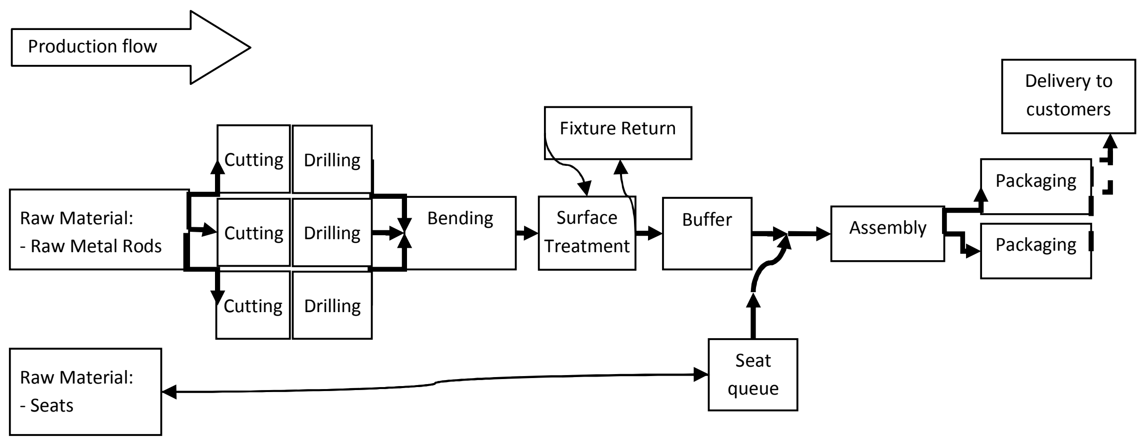


Figure 9 – The basic layout for the production facility

The *basic layout* shows a production facility that produces two types of kitchen chairs. Three types of material are entering the production facility; metal rods (the legs of the chairs) and two seat variants. The metal rods are processed to legs for the chair by cutting the rods into smaller pieces and later processing them to desired shape for assembly. The chair legs form a combined flow with the seats and are then mounted two and two onto each seat forming a chair. The chairs are afterwards packaged and sent to delivery where the production flow ends.

Model specification. When the *basic layout* had been determined it was modelled in Enterprise Dynamics. When the production flow was verified to be working as desired, some of the entity attributes in the model were determined. The attributes include for example conveyor speeds or cycle times in the process steps.

As the *original model* was specified to be a system in need of improvement demonstrating benefits of using simulation, it was desired to design a system inherently containing bottlenecks which could be revealed only by exploiting other bottlenecks. This type of design required an iterative process for determining the model specifications. As seen in fig 8, together with the improvement decisions, the model specification phase constitutes the described iterative process.

Improvement decisions. In the improvement decision phase it was decided which changes to the *BaseModel* that would be allowed to make. The modification possibilities were aimed at being able to exploit bottlenecks found when improving the *BaseModel*. After the first improvement had exploited the first bottleneck, it was desired from a learning-perspective that a new, almost as obvious bottleneck would appear. The identification of bottlenecks was intended, in the same way as when building the base model, to increase in difficulty with every improvement made.

After completing the improvement decision-phase, bottlenecks had deliberately been created and a list of what modifications to their *BaseModels* units would be allowed to make was determined. The list contained all possible modifications written in the form of investment possibilities for improving the factory containing the effect from the improvement and its cost. To limit the amount of possible improvements in the model, an investment budget was set.

Conceptual model. The *conceptual model* (see appendix x) was written as a document that summarized all information needed to create a *BaseModel* simulating the actual system, i.e. simulating the *original model*. In other words, the *conceptual model* contained all the information gathered in the first four steps in Banks model.

The list of possible investments and their effects on the system was also included in the *conceptual model.*

Software guides. Because unit 1 and unit 2 lacked previous simulation knowledge, and hence experience with the software, two documents serving as a guide to the software were constructed. The first was a guide on how to construct the *BaseModel* (referred to as the *software guide*) made in a step by step manner with screenshots from the software to clarify certain modelling steps. Together with the screenshots, describing text was written showing how to perform certain steps in the modelling. An important design consideration was that the first time a new action was to be performed, for instance when introducing a new entity, the modelling step was shown as a whole. The consideration also included not showing the same procedure twice. It was assumed that the individuals in the units would understand how to perform the action again or otherwise that they would check how to perform the action by just returning to where it was described the first time.

The second guide (referred to as the *experiment guide*) described how to conduct experiments in Enterprise Dynamics by using its built-in Experiment Wizard. This was because the modification part included that the units were required to analyze their modified models. The *experiment guide* was designed in the same step by step manner by using text and screenshots as in the *software guide*.

4.1.3 Case execution

The case study units were of different sizes, studied under different circumstances and data was collected from them using different methods. The reason for this inconsistency is mainly due to delimitations outside the influence of the researchers. Figure 10 shows the case execution phase describing unit properties.

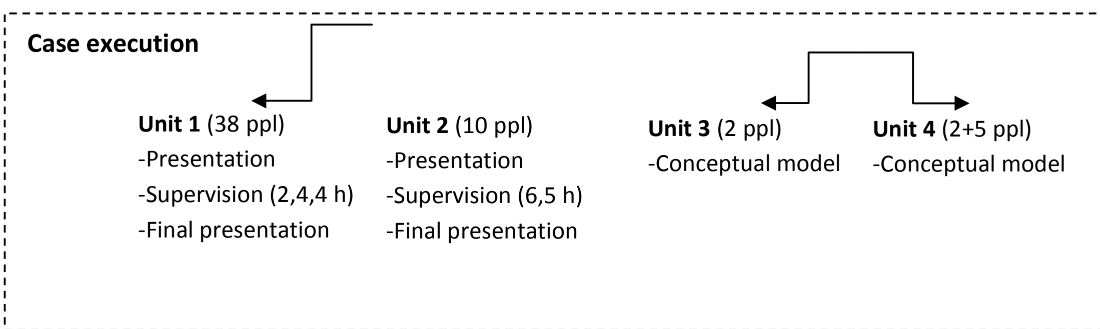


Figure 10 – The case execution

Unit 1 - No simulation experience, no work experience

Unit size and level of previous knowledge. The first unit studied in the case study consisted of 38 engineering students enrolled in their first year on Master's level at a Swedish technical university working in pairs. The case study, viewed from the students' perspectives was an obligatory part within a general production course aimed at getting the students acquainted with DES and Enterprise Dynamics.

Assumptions. Due to the course not requiring any prerequisites within DES, for the studied unit it has been assumed that they had no previous simulation experience.

Material. Because of not possessing any previous knowledge in Enterprise Dynamics, the students were given the step-by-step software guides as a complement to the *conceptual model* to be able to construct the model and conduct experiments on how to improve the factory's performance.

Expected results. Before the work started it was expected from the students to finish modeling the system as described in the *conceptual model* with aid from the *software guide*, thus creating the so called *BaseModel* and having it approved during a supervised session. After this, the students were required to improve the model creating a *FinalModel* which was to be presented before class and later on sent in together with a short report summarizing the students' findings during the project.

Time. The students were given a four hour lecture on discrete-event simulation and Enterprise Dynamics containing a short introduction to the case before a two hour supervised model building session. Two more supervision sessions were later given with one week apart, during which the students were required to finish and to get their *BaseModel* approved before being allowed to conduct improvement experiments. The students also had 8 hours of non-supervised time scheduled for constructing the model and were also able to use non-scheduled time.

Data collection. During the supervision sessions, all questions received from the students were written down and afterwards categorized by why the question was received, to what part of the material the question was related, to which step in Banks model it belonged and how frequent the question was among the other students. After the students finished their project, a survey was handed out and collected with focus on work method and problem areas. Data was also collected while correcting the students' *BaseModels* to see whether problems areas existed which went unnoticed by the students during model building.

Unit 2 - No simulation experience, work experience

Unit size and level of previous knowledge. The second unit studied in the case consisted of 10 engineers employed at a major Swedish telecommunication system provider wanting to learn Discrete-Event Simulation in Enterprise Dynamics. Due to only having four computers with the software installed, the members of the unit were divided into two groups of two and two groups of three engineers.

Assumptions. As with unit 1, it was assumed that the people studied had no prior knowledge within simulation.

Material. The software guides were provided together with the *conceptual model* due to the unit not being familiar with Enterprise Dynamics. Based on experience from unit 1 where the students' attention sometimes felt misguided, in this case the *conceptual model* alone was handed out an hour before the groups were given the *software guide*.

Expected results. Due to the case being presented again in an educational context, the expected result of the unit was quite similar as the expectations within unit 1. The *BaseModel* and the

FinalModel were to be constructed and the results shown in a short presentation before the rest of the participants.

Time. The time specified for the simulation study was divided into two separate occasions consisting of two consecutive seven hour days followed by a four week break before another day dedicated to the study. The first day was dedicated to lectures on DES and contained a general introduction to the software in front of a bigger audience. Because of this, the second day started with a quick introduction to the case simulation study before the groups were allowed to start building their models.

Data collection. Data was collected in the same fashion as for unit 1. Questions were collected, surveys handed out and insights were gathered from *BaseModel* correcting.

Unit 3 – Simulation experience, work experience

Unit size and previous knowledge. The third unit consisted of people with previous simulation experience solving the case individually. One of the members of this unit was consulted to see whether constructing the model by using the *software guide* together with the *conceptual model* was a reasonably difficult task for being used for the training of unit 1 and 2. The other member was consulted to see whether the *conceptual model* alone was enough to build a model which could be validated against the *original model* (see fig 11).

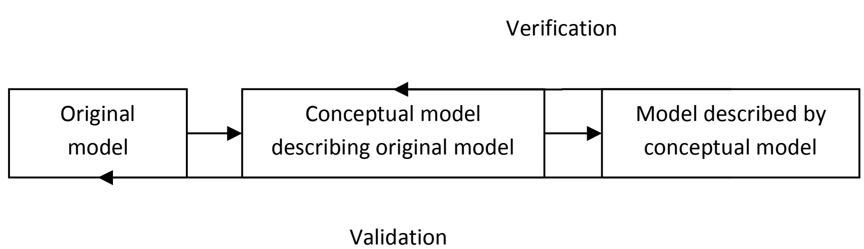


Figure 11 – Verfication and validation

Assumptions. The people in this unit were assumed to have sufficient skills within both simulation and the software to construct the *BaseModel* with only minor interventions from the researchers.

Material. One of the people within this unit was given both the *software guide* and *conceptual model*. The other was only given the *conceptual model*.

Expected results. The members in this unit were only expected to construct the *BaseModel*.

Time. There was no specific time frame set up for the model building. The sample was also considered to be too small to make any generalizations on how long it would take experienced engineers to construct this particular model.

Data collection. Data for the case study was only collected from the unit member constructing the model only using the *conceptual model.* It was initially intended to collect data from the member consulted on the case study difficulty, however since his comments led to changes, it was decided not to collect any data. Questions were collected and categorized and looked upon with a focus on the questions with direct relation to the *conceptual model*. The model was later validated against the *original model* to see if any significant differences existed.

Unit 4 - Expert panel

The researchers also consulted a panel regarded as experts due to their academic and professional experiences within discrete-event simulation. The expert panel was divided into interviewees and survey participants.

Interviewees

The interviewed experts were sent the *conceptual model* before being interviewed. They were then asked how the fictitious *conceptual mode*l compared to a conceptual model in a real-life simulation study on an actual factory, whether they believed that it was detailed enough and what could have been done differently.

Survey participants

The other members of the expert panel in unit 4 constituted a target group for a survey sent out to previous supervisors on a course on DES at Chalmers University of Technology. These individuals were chosen because the part of the course they had supervised had a similar structure to the case study performed by the researchers. The supervisors had similar work tasks as the researchers had when conducting the case study, with the major difference that the supervisors did not produce the material used in the course themselves.

Overview of case study units

Table 3 describes the units studied in the case and gives an overview on how their involvement in the case differs from one unit to another.

Table 3 – Case study units

	U1 – No simulation exp, no work exp	**U2 – No simulation exp, work exp**	**U3 – Simulation and work exp**	**U4 – Expert panel**
Unit size	38 individuals in groups of 2	10 individuals in groups of 2 or 3	2 individuals	2 experts and 5 survey participants
Time	24 hours scheduled + own time.	11 hours scheduled time	2-5 hours	No time spent on solving the case
-presentation	6 hours (4 hours introduction, 2 hours presenting results)	9 hours (8 hours introduction, 1 hour presenting results)		No time spent on solving the case
-supervised	10 hours (on three occasions of 2,4,4 h)	11 hours (two occasions 6,5 h)		No time spent on solving the case
-non-supervised	8 hours scheduled + own time.			No time spent on solving the case
Extra documents	Software guides	Software guides		No time spent on solving the case
Expected results	*BaseModel*, *FinalModel*, Presentation, Report	*BaseModel*, *FinalModel*, Presentation	*BaseModel*	No time spent on solving the case
Data collection	-Collecting and categorizing questions during supervision -Survey after finishing project -Insights from *BaseModel* correcting	-Collecting and categorizing questions during supervision -Survey after finishing project -Insights from *BaseModel* correcting	-Collecting and categorizing questions from model building -Insights from interviews on model building -Insights from validating *BaseModel* against *original model*	-Interviews on conceptual model -Survey

4.1.4 Case data collection

One of the main concerns regarding the case was how to collect relevant data, how to sort and quantify collected data and how to be able to compare the units out of the different contexts they looked at the conceptual model from. This data included time spent solving the case, questions asked by groups during supervision, individual impressions from unit members and insights from looking at constructed models. Figure 12 shows the data collection steps for unit 1-4.

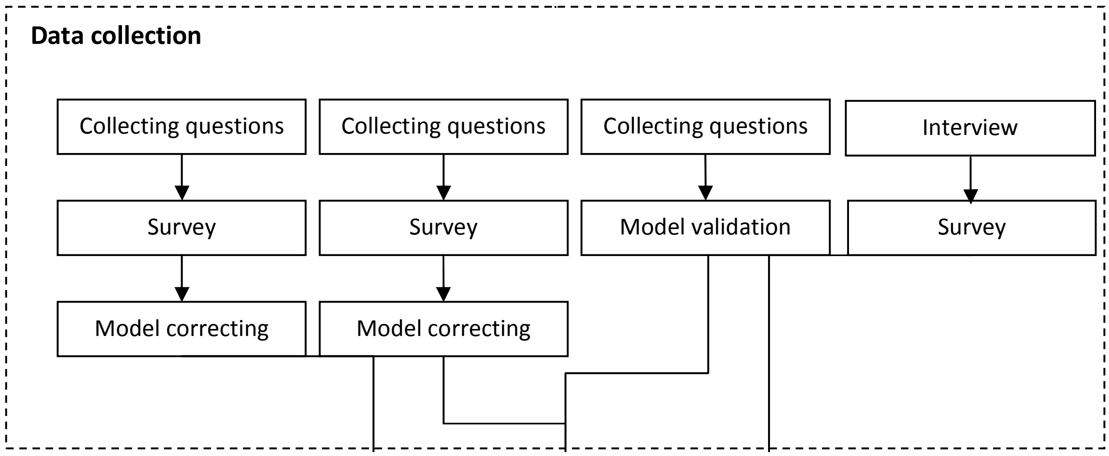


Figure 12 – The case data collection

Collecting and categorizing questions

The primary method of data collection used on the three groups building the case, was collecting and categorizing questions. During the supervised sessions with unit 1 and unit 2, where groups had the opportunity to freely ask questions while constructing the case, all questions were noted together with how frequent the specific question was. The questions were later categorized under:

- In depth-out of scope – The question was on a topic unrelated to the study. For instance a general question on the software capabilities.
- Insufficient description – The question was related to something which had not been explicitly described in documents handed out. Topics that had been discussed verbally (for instance when presenting the case) were also placed in this category.
- Not following the case – The question was answered in the already handed out material.
- Software related – The question/problem was related to limitations in the software.

The questions were provided with individual comments on for instance why the question occurred or where in the material the answer could be found. The questions were also categorized according to what part of the handed out material they were in relation to. A specific focus was also put on the stages of Banks model they were occurring in, categorized under:

- Model conceptualization – The question occurred due to misinformation conveyed during the model conceptualization phase, i.e. the origin of question stemmed from miscommunication in the *conceptual model*.
- Model translation – The question was related to problems with the translation of the *conceptual model* to the *BaseModel.*
- Experimental design – The question occurred when improving the *BaseModel* to the *FinalModel*.

In fig 13, an extract from the excel-document shows the categorizing procedure.

Questions received	Frequency Group 1	Frequency Group 2	Frequency Group 3	Category	Comment, reason, etc	Material
What does the term 'distributing/collecting/blocked/etc' mean in the status monitor?	3			Insufficient description	Can be found in within help file	Final model
What does this "*" sign mean?	2			Insufficient description	Not specifying how to write multiplication in 4d script	Software guide
What does this particular atom do?	1			Not following the case	Written in the software guide	Software guide
What is "Bill of materials"? Why doesn't this correspond to the slides	2			Software related	Using different version of software than case was built in	Software guide
What is logistics suite?	1			In depth-out of scope question		Unrelated

Figure 13 – Collecting questions in Microsoft Excel

Before collecting it was decided that a specific focus was to be put on looking at all questions with high frequencies and all questions belonging to the model conceptualization phase to see where common problem areas lie and where the *conceptual model* lacked information.

Survey

The individuals in unit 1 and unit 2 were given an anonymous survey. The survey was the chosen method for these two units due to their sizes and due to the fact that the participation of their members in the study was not for the study itself, but rather for individual learning purposes. This fact explains why time consuming methods such as interviews were not conducted.

The survey was handed out in written form with both free-text and rated answers and was focused on the participant's general perception of the simulation study, the work procedure, problem areas, time spent and learning.

For unit 1, the surveys were handed out after finishing the final presentations. In unit 2, the surveys were handed out after the end of their full simulation training.

The survey for the five previous supervisors in unit 4 consisted of free text questions about their experience from being in a role similar to the role of the researchers in unit 1 and unit 2. The questions in the survey mostly revolved around the conceptual model, for example if there were any common problem areas related to how it was interpreted. Questions were also asked concerning communication regarding for example when a model is to be built by someone that only has access to a conceptual model.

Interviews

The two interviewed experts in unit 4, with experiences from both academia and business simulations, were given the conceptual model beforehand and interviewed on whether they found it to be similar to a real-life conceptual model and if they believed it was sufficient for them to model the factory in their desired software.

Insights from model correcting

Unit 1 and unit 2 were requested to hand in their *BaseModels*, which were thoroughly gone through, noting all errors in an excel spreadsheet. This was to see which mistakes that could've gone unnoticed by both the researchers during supervision and by the model builders before handing in their final versions. No consideration was taken to what degree of possible effect the error could have on model behavior. This inconsideration was because of wanting to see where errors occur and not which errors that would be "most serious".

Insights from model validation

In unit 3, the *BaseModel* built without use of the *software guide*, was validated against the *original model* to see whether the same output and performance could be acquired. In other words, this step was used to validate whether the *conceptual model* alone contained all information necessary to replicate the system.

4.2 Professional DES-offshoring interviews

The research approach for the professional offshoring was only conducted in the form of interviews. As described in the methodology, chapter 2.4, the researchers had wanted to be able to participate in actual offshoring projects, which unfortunately turned out to be unrealizable.

When deciding what type of people that were desired for interviewing, the researchers wanted to get a nuanced picture of possibly different perceptions from both the sending and receiving end in the offshoring process.

The interviews were in the semi-structured form, meaning that the main topics were decided beforehand and in most cases provided to the interviewee for preparation before the interview.

The interviews were, when possible, undertaken face to face with the interviewee. When not possible, a voice over IP-client was used for communication.

The interviews were recorded, summarized and afterwards sent to the interviewee if requested.

4.2.1 Interviewees

Interviewee A. This interviewee was the company supervisor for the thesis work up until March the 1st. The interview with him focused a lot on the simulation methodology used by PMC Europe. Peter had managed one offshored project conducted in the simulation software Witness and his experiences from this initial project were discussed.

Interviewee B. This interviewee works at the PMC headquarters in Dearborn and was one of the most involved people when the main offshore office was set up. Ravi therefore has a considerable amount of experience from managing offshore DES-projects. The interview was mainly focused on Ravi's offshoring experiences and thoughts.

Interviewee C. This interviewee is a PhD with more than 10 years of simulation experience, both from an academic and professional perspective. His interview mainly focused on simulation methodology and writing conceptual models.

Interviewee D. This interviewee is a PhD student who wrote his licentiate of engineering on methods for input data management. He has previously worked within Swedish industry performing DES-projects. The interview was focused on writing conceptual models and simulation methodology.

Interviewee E. This interviewee works for PMC Seattle and has considerable experience from managing offshore projects. The interview focused on his offshoring experience and thoughts.

Interviewee F. This interviewee works as an applications engineer at PMC India. He is often the receiving part for offshored simulation studies. His interview focused on his offshoring experience and thoughts.

Interviewee G. This interviewee is a former project manger of PMC. He has considerable experience from managing offshore projects. The interview focused on his offshoring experience and thoughts.

Table 4 contains a summary of the conducted interviews.

Table 4 – Professional interviews

	Date	Interviewee	Topics	Method	Time
1	2011-01-25	Interviewee A, Account Manager PMC Europe	DES methodology, offshoring experience	Face to face	3 h
2	2011-02-10	Interviewee B, Consulting Project Manager PMC Dearborn	Offshoring experience, DES offshoring methodology	VoIP	1 h
3	2011-03-09	Interviewee C, Assistant professor in production systems Chalmers University of Technology	DES methodology, experiences from writing conceptual models	Face to face	0.5 h
4	2011-03-09	Interviewee D, PhD Student, Virtual Production, Chalmers University of Technology	DES methodology, experiences from writing conceptual models	Face to face	1 h
5	2011-04-26	Interviewee E, Project Manager PMC Seattle	Offshoring experience, DES offshoring methodology	VoIP	1 h
6	2011-05-13	Interviewee F, Applications Engineer, PMC India	Offshoring experience, DES offshoring methodology	VoIP	1 h
7	2011-05-18	Interviewee G, Former Project Manager, PMC Dearborn	Offshoring experience, DES offshoring methodology	VoIP	1 h

4.2.2 Interview structure and topics

Personal and professional background. All interviews started with a short section where the interviewee's background was inquired. The main topics were usually educational and professional backgrounds.

Main topics. The body of the interview was made up of the main topics and customized for each interviewee. The main topics were:

- DES methodology – What methodology is used by the interviewee when conducting DES-projects?
- Experience from writing conceptual models – Where do problems occur when creating conceptual models? What constitutes a good conceptual model?
- DES offshoring methodology – How is DES offshoring performed in practice? What are the interviewee's experience on this?
- Offshoring experience – Offshoring in general. General thoughts and perception from working with an offshore location?

Future. All interviews ended with a short section discussing the interviewee's views on the future of simulation and simulation offshoring.

5 Analysis

This chapter describes the analysis of the collected data found in the research.

5.1 DES-offshoring case study

This chapter presents and analyzes the data collected in the DES-offshoring case study, first unit-by-unit and later unit-overlapping results regarding the conceptual model. In the last chapter, a short summary is provided.

5.1.1 Unit 1 – No simulation experience, no work experience

Unit 1, consisting of 38 students divided in groups of two, solved the simulation study by using the software guide and the conceptual model. After asking all groups, thirteen of the groups reported the amount of time spent completing the tasks of constructing the *BaseModel, FinalModel,* a final presentation and a report. As seen on the time statistics in table 5, the time spent on solving the case, writing the report and preparing the presentation varied a lot between groups with the total time having a mean of μ = 22.7 h and a standard deviation of σ = 6.8 h. The time spent to finalize the *BaseModel* was perceived to be somewhere between 5 to 10 hours based on observations during supervised hours.

Table 5 – Time spent per group, U1

Time	Mean	Stdev	Median	Min	Max
Supervised time spent on case	8.7	2.1	10	4	10
Non-supervised but scheduled time	5.3	2.7	6	0	8
Outside of scheduled hours	8.7	6.0	6	4	24
Total	22.7	6.8	22	16	38

The impression of the researchers was that the unit consisted of individuals from different universities holding different bachelor's degrees. The perception was also that the unit was diverse regarding computer skills, prior educational skills and commitment to the assignment. The large standard deviation when looking at the time spent solving the same task and the fact that the maximum time is more than twice as large as the minimum is regarded as supporting this impression. This differences in time are shown in the histogram in fig 14.

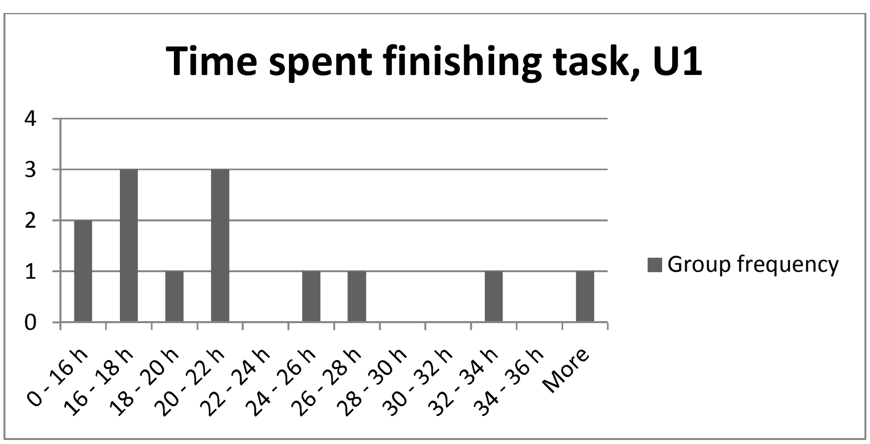


Figure 14 – Histogram showing time spent solving the task in U1

Collected questions

During the three supervised sessions together with unit 1, a total of 136 questions were collected, out of which, 57 variants (41.9 % out of total asked) existed. This gives an average of 7.56 questions in total per group and 13.6 questions per hour for the whole unit during supervision. The total number of questions per group is the lowest per unit (μ = 12.44) and the rate of questions per hour the highest per unit (μ = 7.48). This, together with the notion from the researchers that there was a constant flow of questions during some parts of the supervised sessions, points to the fact that more questions would have been asked if more supervisors would have been present.

When looking at categories from questions asked (as seen in figure 15a), most questions (63 %) are placed in the "insufficient description"-category, followed by 26 % of the questions categorized by groups not following the case description. In a software educational context, this was not regarded as surprising.

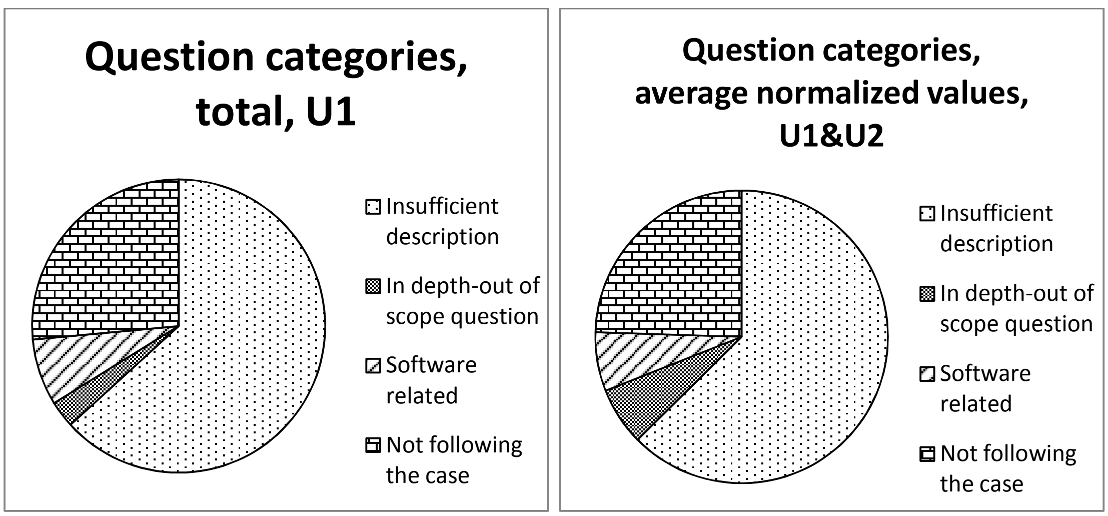
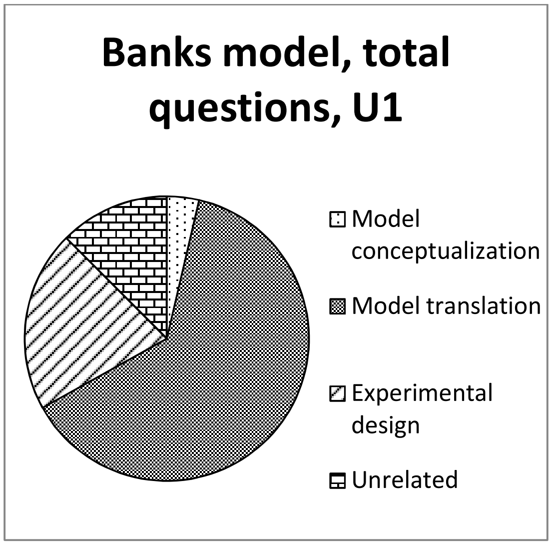


Figure 15a, figure 15b – Question categories in unit 1 compared to all units

When comparing to the normalized average between U1 and U2 (U3 was not included in the normalized values due to having a sample size of 1) as seen in fig 15b, a difference in the "In depth"-category" (3 % compared to 6 %) can be seen. This is possibly suggesting that the members of U1 were more focused on completing the task than in the capabilities of the software.

When looking at the questions posed in relation to Banks model (as shown in fig 16a), it can be seen that most questions (63 %) belong to the model translation phase followed by the experimental design (21 %). This shows that during supervision three times as many questions were asked on the steps in translating the *conceptual model* to the *BaseModel* as questions asked on improving the *BaseModel* to the *FinalModel.*



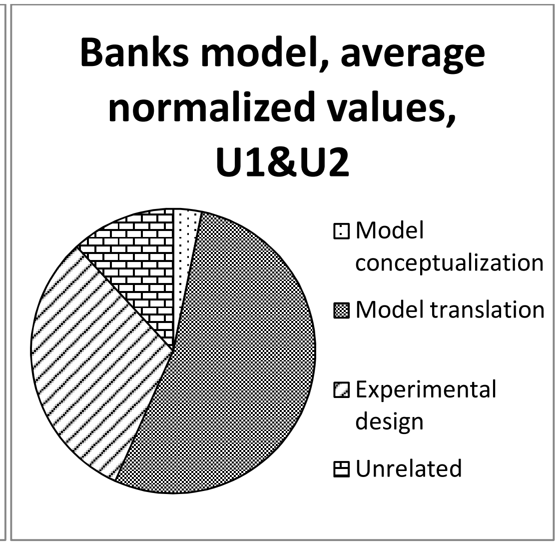


Figure 16a, figure 16b – Questions categorized on relation to Banks model in U1 compared to all units

When comparing this to the normalized average in fig 16b, it can be seen that the questions belonging to the model translation phase are significantly more common in U1 with 63 % compared to 53 %. This difference is mainly compensated by the difference in the experimental design where U1 has 21 % of their questions compared to 31 % of the average.

This difference is believed to be related to the fact that for a few of the groups, the time used to complete the *BaseModel* was the full supervised time leading to fewer groups being able to ask about their final model at all. This claim is supported by the results from the survey, as seen in fig 17, handed out after the course showing that around 45 % of the students found the supervised time to be insufficient to complete their task.

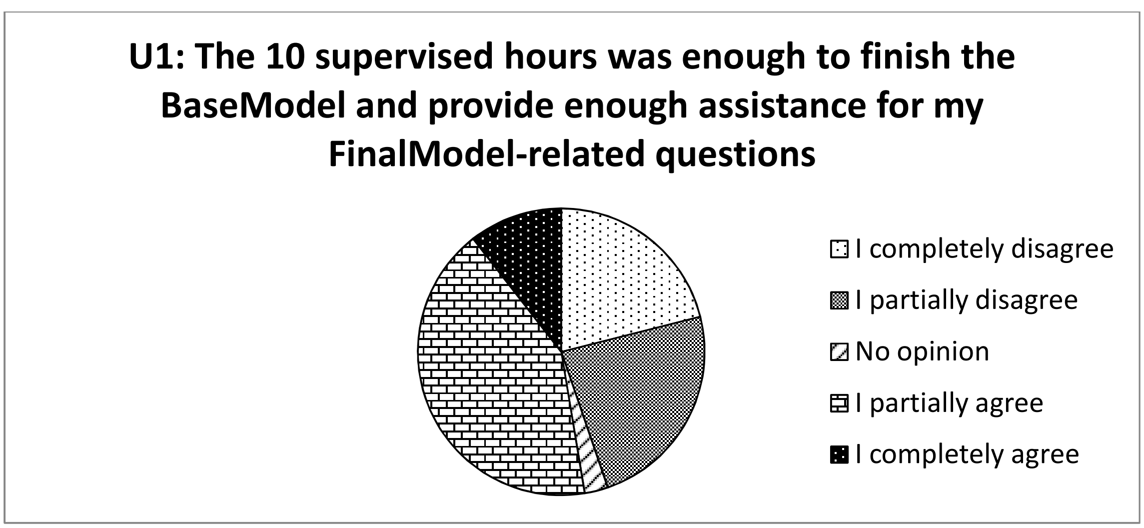


Figure 17 – Perception of supervised time in relation to solving the task in U1

It was also of interest to see where the most common problem areas were while working with the case. Therefore it was decided to look on the most frequently asked questions as seen in table 6.

Table 6 –Most frequently asked questions, unit 1

#	Question	Frequency	Category	Banks model
1	I don't understand how I should use the "send to" in the conveyors/assembler?	22	Insufficient description	Model translation
2	I want to add another assembler to my system - how?	8	Insufficient description	Experimental design
3	Why doesn't this code that I pasted directly in the field work?	7	Insufficient description	Model translation
4	Why do I get "invalid reference"-error?	7	Not following the case	Model translation
5	This channel is red, is something wrong?	5	Insufficient description	Model translation
6	Why is my cutting machine so fast?	4	Not following the case	Model translation
7	HASP license server problem	4	Software related	Unrelated

The first and second most common questions were expected. The conveyor system connected to the assembler was assumed to be the most difficult part of the case. This turned out to be true and some groups even asked several times about the conveyor and assembler logic. The underlying reason for these questions was basically because of the material not giving away too much information and requiring an understanding of the system to be able to proceed with the modeling. This thus forced groups to ask about the case if they lacked understanding. This design aspect of the case was desired regarding Q1 because it gave the researchers in their role of supervisors an ability to see how the groups were progressing after completing the first stages of the model.

Q3 and Q4 were slightly more unexpected. The reasons for their occurrence were both because of inconsistent naming (Q4) and because of being unclear with software limitations (Q3). It was concluded that these questions could have been avoided or at least made less common by being clearer about this particular software aspect in the software guide or presentation.

Q5 regarded the visual appearance in ED when running models. It is not affecting the model performance in any way, but was probably asked to understand a visual phenomenon in new software.

Q6 occurred due to not following the conceptual model but only working with the software guide. When the setup time was supposed to be set for the cutting machines, a special setting was to be chosen from a drop-down list. The software guide only showed which list to choose, but not what data to enter. This resulted in the fact that the cutting machine only worked with the default setup time of 10 seconds instead of the 2.5 specified minutes.

Q7 is a software related error occurring when all available licenses are in use. This error could not be influenced by the researchers.

The reasoning regarding how Q3, Q4 and Q5 later could be avoided was implemented in the presentation given in front of U2 later on to see whether better information could avoid these questions. In the final presentation Q1 and Q2 among others were explained to improve the model understanding.

BaseModel correcting

Partially because time had become a limiting factor when approving *BaseModels* during the last supervision session, it was decided to take a deeper look into all models to see if there were mistakes left that the supervising researchers had missed, or mistakes not corrected when saying "you are approved, but correct this…" when only minor errors had been found.

The *BaseModels* where investigated rigorously and all deviations from the *original model* were collected. No consideration was taken to their possible effects on the model performance because of the special interest of seeing where errors occur. The five most common errors within the 18 groups in unit 1 are shown in table 7.

Table 7 – The five most common errors, U1

#	Error	Occurrence within groups
1	Conveyors not using length + spacing	77.78%
2	Wrong conveyor speeds	77.78%
3	Wrong MTTR/MTTF in bending	55.56%
4	Wrong setup time in packaging	55.56%
5	Wrong total cycle time in drilling	50.00%

The first two errors were probably due to carelessness when modeling at least one of the fifteen conveyors. The other three errors were more disturbing since they in greater magnitude influenced the performance of the system. When looking at why they may have occurred, the obvious "villain" was assumed to be the software guide.

As written in the material creation, chapter 4.1.2, the first time a new task was to be performed when building the model the software interaction was fully visualized, but the second time it was assumed that the groups would know how to redo the task. The MTTR/MTTF in bending and the cycle time in drilling were direct examples of where this learning goal was not achieved in half or more than half of the groups. When reasoning about why this may have happened, the researchers' conclusion was that it may have been due to the fact that groups were not paying attention to the conceptual model and rather modeling the system only using the software guide. The drilling machine was the first machine shown without the "general"-tab, which was where the cycle time was to be entered. Similarly, the bending machine was the first machine shown without the "specifics"-tab, where the failure rates were to be entered.

The packaging machines were the last machines in the flow. So why did their setup become a problem? This is probably also related to the software guide. The packaging setup type was a new type of entity attribute, however the software guide only showed which list option to choose in the software as seen in fig 18. It did however not state what time to enter which lead to the fact that surprisingly many of the groups (10 of 18) did not change the time, but only used default values.

Figure 18 – Setup time in packaging

The number of errors was considered high within the groups (μ = 6.3), however yet again the number of errors found was very diverse (σ = 4.5) as shown in the histogram in fig 19.

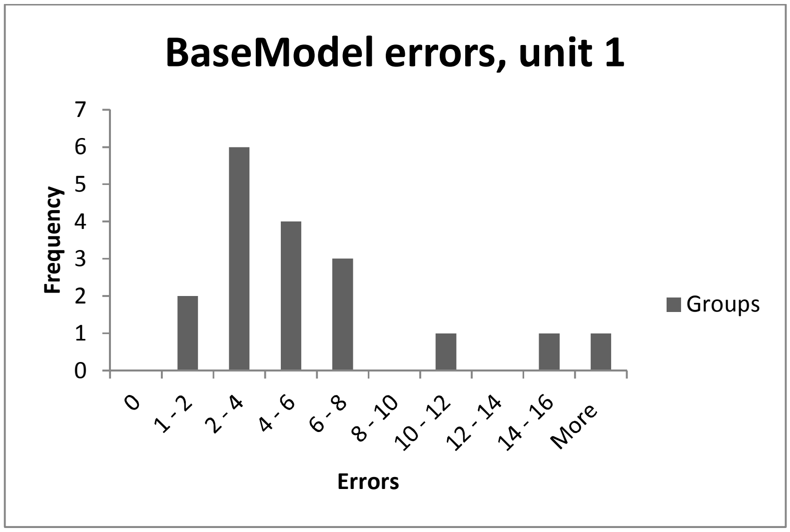


Figure 19 – Histogram showing frequencies of total error numbers per group in U1

The high number of errors triggered an interest to see whether attending all supervised sessions had any impact on both total time spent on solving the case and on the number of errors made. Therefore, for the 13 groups that reported the time spent on solving the case, the following performance indicators were calculated for each group:

$$Time\ efficiency = \frac{Total\ time\ spent}{Average\ time}$$

$$Error\ efficiency = \frac{Total\ errors\ made}{Average\ number\ of\ errors}$$

$$Overall\ performance = Time\ efficiency * Error\ efficiency$$

An indicator value > 1 indicates that the group performed worse (more errors, longer time) than average, an indicator value < 1 indicates that the group performed better than average. The indicator averages were then categorized by the groups' supervision attendance to be able to see if any relationships existed which is shown in table 8.

Table 8 – Case performance based on supervision attendance

Supervised time	Time eff	Error eff	OP
100 % (8 groups)	1.09	0.98	1.17
75-100 % (2 groups)	0.75	1.19	0.89
0-75 % (3 groups)	0.94	1.01	1.08

The results show no clear relationship between performing better or worse on any indicator depending on supervision attendance. The small sample size also contributes to uncertainty in drawing conclusions from the results. An additional uncertainty is the fact that the performance indicators are calculated based on the total time spent on the simulation study, due to not being able to derive the time spent only on the *BaseModel.*

Another possibility for not finding any clear connection between the results might be that groups have different skill levels compared to each other and skilled groups may not attend all supervisions because of being able to solve problems on their own.

Individual understanding and simulation study confidence

When looking at the perceived learning achievement and individual simulation confidence acquired from conducting the study, the survey provided the results shown in fig 20a, 20b, 21a, 21b.

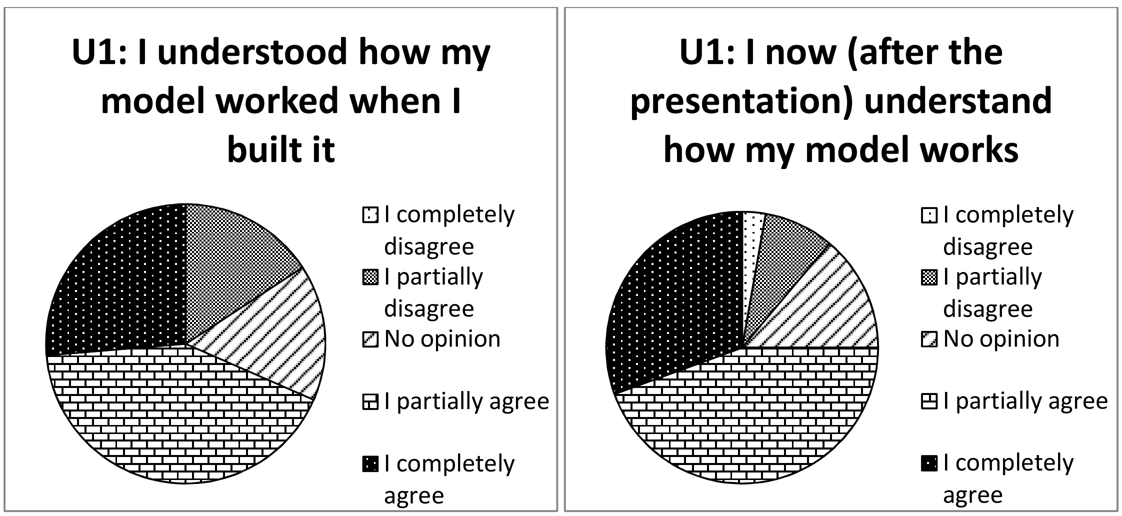


Figure 20a, figure 20b – Model understanding before and after final presentations, U1

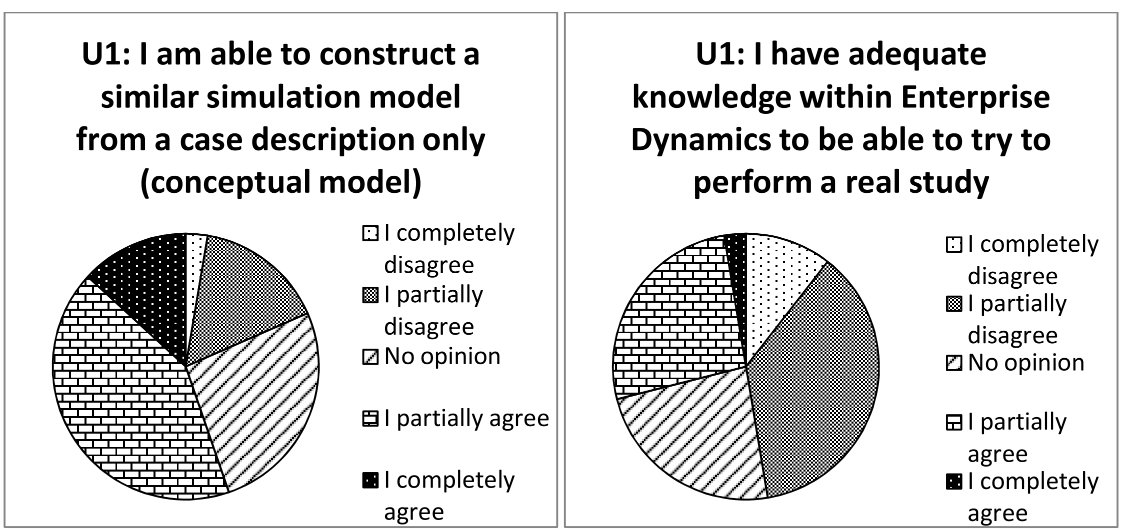


Figure 21a, figure 21b –Theoretical and software knowledge, U1

As seen in fig 20a, no student completely disagreed with understanding their model when building it. 68 % (completely or partially) agreed with understanding the model during construction and 16 % (partially) disagreed. Before the groups' final presentations, a repetition of the *BaseModel* was given and its tricky parts were explained. This apparently gave results as 75 % agreed with understanding the model afterwards as shown in fig 20b.

In fig 21a, the perceived confidence of the students after finishing the simulation study is shown. More than half the students (55 %) agreed on having sufficient knowledge to construct a similar model from a conceptual model only, while about a fifth (19 %) disagreed.

When looking at the confidence in performing a real study using the software, as seen in fig 21b, the results was more pessimistic (29 % agreed, 48 % disagreed). This result is still regarded as positive with respect to only working with the simulation software for less than 23 hours on average with only 6 hours of lecturing in addition to not possessing any work experience.

Qualitative survey results

It was difficult to draw any definitive conclusions from the survey. This was because the answers were very diverse. This is believed to be partially explained by the perceived varying educational background of the individuals in the unit.

What however can be concluded to some extent is that the structure of using a software guide along with a conceptual model was considered to be a good approach. Regarding the possibility of building the *BaseModel* with the *conceptual model* and the *software guide* only having access to assistance from supervisors twice a day via electronic communication the answers provided inconclusive data.

Observations during supervision

Some of the thoughts that occurred during the case study about the unit were, as mentioned a few times, regarding the large diversity in skill. Furthermore when providing assistance, in some groups the researchers were surprised by the low English proficiency and the perceived notion that the task of the supervisors was to give away the solution rather than to aid understanding.

Based on observations from the first supervision, before each following session, it was emphasized to work with the *conceptual model* as a base, using the *software guide* only to see how new actions in the software were to be performed. This recommended approach, for some reason in some cases seemed to have been ignored based on the errors found when correcting the *BaseModels*.

This conclusion led to a different approach when handing out the material in unit 2 where the groups first were given the *conceptual model* only, in order for them to get a basic understanding of the factory before starting their model building.

5.1.2 Unit 2 – No simulation experience, work experience

Unit 2, consisting of 10 people working within the same company participating in a five day training in Discrete-event simulation and Enterprise Dynamics, was due to having four ED-licenses divided into four groups consisting of 2-3 individuals. The data for the analysis was mainly gathered during the two days when the unit worked on the simulation study. The only difference in the data collection was that the survey was conducted after the full five day training.

All groups constructed a *BaseModel, a FinalModel* and prepared a very short presentation of their results and reasoning on their improvements of the *FinalModel*. All groups finalized their *BaseModel* during the end of the first day after 5-6 hours of modeling. The second day of the simulation study took place about four weeks after the first and during five more hours all groups were required to finish their study.

The impression from the researchers was that the unit was quite homogenous, mainly consisting of production engineers and people otherwise involved with production. Their work experiences ranged from newly graduated to having extensive work experience.

Collected questions

During the two days, a total of 71 questions were posed, out of which, 46 variants (64.79 % out of total asked) existed. This gives an average of 17.75 questions per group and 6.45 questions per hour for the whole unit. The number of questions per unit was the highest in the three units ($\mu = 12.44$), which could be explained by the constant presence of the supervisors and a small number of groups. However the impression was that help was available for any group at basically any given time.

In unit 2, just as in unit 1, most questions (62 %) lie in the “insufficient description”-category followed by 23 % of questions in the “Not following the case”-category as shown in fig 22a.

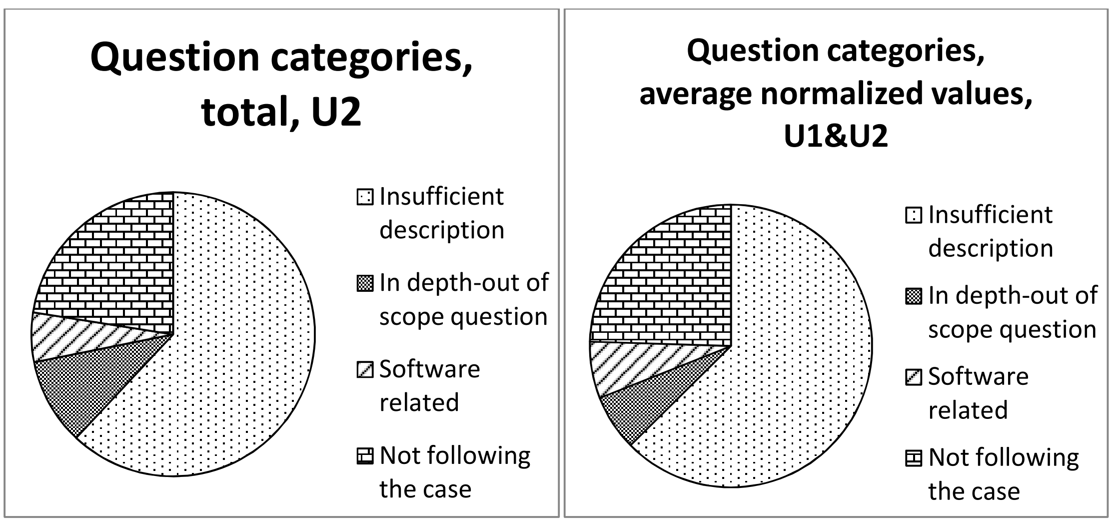


Figure 22a, figure 22b – Question categories in U2 compared to all units

When comparing to the normalized average questions posed in U1 and U2 in fig 22b, the biggest difference lies in the “In depth”-category (10 % compared to 6 %) which may suggest that the members of U2 had a larger interest than unit 1 in finding out how to apply both simulation and the software in their normal work. The percentage of questions in the “not following the case”-category was smaller than average possibly indicating a better focus on following instructions. This despite having the ability of asking questions whenever possible. This could also be an effect from handing out a printed version of the *conceptual model* about an hour before handing out the printed *software guide*.

The questions were also related to their position in Banks model. In fig 23a it can be seen that questions in the experimental design phase are almost as common as questions in the model translation phase (42 % compared to 44 %).

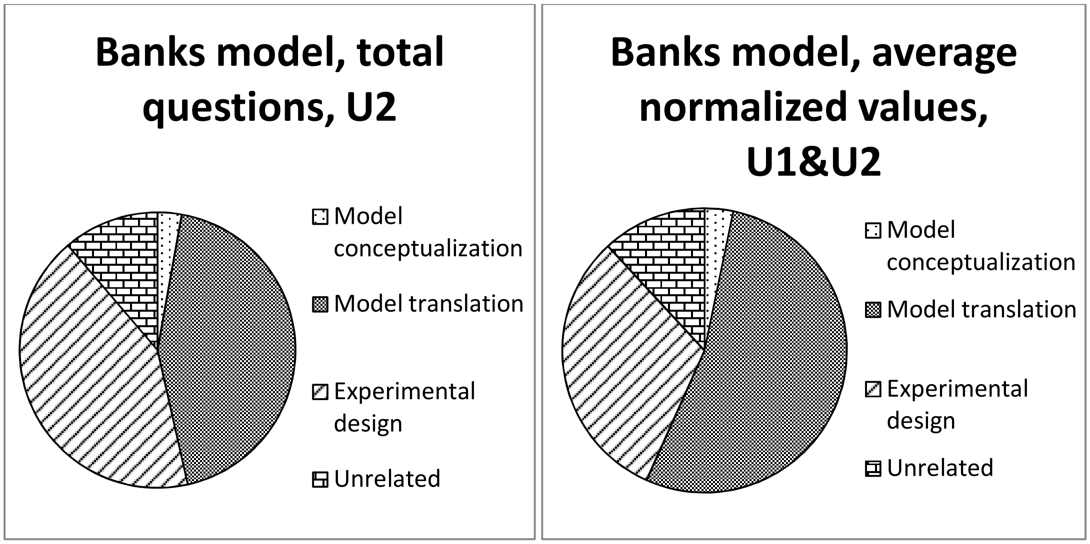


Figure 23a, figure 23b – Questions categorized on relation to Banks model in U2 compared to all units

When comparing to the normalized average in fig 23b, we see that the model translation makes up a much larger part than in the average diagram (42 % compared to 31 %) on the cost of the model translation step (44 % compared to 53 %). This is probably caused by finishing the *BaseModel* early and therefore being able to spend half the supervised time asking about improvements.

In U1, many groups finished their *BaseModels* very late which made it impossible for them to ask about their experiments. In U2, this was not believed to be the case, which is supported by the results from the survey conducted in the end where everyone agreed (56 % completely and 44 % partially) with the statement that the supervised time was sufficient (as seen in fig 24).

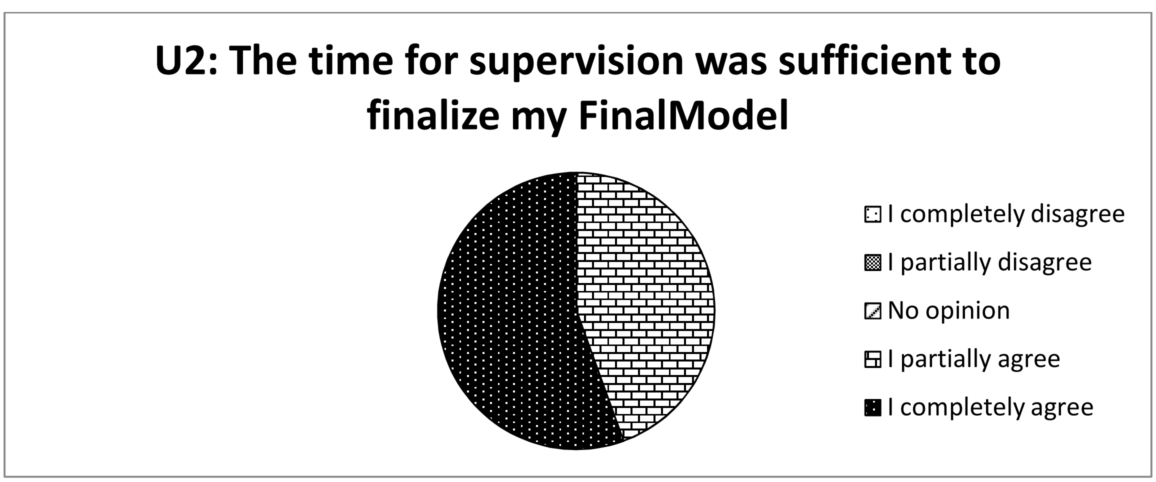


Figure 24 – Perception of supervised time in relation to solving the task in U2

The most common problem areas leading to questions within U2 are shown in table 9.

Table 9 –Most frequently asked questions, unit 2

#	Question	Frequency	Category	Banks model
1	I want to add another assembler to my system - how?	6	Insufficient description	Experimental design
2	I don't understand how I should use the "send to" in the conveyors/assembler?	5	Insufficient description	Model translation
3	Why does my fixture conveyor deadlock when I add one more fixture?	4	Insufficient description	Experimental design
4	What does the term 'distributing/collecting/blocked/etc' mean in the status monitor?	3	Insufficient description	Experimental design
5	How does the counter work in the conveyor system?	3	Insufficient description	Model translation
6	What is the function of the channels on this atom?	3	Insufficient description	Model translation

As seen in table 9, Q1 and Q2 are familiar from U1. This time they are in the reversed order, which possibly is an effect from the units having more supervised time when working on the experimental design-step. This effect is also seen in Q3 and Q4 where the questions are related to experimenting. In Q3, the deadlock in the fixture was deliberately created to explain the difference between a non-accumulating and an accumulating conveyor. Q4 talks about the properties of the status monitor, an entity used for monitoring the states of other entities during a simulation run.

Q5 is an in-depth question about the logic in the conveyor system involved in Q1 and Q2 and was also a question that the researchers were prepared to be asked about.

Q6 is an Enterprise Dynamics-specific question that is believed to occur when a deeper understanding of the entities (in the software usually referred to as atoms) in the software is desired.

In the final presentation, Q1, Q2, Q3 and Q5 were explained to improve the understanding of the model. As is also seen, the common problem areas in U1 which were emphasized before U2 were not asked among the top questions and thus this action was regarded as having desired effect.

BaseModel correcting

Partially due to the large amount of remaining errors in the *BaseModels* in U1, it was decided to also check the groups in U2’s models for remaining errors. Because of the experience of finding many serious remaining errors in U1, the *BaseModels* in U2 were more rigorously gone through during supervision before groups were allowed to start with their *FinalModel*. Despite this, their *BaseModels* were still gone through and the six most common errors in the four groups in U2 are shown in table 10.

Table 10 – The six most common errors, U2

#	Error	Occurrence within groups
1	Wrong rotation on conveyor #4	75.00%
2	2D-product icon not unchecked	75.00%
3	Conveyors not using length+spacing	50.00%
4	Wrong conveyor speeds	50.00%
5	Wrong dimension on Metal Rods	50.00%
6	Wrong position of initialize atom in the model tree	50.00%

As we can see, E1 and E4 are also present in U1. The occurrence of this error type is also here believed to be due to carelessness when adding properties in one or more of the fifteen conveyors.

In the case of unit 1, the conveyor errors were regarded as perhaps the least serious errors in among the top five. In the case of unit 2, they are actually the only errors influencing the model performance, while the other are either purely cosmetical (E1, E2, E5) or producing an unnecessary error message when opening the model (E6).

The number of errors within the groups was not too high (μ = 4.25) with (σ = 2.06) as shown in the histogram in fig 25.

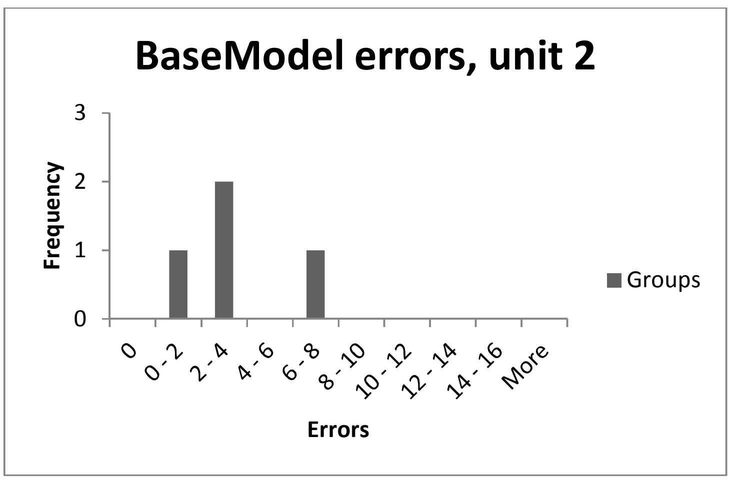


Figure 25 - Histogram showing frequencies of total error numbers per group in unit 2

The groups finished in the same amount of time, attended all supervised sessions and, as supported by to the survey result in fig 26 (8 of 9 responding “completely disagree”, 1 responding “partially disagree”) did not spend much time during non-scheduled hours working on their case. Therefore, the performance indicators used in chapter 5.1.1 to study a possible relationship between attending supervised sessions combined with performing better were regarded as of no use in U2.

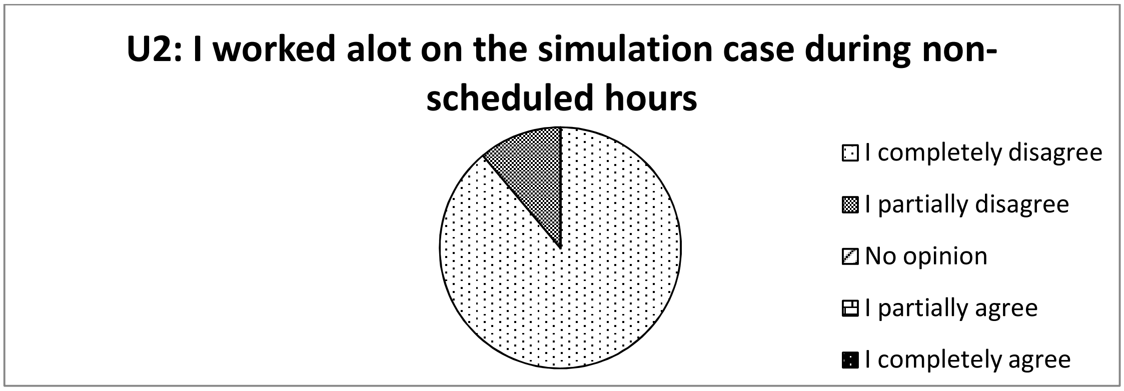
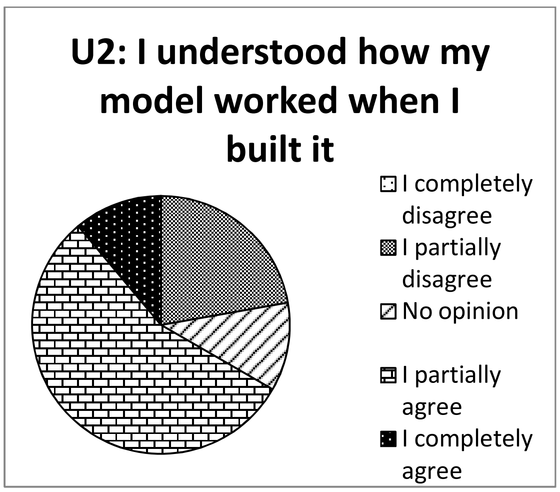


Figure 26 – Working on the simulation study during non-scheduled hours, U2

Individual understanding and simulation study confidence

Regarding the perceived learning achievement and individual simulation confidence, the survey results are shown in fig 27a, 27b, 28a, 28b



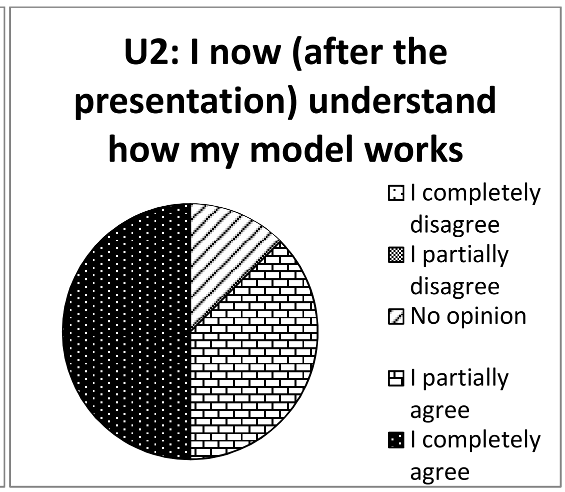
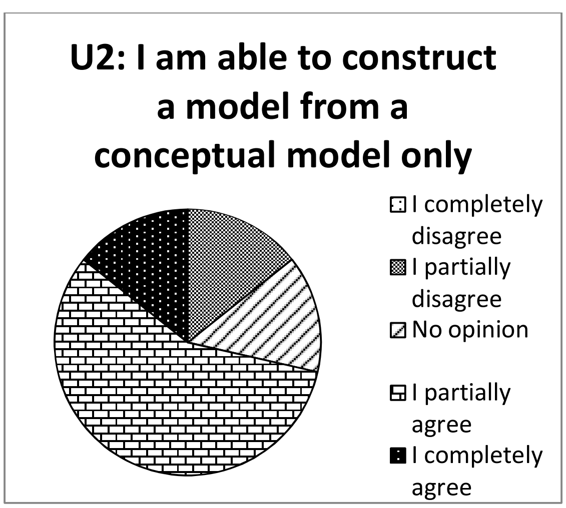


Figure 27a, figure 27b – Model understanding before and after final presentations, U2



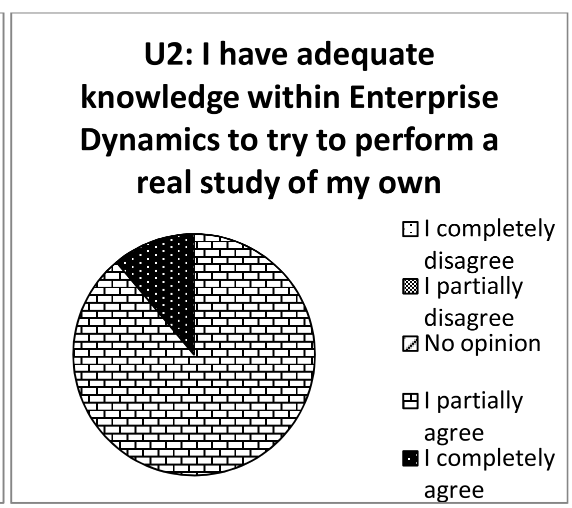


Figure 28a, 28b –Theoretical and software knowledge, U2

The understanding of the modelled system was, as in U1, improved after giving an explaining presentation of the model at the end of the simulation study. After having a 67 % understanding (11 % completely agreeing, 56 % partially agreeing) of the model as shown in fig 27a, this number went up to 88% (50 % completely agreeing, 38 % partially agreeing) as seen in fig 27b. An odd detail was that when looking at the survey of the person giving the only "partially disagree"-answer on post-presentation model understanding had changed his/her answer from previously being "partially agreeing" during model building. The belief is that the question was misunderstood, but due to the anonymity given in the surveys confirming this belief was not regarded as possible and the data was left unaltered.

Fig 28a and 28b, show the confidence of the individuals after the full five day training which also included topics such as communication between Enterprise Dynamics and Microsoft Excel and giving a more theoretical lecture in 4D-script, the language used in Enterprise Dynamics and more model building. To analyze this data in the context of the case study is hard, but we can see that with the simulation study used in the case as a basis, two extra lectures given (about 2 hours in total) and basically two more days of supervision, the confidence in Enterprise Dynamics is high with 100 % of the individuals agreeing or partially agreeing to have adequate knowledge to perform a real study of their own.

When looking at the model translation step from a conceptual model written by someone else, the confidence is a bit lower with 71 % agreeing (14 % completely agreeing, 57 % partially agreeing) and one person completely disagreeing.

Qualitative survey results

From an educational point of view, the qualitative free text survey results concluded that the approach of using a conceptual model together with a software guide was considered to be a good approach. However one answer stressed that in some aspects a software guide exactly depicting certain steps can disrupt the learning process because of not forcing the learner to reflect on what is done.

Another educational aspect arose due to one license failure in the later parts of the training. This forced the participants to form new groups of 3-4 individuals per computer. Most of the surveys stated that it would be better to be no more than two individuals at each computer in order to maximize learning.

Most of the individuals considered it possible to create the *BaseModel* with the *conceptual model* and the *software guide* having only the possibility to use electronic communication twice a day to ask for assistance. Although this was believed to be a lot more time-consuming than having supervisors present to answer questions, it can in a minor extent be deduced that from a professional DES-offshoring point of view the *conceptual model* was of acceptable quality.

Observations during supervision

When supervising U2, the impression was that its members had a serious interest in the given tasks and in learning how to use the software and how to apply simulation in their daily work. Despite being the unit asking the most questions per group, the feeling of the researchers was that the groups in most cases tried hard to find out solutions on their own before asking. This feeling could partially stem from the fact that the questions received per hour was less than half (47.5 %) of the questions received per hour when supervising U1.

The commitment to solving the task and understanding was also felt to be very high. Many of the groups seemed to partially forget about usual workday essentials such as time, taking coffee breaks and going for lunch at 11:30 sharp.

Another reflection was that the basic understanding of the fictitious factory was higher than in U2. This observation was supported by the fact that no machine data was missing and among all the committed errors only two were considered serious (a missing conveyor and a wrongly dimensioned buffer) when looking upon the performance of the factory. This understanding could have originated either from working as production engineers or from being forced to study the conceptual model without the software guide initially or both factors.

5.1.3 Unit 3 – Simulation experience, work experience

Unit 3 consisted of two experienced simulation engineers. One of them, the company supervisor, checked the difficulty level of the *conceptual model* and *software guide* before it was used on unit 1 and unit 2. The other, an engineer with previous experience from modeling within the software, built the model only using the *conceptual model* to validate whether it contained all necessary information. Due to the fact that the company supervisor was checking the model difficulty and proposed changes which later were implemented, no data collection was made on this preparatory moment.

The engineer using both documents constructed the model in two hours, the engineer with the *conceptual model* only used five hours to finish the *BaseModel*. No conclusions were drawn from time spent.

Collected questions

The question collecting was similarly performed in U3, where the researchers were present as supervisors to be able to answer any questions on unclarities in the conceptual model. All questions were collected and categorized. In total 12 questions were asked in the single analyzed group. This number was lower than U2 ($\mu = 17.75$) but higher than U1 ($\mu = 7.56$), which gave a question/hour rate of 2.4.

Most questions (50 %) were in the “not following the case”-category as seen in fig 29a. This is believed to be due to the comfort of being able to ask questions instead of searching through the *conceptual model*, where all answers to these questions could have been found. Of the six remaining questions, five were categorized as “insufficient description” and one was a software related syntax question.

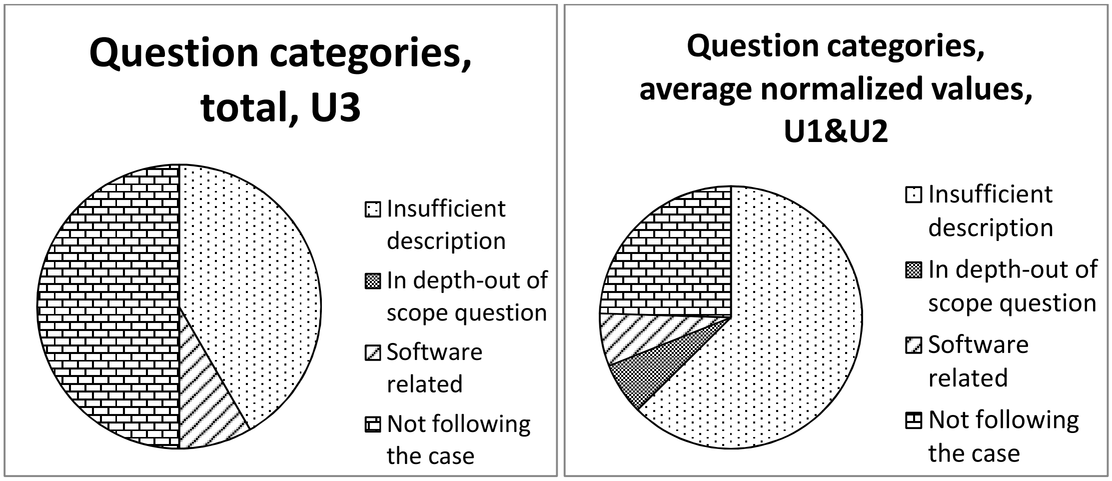


Figure 29a, figure 29b – Question categories in U3 compared to all units

When comparing the question categories to the normalized average from U1 and U2 in fig 29b, it can be seen that the biggest difference lies in the “not following the case”-category. As explained above, the reason for this could be “out of comfort”, but the sample is however considered too small to draw any kind of conclusion.

When looking at the questions posed in relation to Banks model we see that the experimental design phase is nonexistent. This is of course due to not conducting any experiments when only modeling the *BaseModel*. As shown in fig 30a, most questions (58 %) lie in the model translation phase followed by the model conceptualization phase (33 %).

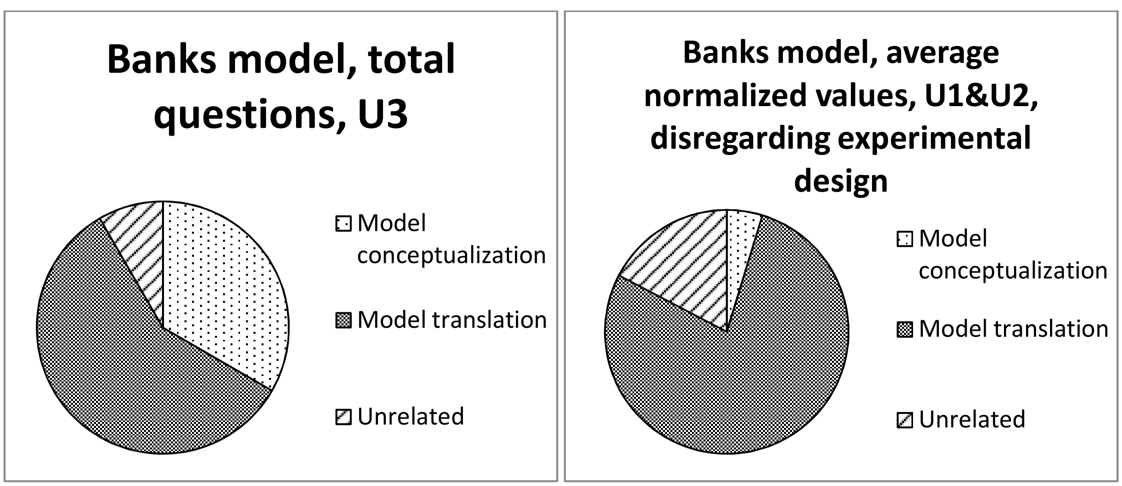


Figure 30a, figure 30b – Questions categorized on relation to Banks model in U2 compared to all units

To be able to give a fair comparison, the normalized values regarding Banks model for U1 and U2 have the questions on experimental design removed as seen in fig 30b. When comparing U3 to U1 & U2 the major difference, by far, lies in the model conceptualization phase containing 33 % of the questions compared to 7 %.

This difference was not surprising given that the studied person in U3 only had the *conceptual model* and therefore would spot more questions related to mistakes from writing it. Since the question collecting was performed on only one individual, it was of course of no use to look at the most frequent questions. All questions regarding the model conceptualization were however added to an unit-independent comparison in chapter 5.1.5.

BaseModel validation

When looking at the *BaseModel* constructed by the engineer, the most striking thing is the visual difference in the model. Since the only depiction of the production flow in the conceptual model is the flow seen in fig 9 (chapter 4.1.2), the mere fact that it differs was not surprising to the researchers, but the extent of the visual differences was surprising. The 2D-model layout of the *original model* constructed in Enterprise Dynamics and the *BaseModel* built from the *conceptual model* only are shown in fig 31 and 32.

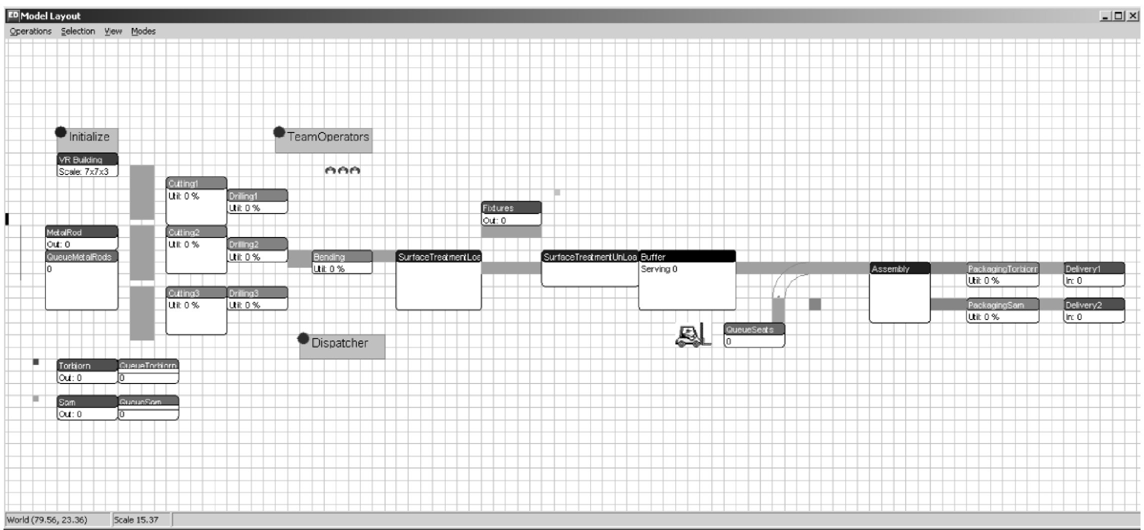


Figure 31 – The original model constructed in Enterprise Dynamics

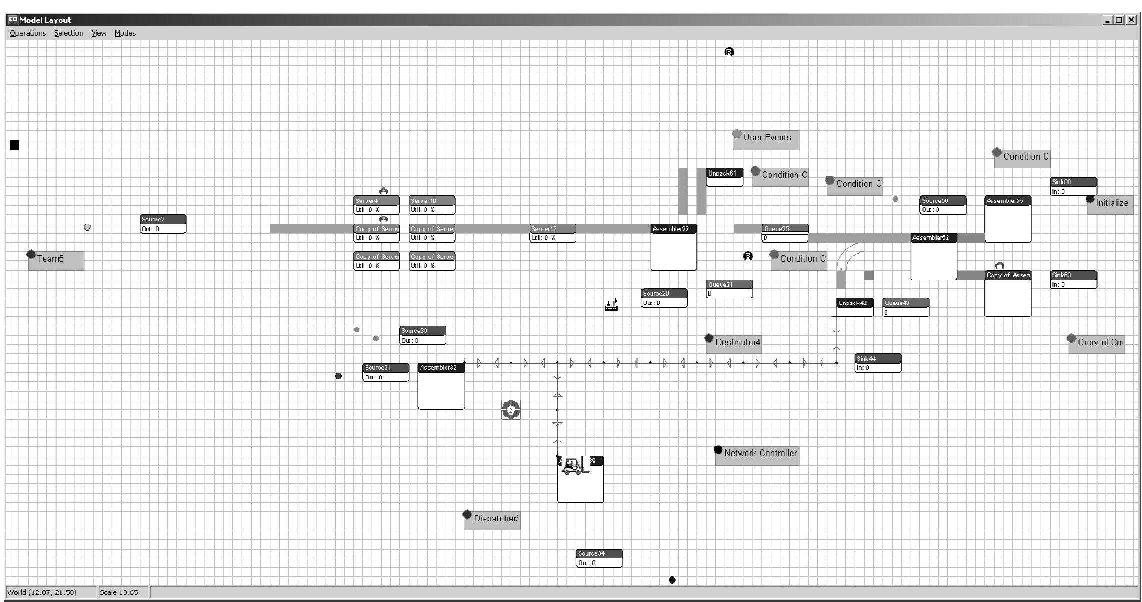


Figure 32 – A BaseModel built only from the conceptual model

One thing that can be directly noted is that the standard conveyor lengths should have been provided in the conceptual model and not only standard speeds and product spacing.

When looking more in detail at the model however, it performs very similar to the real model. On the checked 160 hours, the original model has an average output of 774 finished products per variant ($\sigma = 1.48$) based on five runs. The BaseModel performs very similar with a slightly higher output per product variant observed ($\mu = 777$, $\sigma = 1.34$ based on five runs) which is regarded as a very good result.

The visual appearance differs, and so does the way of solving some of the logical issues in the flow. However, the dynamics of the system are working as described in the *conceptual model* which, of course, is the most important feature.

5.1.4 Unit 4 – Expert panel

The analysis for unit 4 is divided into interviewees and survey participants.

Interviewees

As described in chapter 4.1.3 the conceptual model belonging to the case material was presented to two interviewees experienced in DES and constructing of conceptual models. Their general thoughts were that the *conceptual model* was well made but differed in a few important aspects from a real life conceptual model.

Firstly, the *conceptual model* included a lot more detailed data concerning for example cycle times than a real life one. This type of data is not generally available when the conceptual model is constructed and such data is also not generally crucial for the model translation step.

Secondly, a real-life conceptual model would contain a lot more visual representation of the system, for example in the form of pictures or CAD-drawings. Since the person building the model in an offshored setting cannot see the system, visualization is important in order to better understand the system and how it operates. What also was stated was that a lot more background information would have been included, such as background information on the client that had ordered model and why the model is to be made. Also more descriptive text regarding the logic in the *conceptual model* would be recommended in order to decrease the risk of misunderstandings.

Nevertheless, in an overall perspective, the *conceptual model* used in the case was stated to be a fair representation of a real life conceptual model apart from the above mentioned concerns. What can be concluded is that most of the information differing when comparing the *conceptual model* to a real life conceptual model can be originated from the fact that the system in the *conceptual model* was fabricated with one of its purposes being to be used as an educational tool.

Survey participants

The surveys sent out to the previous supervisors in the DES-course given at Chalmers Technical University were unfortunately only answered by two individuals. Nevertheless, the answers were well formulated and were therefore considered insightful.

The first question in the survey was to estimate the portion of time needed for communication if the conceptual model used in their course was to be sent to an offshored simulation engineer instructed to perform the model translation. The two estimates given were 5-10 % and 15-30 %.

Several questions posed in the survey regarded their conceptual model. What was emphasized in the answers was that it is important not to leave too much room for interpretation in a conceptual model. In an educational setting however, it might be good to leave some room for interpretation because it will be less likely that students will get stuck and spend an unproportionate amount of time on some parts of the model building. In a real life setting though, as little room for interpretation as possible should be given.

One answer highlighted that certain types of logic can be difficult to explain through a written conceptual model, for example how fixtures can move about in a production flow.

Regarding letting a simulation engineer construct a model from a conceptual model one of the answers highlighted that the simulation engineer should participate in the making of the conceptual model in order to ease the model translation step.

5.1.5 Questions related to the model conceptualization phase

It was decided to look at all questions categorized as being in the model conceptualization phase since those questions would have occurred due to unclarities in the *conceptual model*. In other words, the researchers wanted to see where they had created questions not answered by their *conceptual model*. All the eight question variants from the 24 groups solving the case are displayed in table 11.

Table 11 – Collected questions originating from the model conceptualization phase

#	Question	Frequency (Unit)	Category	Banks model
1	Is an operator driving the truck?	2 (U2, U3)	Insufficient description	Model conceptualization
2	Is the coffee breaks calculated on each operator? Does this make any sense?	1 (U3)	Insufficient description	Model conceptualization
3	Are there seats available all the time?	1 (U3)	Insufficient description	Model conceptualization
4	Does loading fixtures require operators?	1 (U3)	Insufficient description	Model conceptualization
5	Do I need to make an operator repair my machines?	1 (U2)	Insufficient description	Model conceptualization
6	What length should my conveyors be of?	2 (U1)	Insufficient description	Model conceptualization
7	How specific is "approximately 45 meters"	2 (U1)	Insufficient description	Model conceptualization
8	Is the drilling automated or is just the loading/unloading automated?	1 (U1)	Insufficient description	Model conceptualization

When looking at where the questions arose, it is seen that half the question variants (Q1-Q4) were asked by the single person in unit 3 only working with the conceptual model.

When looking at the question areas, Q1, Q2, Q4, Q5, Q8 regard the operators. In the case for Q4, Q5 and Q8, the operators were not explicitly stated to *not* be required. It was therefore mistakenly assumed that since there was no mention, there would be no need to add them. Regarding Q1, it was written that an operator was driving the truck and performing loading and unloading. Since the driver was mentioned to be an *operator*, uncertainties arose whether he was one of the usual operators working in the factory or not. In the case of Q2, the question arose because of the setup time in the packaging where it was stated that the operators were allowed to take coffee breaks after having packaged a certain number of boxes. However in the *original model* no operators were dedicated to any workstations and since they were called randomly whenever free, this made no sense in a real life setting.

The reasons Q3 and Q6 arose were because of leaving out information. The assumption that seats should be available at all times should have been written and in the same way should the conveyor lengths have been stated.

The last question, Q7, arose because of vagueness. The truck distance was not really regarded as an important aspect for the model performance; however using words such as “approximate” triggered the question on how approximate it was.

To summarize, the questions relating to the model conceptualization phase were asked because of

- Not stating that something is *not* needed (Q4, Q5, Q8)
- Using inconsistent naming (Q1)
- Describing an illogical procedure (Q2)
- Leaving out necessary information (Q3, Q6)
- Being vague (Q7)

5.1.6 Analytical summary

Unit 1 – No simulation experience, no work experience

Unit 1 was a diverse group both when looking at prior knowledge, engagement and results. Some groups performed astonishingly well with a low number of errors and short time used for the study, thus ending with a final value on the generated performance indicator of 0.31 at its best. Other groups succeeded less well, spending a lot of time and still making a lot of errors generating a performance indicator value of 3.71 at its worst with 16 errors and 33 hours to finalize their study.

There was a surprisingly high occurrence of errors in the *BaseModels*, and the most common ones were due to carelessness in entering data, and focusing too much on the *software guide* and thereby ignoring data in the conceptual model despite being specifically told to review the model.

When looking at the questions posed, most (63 %) were categorized as “insufficient description”, meaning that the reason for the question was that the answer was nowhere explicitly stated. In the software training context U1 worked in, this was not seen as surprising. When relating the questions to Banks model, most questions were asked in the model translation step (63 %) followed by experimental design (21 %). When comparing this to U2, the experimental design-proportion is significantly smaller. This was believed to be due to U1 finishing their *BaseModels* late during supervision and not having time to ask about experimental design, a statement which was partially supported by the perceived need for time in the course.

Three of the seven most frequent questions were regarded as avoidable if emphasized when presenting the case. This was later tested in U2, where informing about these possible problem areas had the sought for effect.

The understanding of the task performed was perceived as good and after listening to a final presentation of the model, also explaining the two most common problem areas in detail, this understanding further increased. The confidence in trying to build a similar model solely from a *conceptual model* was higher (55 % completely or partially agreeing to be able) than the confidence in performing a study of their own (29 % completely or partially agreeing to be able).

Unit 2 – No simulation experience, work experience

Unit 2 was considered quite homogenous when looking at positions of individuals in the company, prior knowledge, interest and results. All groups finished their *BaseModels* within a small time interval the first day and all groups were able to finalize their *FinalModels* during the second supervision session four weeks later.

The errors found in the *BaseModel* were in most cases not regarded as serious when looking at possible performance effects on the system. This is believed to be because of paying more attention to the *conceptual model* than the software guide and therefore having a better understanding of the system.

The group posed more "in depth-out of scope"-questions than other units, which is believed to be an effect from wanting to use the software in their normal work. When looking at the collected questions in relation to Banks model, the unit posed a larger proportion (42 %) of their questions in relation to the experimental design-phase than the other units. The reason for this is believed to be that the unit groups finished their *BaseModels* faster and thus had more supervised time when experimenting than groups in the other experimenting unit (U1). The most common questions were related to the difficult parts in the model and were explained in a final presentation to improve understanding.

The understanding of the model was good during model building (67 % completely or partially agreed with understanding their model) and improved after the model had been thoroughly explained in a final presentation to 88 % understanding rate. Due to the fact that U2 participated in more ED-training apart from the case, the survey data regarding confidence on the software and building a model from a conceptual model only is hard to compare with that of U1, however the data shows that a five day intensive training given to a unit of 10 individuals is sufficient to give good results on a personal confidence level where 71 % completely or partially agree to be able to build a model from a conceptual model only and 100 % partially or completely agreeing to have adequate software knowledge to perform a study of their own.

In comparison to U1, the notion was that the understanding of the fictional production facility and the commitment to the task was higher in this unit. Due to a license failure later in the training, the free text answers in the survey concluded that in a software training aspect, it was desired to be no more than two individuals per computer in order to maximize learning.

Unit 3 – Experience within simulation and Enterprise Dynamics

This unit mainly consisted of one engineer solving the case only using the *conceptual model*. The main impression from his model was the big difference it posed visually and internally on how he had chosen to solve logical relationships in the software.

His questions made up half the variants of the questions relating to the model conceptualization phase, which showed where the researcher's had been unclear when writing the *conceptual model*.

His *BaseModel* showed that the *conceptual model* was sufficient to solve the case giving an output per product variant of $\mu = 777$, $\sigma = 1.34$ based on five runs to compare with $\mu = 774$, $\sigma = 1.48$ based on the same amount of runs in the *original model*.

Unit 4 – Expert panel

The interviewed experts claimed that the *conceptual model* was more detailed than a real life conceptual model given in early stage of a simulation study. Furthermore they stressed that a real conceptual model would contain more visual information and more background information to decrease misunderstandings. Apart from these two facts, they stated that the *conceptual model* in general was a fair representation of a real life conceptual model.

The results from the survey claim that emphasis should be put on not giving any room for assumptions when writing conceptual models and, if possible, that the conceptual model should be constructed together with the simulation engineer.

Questions related to the model conceptualization phase

A certain look was given to the questions in relation to the model conceptualization phase to see where the conceptual model had been unclear for the person posing the question. Among the eight variants, four were posed by the engineer in U3 building the BaseModel with the conceptual model only. The five reasons behind the questions occurrence were stated to be "not stating that something is *not* needed, using inconsistent naming, describing an illogical procedure, leaving out necessary information and being vague.

5.2 Professional DES-offshoring interviews

This chapter contains an analytical summary of the subjects discussed in the interviews with people having experience from academic and professional settings on discrete-event simulation and offshoring.

5.2.1 DES methodology

Regarding discrete-event simulation, the preferred methodology differed between interviewees. The main difference between the interviewees is that some preferred to use Banks model while others preferred to use what is referred to as the "nine-step methodology". Both approaches however in practise are very similar, basically only differing in step naming and categorization. A general perception from the interviewees was that it does not matter which methodology is used as long as the people involved in the project knows which one to use.

5.2.2 Experience from writing conceptual models

As seen in table 4 describing the professional interviews, the experience from writing conceptual models was brought up with two of the interviewees. Even though there were only two sources of information, the interviewees' knowledge, expertise and experience were considered more than enough to provide well founded guidelines regarding the writing of conceptual models. Important aspects brought up in the interviews concerned:

- Background information
- Descriptive text on why the system is to be modeled
- Visual information
- Descriptive text on how the system works
- Special considerations

Background information. The background information includes information about the company that has ordered the model, for example company history, photos of the work environment, pictures of components, machines, products etcetera. The background is especially important when the person that is to build the simulation model does not have the opportunity to see the system in reality.

One of the interviewees exemplified this by stating that one of the reasons to provide background information is for example the simple reason that a factory manufacturing titanium parts for a space shuttle and factory manufacturing tea differ a lot from each other, to say the least.

Descriptive text on why the system is to be modeled. Knowing why the system is modeled in the first place is important because that fact will affect how the system is modeled. A description of why the system is to be modeled should preferably be provided in writing from the company that has ordered the model.

Visual information. The visual information is very important in order to get an overview of the system. A 2D-layout can be provided in the form of blueprints or in a boxes-and-arrows type of manner. According to the interviewees, the more ways to visually represent the layout of the system, the better. To complement the 2D-layout, 3D-layouts can also be provided if possible. It can also be desired for certain parts of the model translation step to provide video recordings, CAD-models or photographs to mention a few.

Descriptive text on how the system works. To complement the visual information, a descriptive text that thoroughly describes the system dynamics should also be included.

Special considerations. If data is included in the conceptual model, it must be clearly defined because an unclear definition can cause problems since for example the concept “cycle time” sometimes includes setup time and sometimes does not. Another example concerning data is that if it stated that a machine has a utilization of 80 % this does not really say much about the machine. For example 80 % utilization can mean that the machine is down one week every five weeks or that the machine is down one minute every five minutes. These types of uncertainties must be taken into consideration during the model conceptualization phase.

Faulty assumptions concerning logic can also cause problems for obvious reasons. In the case of not knowing how the logic works which is often the case in dynamic flows it is better to state that the information is not available at the moment than risking a time-consuming rebuild of the entire model at a later stage.

5.2.3 DES offshoring methodology

The interviewees with experience from offshoring of DES stated that from a project manager's point-of-view the methodology did not differ when performing an offshored DES study compared to an onshored. They either both followed Banks model or the "nine-step metodology". The interview structure followed the stages in Banks model divided into the following five phases:

- Step 1 – 2: The initial phase
- Step 3 – 4: Model conceptualization phase
- Step 5 – 7: Model building phase
- Step 8 – 10: Experimentation phase
- Step 11 – 12: Finalizing phase

The initial phase. The initial phase concerns the acquirement of the project, the setting of objectives and the construction of an overall project plan. The people mainly involved in the project at this time are salespeople and project managers. Sometimes audiovisual recordings from meetings with the client are made during this phase that offshored simulation engineers can take part of afterwards, for example when constructing the conceptual model.

Model conceptualization. As the name foretells, during the model conceptualization phase the conceptual model is constructed. In this phase the project manager at the onshored location starts communicating with the offshored simulation engineer. The project manager hereby starts the transferring of information needed for the simulation engineer to participate in the simulation project. In other words, in this phase the offshored simulation engineer becomes actively involved.

The conceptual model is created by both the project manager and the simulation engineer. The communication needed for the offshored engineer to be able to participate in the construction of the conceptual model is both direct, using for example a "Voice over IP"-client, and indirect in the form of documents containing for example flow charts or layouts of the system. Usually the project manager uses these documents as an aid to verbally explain in an online meeting how the system works and what is of interest to model for the simulation engineer. In a typical project, the first online meeting in the model conceptualization phase takes around two hours. Afterwards, the simulation engineer starts works alone on the model for about a day until the next online meeting with the project manager occurs. If by then, the conceptual model is satisfyingly constructed the project goes into the next phase, otherwise the conceptual model is revised and changed accordingly. For large projects this process can take up to one week.

Many interviewees emphasized that during the construction of the conceptual model a large portion of the time is spent on communication between the project manager and the simulation engineer.

Model building. During this phase the model translation step is carried out (step three in Banks model) and the need for communicating via online meetings between the project manager and the simulation engineer is little compared to the previous phase. The model is solely built by the offshored simulation engineer unless the simulation engineer for some reason is unable to. During this phase the data collection (step four in Banks model) is also carried out. It is normally up to the client to provide data that is needed. The data is then sent to the simulation engineer where it is incorporated into the model.

To keep the project manager up to date on the status of the model building the simulation engineer sends a standardized email at the end of each work day where what has been done, what is needed to be done and what current issues there may be is stated. In addition to the email an FTP-server is used for uploading the latest files that concerns the project, for example the latest version of the model. The folders on the server are named in a standardized way to make it easy for both the project manager and the simulation engineer to keep themselves updated on the progress of the project. In addition to this, there are still online meetings every two or three days where the project manager gets updated on the project and the simulation engineer can get updates that concerns the project. The meeting is also held in order for the project manager to keep the client up to date on the progress of the project.

When the model is considered to be finished the verification and validation (step six and seven in Banks model) of the model is starts. If possible, the validation and verification is made by the simulation engineer using real data from the client. One interviewee stressed that this step can be time consuming due to the fact that the simulation engineer hasn’t visited the system site nor, in most cases, communicated directly with the client and therefore may not have the same mental image as the project manager.

After being verified and validated, the client is also asked to ensure that the model is working satisfyingly.

Experimentation phase. When the model has been verified and validated the experimentation phase begins. It is during this phase that step eight through ten in Banks model is performed. In this phase of the project the frequency of communication between the project manager and the simulation engineer increases. This is due to the inherent need for feedback when conducting experiments. For example if the objective of the project is to increase the throughput of a factory the model builder must know what changes to the model that can be made from a real life perspective.

During this phase the simulation engineer conducts experiments, derives results from them and relays them to the project manager. After an experiment or a set of experiments are made the simulation engineer must wait for feedback from the project manager because the project manager may have to relay the findings to the client. The project manager will after consulting with the client either conclude that no more experiments are needed or give the simulation engineer further information on what experiments to conduct. Since the simulation engineer must after each experiment or set of experiments get feedback from the project manager this stage in the project requires a lot of communication, for example in the form of online meetings. This need for communication can cause efficiency problems. To mitigate this problem, the project manager can develop “what if”-scenarios together with the client for the simulation engineer.

Finalizing phase. When all the experiments are finished and the objectives of the project are met the completion of the project is near. What is left to be done is to present the results to the client and to create documents according to the client’s preferences. This documentation can for example be a PowerPoint presentation or a more extensive report. The finalizing phase represents step eleven and twelve in Banks model. After completion, the project manager and simulation engineer together evaluate the project and document the lessons learned.

5.2.4 Offshoring experience

When discussing offshoring in general with the interviewees a few subtopics came about. These subtopics were:

- Cultural aspects
- Location aspects
- Globalization aspects
- General operative aspects
- Financial aspects

Cultural aspects. The cultural aspects are important to take into consideration for the simple fact that they do matter. What was stated was that there were of course cultural differences between the US and India offices but that they generally were of no major concern. The staff at the Indian office could adapt from the more hierarchical structure that is common in the Indian business culture to the more flat organization that is common in the US (compare power distance index in fig 5). What were also stated to take into consideration were holidays. Since holidays are important for most people and that holiday dates in the West and India differ from each other, one must keep in mind not to expect people to work during such holidays. For example most people do not want to work around Christmas in the west and similarly, most people wants to be off from work around Diwali in India.

Location aspects. Location both concerned time zone effects and location selection for an offshored office.

Different time zones were seen as both being advantageous and disadvantageous. The advantage is that more hours can be used during one day since some of the work on a project can be carried out in parallel. The time difference is disadvantageous when having online meetings since one of the parties must attend the meeting outside office hours. For one of the interviewees this means that he has to be up in the middle of the night sometimes due to a 12.5 hour time difference. This is balanced out by trying to have half the meetings outside office hours for one party and the other half of the meetings outside office hours for the other party, i.e. striving to make it “equally inconvenient”.

Regarding meetings and contacts overall with the offshored simulation engineers, one important issue that could cause problem was the fact that some of the simulation engineers only were accessible while being at the office. This because not having broadband internet connection at home. On another note, an unrelated, but for the researchers nevertheless interesting fact is that the offshored office is located in an area where planned power cuts have occurred due to energy rationing. This was tackled by having a backup power generator at the office building.

The chosen location for the office in India from a start up point of view was also discussed. It was stated that consideration had to be taken to the fact that talent retention can be difficult in India. Therefore, the approach taken when starting up the Indian office was to choose a city which was not very large and that had a good university. This choice was made for the possibility to hire locally attached engineers which were considered less likely to move to another city or country if given the opportunity. Also in a smaller city, the risk of losing engineers to a competitor is considered less likely. In other words retaining talent would be easier. Apart from choosing a smaller city, two other considerations were stated to be important for talent retention. These were to pay a salary that would motivate them and to satisfy their professional development needs. Satisfying professional development needs is made through among other things by after two years of employment, providing the opportunity of going to the US to study for a Master of Science degree sponsored by the company.

The people hired have at least a bachelor's degree. Since knowledge of discrete-event simulation is rare in India it is very common to hire people straight from school since it is usually easier to teach such an individual new things. One estimate given by an interviewee was that it takes 8-9 months of employment before a newly hired engineer is fully productive. The interviewee also estimated that it took about two years of initiation before the offshored office was considered to be fully operational.

Globalization aspects. The researchers were interested in discussing what the general thoughts from clients were regarding the fact that parts of simulation projects are offshored. This was of interest to see if there were any issues with clients being uncomfortable with "jobs being sent away" as is not entirely an unusual mindset when discussing globalization. One of the interviewees stated that it was not a big issue, most clients were not in anyway concerned with the fact that parts of a simulation project is offshored. The company offers their clients the option to choose whether or not to use the offshored office stating that the project cost differs depending on location since labor cost in India is significantly lower. What is of concern for most clients is only the quality of work.

Another concern that was brought up was if there were any issues with sending certain information to another country for security reasons, for example if the client did not want certain data to be sent away. This was usually not a major concern because of non-disclosure agreements with the client to guarantee the safety of the data. The only project types consistently not being offshored are projects that have to do with defense (military).

General operational aspects. In this subtopic, general thoughts and facts concerning DES-projects were placed.

Communication is regarded as a crucial aspect in order to succeed with a simulation project. When offshoring, this is even more important and therefore it was in the interest of the researchers to find out how much time that is spent on communication between the project manager and the simulation engineer. It was stated by one of the interviewees working as a project manager that 20% of the entire project time is budgeted for communication with the offshored simulation engineer. This percentage had been derived by empirical studies of simulation projects offshored in the past. This can be compared to the 15 – 20 % budgeted when managing a project where the simulation engineer works at the same office as the project manager.

When touching upon the subject of what projects that is not possible to offshore it usually is projects which are very urgent and that the extra time for communication between the project manager and the simulation engineer is considered so large that the deadline for the completion of the project is not able to be met if the project would have been offshored.

Regarding the number of projects that can be run simultaneously for a project manager it was said that it was possible to handle up to eight projects at once, but then with at least one or two of them on hold and all other being in different stages of completion. For the simulation engineer usually one project is done at a time, but sometimes several. The reason for it sometimes being several projects is that one or more project is on hold due to for example waiting for input data.

Financial aspects. The financial aspect was of interest for the researchers but unfortunately concrete figures were hard to derive during the interviews due to confidentiality reasons. What could be concluded is that the cost savings when offshoring is substantial and this solely due to the difference in labor cost.

5.2.5 DES future

Here the interviewee's impression of the future of DES and DES offshoring was taken up. The general thought was that in some aspects the demand for simulation will increase but in some aspects it will remain relativity unchanged. The reason that it will increase is that more companies discover the benefits of simulation. Another important reason is that simulation is starting to be used in areas where it has not been used before, for example within healthcare and environmental projects.

The interviewees with experience from India were more than convinced that the demand for simulation will increase in India, but this will take some time because currently simulation is regarded as a new and rare "thing". A reason to a possible increase in demand in India is that it is common that when labour costs go up so does the demand for simulation since it is and effective tool for making efficient and well founded decisions in order to allocate resources where they are needed.

Since simulation overall was considered to increase or at least not decrease, the need to offshore DES-projects was considered to become bigger, mostly for competitive reasons.

5.3 Operative offshoring cost model

Despite not being told or finding specific figures on the cost benefits from offshoring, there is still a possibility to see when it is financially beneficial. For this calculation, we look at a normal sized DES-study where the model is built by an offshored simulation engineer managed by an onshored project manager familiar with the real system. The calculation looks at operative offshoring, where an offshored office already exists, which is true in the case of the company.

It is assumed that the onshored project manager alone is capable of performing the offshored part of the project (i.e. building the model) at the same speed as the offshored simulation engineer. It is also assumed that the communication is sufficient for the offshored engineer to be able to work on the project at full speed when not communicating.

To do this, the following variables are identified:

C_{on} = The hourly cost for the onshored project manager
C_{off} = The hourly cost for the offshored simulation engineer
α = The time proportion of the offshored project spent on communication
$(1 - \alpha)$ = The time proportion spent working on the project

Therefore an offshoring is financially beneficial when the combined cost for the time spent working and communicating from/to an offshored location is smaller than the same amount of time working at the onshored location.

$$(1-\alpha)C_{off} + \alpha\left(C_{off} + C_{on}\right) < (1-\alpha)C_{on}$$

Which can be simplified to

$$C_{off} < (1-2\alpha)C_{on}$$

Using the 20 % used for communication stated by an interviewee in chapter 5.2.4, we see that an offshoring in this case is financially beneficial when the hourly cost for the simulation engineer is less than 60 % of the project manager's.

6 Results

This chapter meets the set objectives and concludes the necessary information needed to fulfill the purpose of the master's thesis being "to understand process of offshoring discrete-event simulation projects and to create general guidelines for how to perform the process successfully". It is divided into three parts:

- Business motivations for DES-offshoring
- Initiating DES-offshoring
- Operative DES-offshoring

The first two chapters provide the background needed to understand the DES-offshoring process. The third chapter, Operative DES-offshoring, answers the thesis main question being how to successfully offshore parts of or entire DES-projects and creates guidelines for this by answering the sub-questions.

6.1 Business motivations for DES-offshoring

When looking at the business motivations for DES-offshoring one approach is to separately look at the business motivations for DES and offshoring. The main business motivation for offshoring is the cost reduction possibility from lower labour costs. Regarding DES, the financial motivations are important; however they may not always be the main reason to conduct a simulation study.

The business motivations for offshoring and discrete-event simulation do however not contradict each other. This fact combined with one of the interviewees stating that the main motivations for their DES-offshoring was for competitive and cost-reduction reasons it can be deduced that it is possible to combine the business motivations for DES and offshoring.

6.2 Initiating DES-offshoring

Before looking into what needs to be taken into account to successfully engage in a DES-offshoring in an operative environment, this chapter gives a brief picture of considerations that should be taken into account when setting up an offshore office.

First of all, it is important to be aware of the fact that the ramp-up time before an offshored office is fully operational with intended results can be long. One of the interviewees stated that it took about two years before the cooperation with the offshored office worked as originally intended.

When it is decided to start up an offshored office, one of the most important aspects to decide is its location. To be able to decide a location, several factors need to be taken into consideration. Some of the more important factors include:

- Country – In this thesis, China and India have been discussed. India has a comparatively long tradition in information technology offshoring and is still today in most cases a preferred location. China has recently seen a rapid economic development resulting in a rapid knowledge growth possibly resulting in being a future prospect for knowledge industry offshoring.
- Government – To engage in offshoring it is important that governments of both the onshored and offshored locations enable border-crossing cooperation.

- City – As one of the interviewees stated, deciding what kind of city to place the office in is of importance. In their case, they chose a smaller city because of a desired “small town mentality” in the employees which was believed to increase the likelihood of talent retention.
- Technology – The location has to fulfill the technological requirements needed for communication. This can include necessities such as a stable power grid, broadband internet connection and mobile phone coverage.
- Level of education – It is important to consider if the intended location can offer the needed expertise for the intended task or if employee training is required. One of the factors mentioned by an interviewee when discussion their chosen location was the vicinity to a good university providing a well educated employee basis. He however added that the simulation skills in the country were virtually nonexistent and therefore a newly hired employee need up to nine months of training before being considered productive.
- Language – Friedman claims that one of the three main reasons for the outsourcing popularity to India is due to the fact that the country houses the world’s second largest English speaking population.

6.3 Operative DES-offshoring

This chapter answers the main question posed in chapter 1.2 being “how to and in which way can parts of or entire DES-projects successfully be offshored?” by providing answers its five supporting sub-questions.

6.3.1 What cannot be done elsewhere than on-site or from the local office and why?

The methodology used to describe a discrete-event simulation project in this master’s thesis is named “steps in a simulation study” normally referred to as Banks model. What was stated by interviewees involved with DES-offshoring is that in theory, all steps in a simulation study can be performed all the way from acquiring a project to final implementation.

The usual approach however is a bit different since the simulation engineer normally does not participate in any client interaction and therefore interacts with the project manager in most of the steps in a simulation study. The practical approach is displayed in figure 33 – Banks model modified for an offshoring setting.

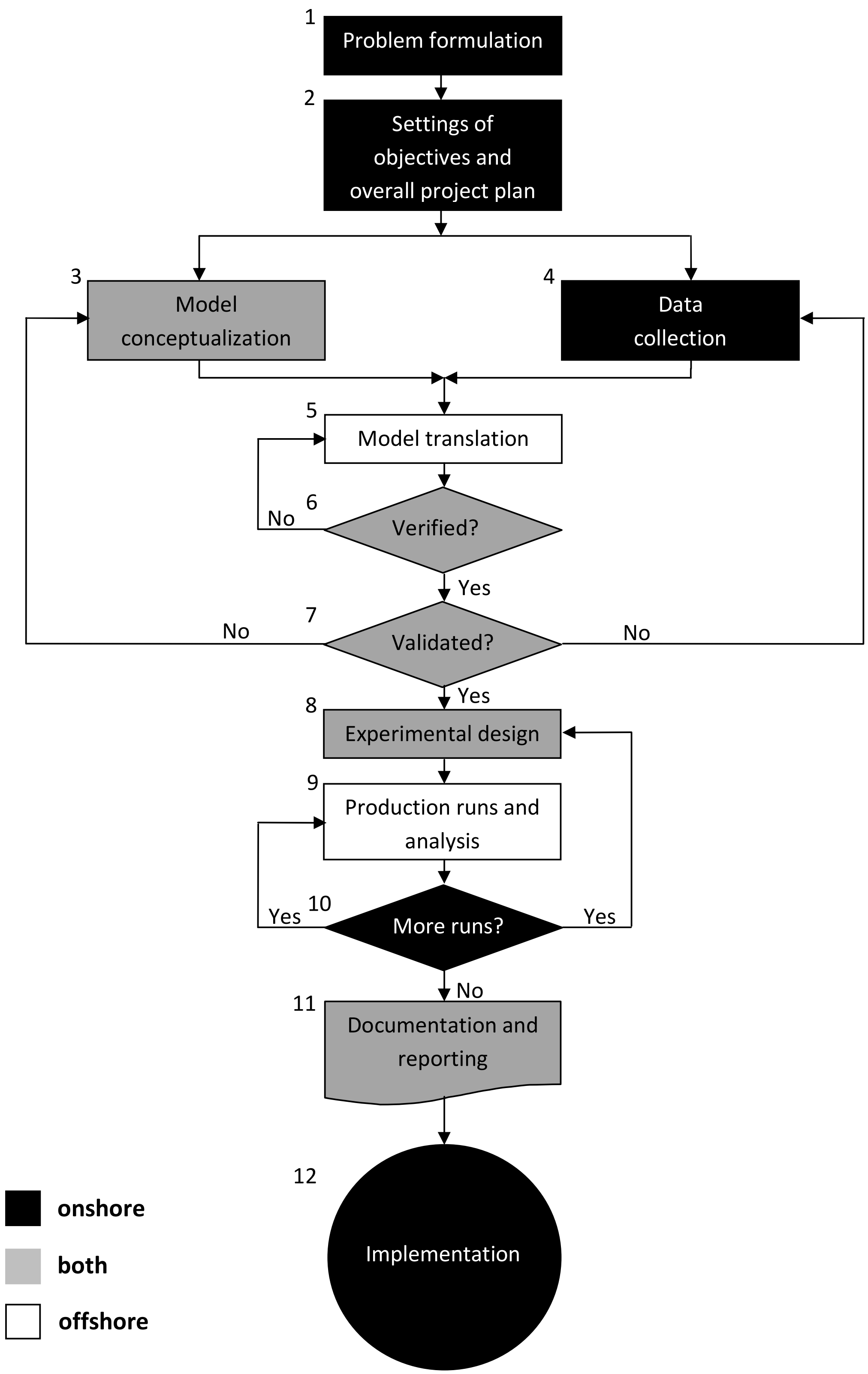


Figure 33 – Banks model modified for an offshoring setting

Step 1 and 2 are made onshore because of the simple reason that they require client interaction. Step 3 is made in cooperation between the manager and the simulation engineer in order to simplify the model translation step. Step 4 is made onshore since the data originates from the client, who also usually is responsible for delivering the data. Step 5 is done offshore. This is when the simulation engineer builds the model. Step 6 is done in cooperation to verify that the model works as described in step 3 and that no mistakes have occurred during step 5. To make sure the model is imitating reality, step 7 is also performed in a cooperative manner. When the model has been validated, step 8 is cooperative because it requires client interaction. Step 9 is performed offshore and afterwards the decision on whether the model gives satisfying results is made onshore in step 10. Thereafter, the project manager and simulation engineer together document the model in step 11 and finally the project manager implements the model at the client in step 12.

6.3.2 What type of discrete-event simulation projects can or cannot be offshored and why?

According to results from several interviewees, all types of projects *can* be offshored. However, what usually is not offshored are projects with a very short timeframe from start to finish and projects that according to legislation have to be performed onshore, for example projects in the defence industry.

6.3.3 What requirements are there on communication between an onshored and an offshored office and how often should it occur?

When talking about communication, it can be said that it is difficult, to say the least. This can be exemplified by communication theory stating that what is referred to as a paradigm sets rules on how concepts are interpreted. In other words, communication success depends on the paradigms used by communication participants.

A famous model for the more practical aspects of communication is the Shannon-Weaver model describing the steps information takes from its source to its destination depicting that information may be distorted along the way. One example of this is how the researchers' inner picture of a fictional factory, transmitted through the form of a conceptual model, is received and interpreted by the engineer in unit 3 creating a visually deviant model however working as intended.

When looking at the case study from a higher level of abstraction, the researcher's role was to communicate all the information needed to simulate the fictional factory in the form of a model in a DES-software. The researchers' approach was to use several communication mediums such as written material and audiovisual presentations. Despite this, none of the studied unit members managed to complete the task without asking supplementary questions. Even in the light of this, not a single member managed to replicate the factory without making any errors.

To make certain that this was not due to handing out bad material, the conceptual model itself was checked by experienced simulation engineers claiming that it held a sufficient standard and a high level of detail.

The conclusion of the researchers is therefore that no matter how well your information is formulated and presented, misinterpretations, misunderstandings and other mistakes will occur. Also when scrutinized by many individuals, actual mistakes in your information will be found. In the case of the *conceptual model* written by the researchers, five categories of miscommunication could be derived:

- Not stating that something is *not* needed.
- Using inconsistent naming
- Describing an illogical procedure
- Leaving out necessary information
- Being vague

The humoristic "laws" formulated by Osmo Wiio state that if communication occurs, communication will somehow fail. The only thinkable solution to this is to increase the rate of communication until found sufficient for the task. Also use communication means proving to be most efficient for end results. In the DES-offshoring setting which many of the interviewees experiences stemmed from, the communication used the following means:

- Instead of the project manager sending over a written conceptual model to the simulation engineer, they together discuss the system that is to be modelled according to the manager's perception and based on that, the simulation engineer creates the conceptual model.
- Daily written updates on project progress by using a standardized e-mail template from the offshored engineer to the onshored project manager.
- Daily upload of the latest versions of project files to a shared FTP-server.
- Online meetings on a regular basis using both Voice over IP and screen sharing applications at least every two or three days depending on project progress.

6.3.4 Which are the limiting factors regarding the profitability of offshoring a discrete-event simulation project?

It was hard to get any financial data from the interviews. Therefore a model looking at the percentage of a project budgeted for communication comparing project costs for an onshored project manager working with an offshored simulation engineer was developed. This model assumed that the project manager was capable of doing the same amount of work as the simulation engineer in the same amount of time and looked at under which hourly cost difference an offshored project would be financially beneficial. The cost model

$$C_{off} < (1 - 2\alpha)C_{on}$$

has the parameters C_{off} , C_{on} and α, representing the hourly cost for the offshored simulation engineer, the hourly cost for the onshored project manager and the time proportion of the offshored project part spent on communication.

When using the data given in an interview stating that 20 % of the time in an offshored project is budgeted for communication, it can be shown that the project is financially beneficial for offshoring if the hourly cost for the simulation engineer is less than 60 % of the project manager's hourly cost. This simple model indicates that one very important factor regarding profitability is the hourly cost of an offshored simulation engineer.

This cost model does not take factors such as time and problems which may or may not occur due to working with an offshored location into account when looking at project profitability.

6.3.5 Which cultural and practical factors need to be taken into account when offshoring?

Regarding cultural differences, the impression received from most interviewees was that they easily can be bridged. However it is important to be aware of the fact that cultural differences exist and may have to be mitigated in some way. One example where an interviewee had to mitigate differences was when he managed a project in cooperation with a simulation engineer reluctant to refuse a, for him, unsuitable proposed meeting time because of belonging to a business culture where a subordinate does not refuse a manager's proposal.

As an aid in order to understand possible differences is Hofstede's cultural dimensions, categorizing national cultures under the five dimensions power distance, individualism, masculinity, uncertainty avoidance and long term orientation can be used.

Regarding a practical aspect of cultural differences, something that was mentioned by almost all interviewees was the fact that holidays may differ. If not properly planned for, this can bring about problems.

Another practical aspect is time zones which can be both and advantage and a disadvantage. A proposition made by Gold is a creative use of time zones spending more hours of the day collaborating on the same project. However in reality, time zones are usually regarded as a disadvantage. The mitigation method when time differences are large used by several of the interviewees is to try and make meetings "equally inconvenient" by having an equal proportion of the meetings outside office hours both onshore and offshore.

A practical factor which most likely will occur in DES-offshoring is that employees will have to learn how to use new software. This happens both after recruiting a new employee and if new software is introduced in the company. Education however, turns out to be even more important when offshoring DES to India. According to interviewees, discrete-event simulation is not commonly being taught at Indian universities, creating a need not only to learn new software, but also to master the art of simulation.

When providing training in a DES-software, some of the insights gained from the case study include:

- Using the "tell them"-principle, i.e., telling the students what they are going to learn, then letting them learn and finally telling them what they have learnt seems to increase the perceived simulation knowledge gained from the student's perspective.
- The practical approach used to teach DES with a conceptual model containing all necessary information for the model together with a software guide showing step-by-step how to construct the model in the software was perceived as a good approach. However showing in too much detail how to perform each step can be dangerous if causing the student not to think but just follow instructions. This pattern was observed in one of the units of the case study leading to trying different approach, handing out the conceptual model one hour before the software guide, in another unit. This approach is believed to have resulted in the other unit having a better system understanding.
- When contact was lost with an online license, some students were forced to work in groups of 3-4 individuals instead of 2-3, which led to a common comment in the surveys being that smaller groups per computer is advantageous over larger.

7 Discussion

This chapter is more informally written, containing general thoughts on the master's thesis project work.

The first chapter discusses the process of fulfilling the purpose of thesis, i.e. "to understand the process of offshoring discrete-event simulation projects and to create general guidelines for how to perform the process successfully". This is done by looking at the researchers' perceptions of the answers given to the main- and sub-questions in chapter 6.

The second chapter discusses the overall work conditions under which the thesis has been conducted.

7.1 Fulfilling the purpose

Five sub-questions were set up in order to answer the main question being: *How to and in which way can parts of or entire DES-projects successfully be offshored?*

The first sub-question was: *What cannot be done elsewhere than on-site or from the local office and why?* This question was answered by combining Banks model and offshoring, according to the interview results on how it's done in reality at the company. The researchers were never able to validate this derived model through a real life project, which of course was a disadvantage. However, the belief is that it is applicable in real life setting since it is similar to the operative work with offshoring of DES-projects at the company that is carried out today.

The second sub-question was: *What type of discrete-event simulation projects can or cannot be offshored and why?* This question was given a very short answer, due to the simplicity of its answer. Because the answer to this question was very straight forward there were never any doubts concerning the validity of the answer.

The third sub-question was: *What requirements are there on communication between an onshored and an offshored office and how often should it occur?* This question turned out to be more extensive than originally thought. Depending on the way it is looked upon from, its answer can be either very abstract or very practical. The approach was to try and find a path between these two extremes. A more abstract approach could regard looking at the different paradigms that can exist between the offshored engineer and the onshored manager. A more practical approach could be to write down specific guidelines on how to communicate as efficient as possibly using strict guidelines, certain means and predetermined frequencies. The "golden mean" in this thesis finally turned out to be to look at where miscommunications occurred in the conceptual model written by the authors and to see how DES-offshoring is performed in practise based on interview results.

The fourth sub-question was: *Which are the limiting factors regarding the profitability of offshoring a discrete-event simulation project?* This question also turned out to be hard to answer since there were a lot of constraints on what information or data regarding financial figures that was possible for the researches to collect. Even though such information was hard to derive it was seen as important to still give an indication on the possible factors that could limit the probability. As seen in the answer a simple cost model was developed and it is believed to give the indication that was sought after despite its simplicity and generalizing assumptions.

The fifth and final sub-question was: *Which cultural and practical factors need to be taken into account when offshoring?* The answer of this question can be regarded as quite vague however that is also usually people's perceptions of things. The answer is more meant to give a perception of the fact that the interviewees had found ways to bridge both cultural and practical obstacles and that this can and most likely will have to be done.

When looking more generally at fulfilling the purpose by answering the sub-questions, the belief of the researchers is that something which may have given better results would be the ability to participate in a real project. For example, the views of the interviewees were in many ways similar, which points at the fact that their perception is similar concerning the work procedure. However, a shared perception between people working with each other may still not be the same as the perception of an outside observer.

7.2 Work conditions

Writing a master's thesis in the researcher's case provided a freedom rarely seen in most previous academic projects. In this case a freedom that may even have been larger than the freedom in many other theses.

The researchers started the thesis work with a supervisor at the company who was in the middle of the process of switching jobs and at the same time mainly being located in another city. This however, worked quite well as he was frequently available on the used VoIP-client for questions and help. He however basically left the supervising task after a month and a half. The fact that this would occur was known on beforehand and therefore all possible measurements were taken to get as much knowledge as possible from him in the early stages of the thesis work.

From Chalmers, the researchers were promised a supervisor in a conversation with the examiner. However when contacting him, he said that he was too busy supervising other projects and working with his own task, which led to the fact that the examiner took the responsibility of acting both as the Chalmers supervisor and examiner.

This basically meant that after a month and a half, the researchers only had one person to turn to when questions arose during the rest of the thesis work. In most cases this worked satisfactory as the freedom of working without too much boundaries was being used. However, when wanting specific criticism on for example writing the report, only relying on one person is not to be recommended. In retrospect, a lesson learned would be to at least try to find a dedicated supervisor at the university to have both a supervisor and an examiner to be able to help out with problems.

8 Future work

This chapter describes how aspects and results from the thesis can be used and further developed in the future.

The case study used in the thesis to look at communication and to emulate offshoring can preferably be used to look at educational aspects. The method of collecting and categorizing questions is, according to the researchers' beliefs, a good way to objectively collect data while at the same time supervising. This can be used to evaluate training material but also to compare units using the same material to each other. The categorizing can be quite time consuming but if only a few categories are looked upon, the procedure can be sped up.

A way to use the case study, which would be more relevant for the results in the thesis would be to use the same material on similar units to validate the perceived differences between, for example, units without simulation experience either having or not having work experience. A recommendation from the researchers is then to study the units under similar circumstances looking to aspects such as time, group- and unit size and handout material to mention a few.

When looking at the results from the project and how they can be applied in reality, it would be interesting to see if the offshored version of Banks model (fig 33) can serve as a base for offshored simulation projects.

The focus of the thesis has been on the operative part of DES-offshoring. An interesting related field to look into is the initiation phase for DES-offshoring. A few of the specific factors that could be interesting to investigate include simulation skills worldwide, time zones, costs, holidays etc. In other words: looking at possible locations for an offshored simulation office.

The results are quite general and meant to be able to apply on most situations. What could be interesting to do is to develop stricter guidelines in forms of checklists, procedural orders, measuring percentages of projects spent on different phases to see if they in practice can become more effective.

Regarding communication, several more aspects can be considered. Some of the specifics that could be looked into contain questions on how to make communication more effective (seen from time, quality and cost perspectives), looking into which paradigms offshored and onshored people communicate in, comparing different means of communication etc.

To conclude, the possibilities to use the thesis as a basis for future work are many. A strong belief of the researchers is also that the thesis itself can be used whenever looking at simulation offshoring to get a general understanding of the subject.

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Appendix A – The conceptual model

This appendix contains the conceptual model used for unit 2 in the case study. The corresponding document for unit 1 and unit 3 was basically the same document only with a different front page due to different hand-in requirements.

Enterprise Dynamics Training Case

Attached is a document that describes a production system in need of development. Your task is to create a model of the production system in Enterprise Dynamics (ED), simulate its weaknesses and from an analysis suggest proposals for investments able to make the production flow more efficient.

Your work should follow this work flow:

1. Create a *base model* of the production system as it works today. Validate the base model by demonstrating how it is running and show it to a supervisor.
2. Perform your choice of simulation experiments. Adjust the base model and input data as needed. Analyze the impact on the production output.
3. Prepare a final presentation and present it at the end of the training to the other groups and the supervisors.

The final presentation can contain for example these topics:

Base model

- Describe your base model shortly including important assumptions you've made.
- Present the production output from the base model (today's production system)

Experiments overview

- For each experiment conducted present shortly:
  - Investments
  - Production output
  - Additional comments

Final model (your recommendation for an upgraded production system)

- Investment plan
- Production output
- Summarize your analytical insights

If you want a confirmation that your *BaseModel* works accordingly or if you have any questions regarding the case, please feel free to email us.

Good Luck!

Chair AB

Background

You are newly hired to work at the production development department at Chair AB. The company has a lot of problems at the moment and the poor delivery precision of finished goods is only one example that affects the customers. The management team guesses that the root causes of the long lead-times from raw material to finished goods and frequent production disruptions are to be found in the old machines as well as in lack of production planning. Hence, the company management has decided to modernise the factory and has ordered an investigation which will deliver decision support for future investments.

Products

Chair AB manufactures two types of kitchen chairs called "Sam" and "Torbjörn". The legs of the chairs arrive to the factory as raw metal rods and the seats arrive pre-manufactured from a supplier. The variants are of the same dimensions, use the same assembly process and are equally popular on the market.

Goal

The goal is to improve the throughput of products at the factory. The task is to analyse the dynamics of the product flow within the factory, find its weaknesses and present possible investments within the frame of a fixed budget in order to increase the performance of the company. The investment budget for this task is $ 150.000.

Production system descriptions

The existing production flow is presented in Appendix I.
A list of possible investments and their costs is presented in Appendix II.

If there are any obscurities, use your engineering skills to make assumptions that are relevant for the described production system. Mention your assumptions in the final presentation.

Factory hours

The factory is open for production 160 hours per month.

Conveyors

Every movement within the factory is made with conveyors, which are both accumulating and non-accumulating (non-accumulating unless otherwise specified!). The conveyor speed is 0.3 meters per seconds by default. For safety reasons, no materials are allowed to be positioned closer than 0.2 meters from each other while travelling.

Arriving Material

There are three kinds of products arriving from suppliers to the factory.

Raw Metal Rods. The raw metal rods are used as the legs of the chair. They arrive in straight 4.5 meter long rods. The rods are assumed to always be available when needed.

Seats. The two kinds of seats are manufactured by two different suppliers and arrive at two different locations next to each other. The seats are assembled to the processed rods and are assumed to be available when needed.

Cutting

The first step in the production process is to cut 4.5 m Raw Metal Rods into Metal Rods of 1.5 meter each.

- There are three old automated cutting machines in the factory today.
- Loading a new Metal Rod into place takes 2.5 minutes for one operator.
- The cutting machine then performs two simultaneous cuts (generating 3 Metal Rods at the same time). Time required to perform cut is 10 seconds.
- MTTF = NegExp distribution with average value of 4 hours
- MTTR = TriangularTop distribution: mode 35, min 25 and max 45 minutes

Drilling

After the cutting process the Metal Rods are directly put into a drilling machine (no conveyor in between). The drilling machine prepares each Metal Rod with four holes to facilitate later assembly operation. Each cutting machine has its own drilling machine directly after itself in the flow. A drilling machine only handles one Metal Rod at a time, including loading and unloading.

- Automatic loading time is 13 seconds per Metal Rod.
- Drilling speed is 10 seconds per hole.
- Automatic unloading time is 13 seconds
- MTTF = NegExp distribution with average value of 3.5 hours
- MTTR = Normal distribution: μ= 1500 seconds σ = 20
- Breakdown can happen during drilling, as well as during loading or unloading.

Bending

After the cutting and drilling operations the Metal Rod has to be bent to get the right shape for future assembly. This station is fully automated and single, which means that the flow has to come together from the three preceding machines. The bending process gives the Metal Rod a U-shape with 0.5 m leg length and takes 15 seconds per Rod.

The time between failures and repairing times for the equipment has been measured during a consultancy project that finished one month ago.

- MTTF = NegExp distribution with average value of 7 hours
- MTTR = 25 minutes

Surface Treatment

At the Surface Treatment station, the Metal Rods are put on a fixture and coated to get the correct surface finish.

- The fixture travels through a spray booth on a fixture conveyor system with a speed of 0.1 meters per second.
- 3 fixtures are available
- Travel distance for each fixture is 5 meters on the fixture conveyor system.
- Loading the fixture follows a lognormal distribution with 10 seconds μ and 2 seconds σ.
- Unloading the fixture takes 20 seconds.
- Return fixture consists of an identical conveyor as above, but with speed 1 meter per second.

Buffer

Before the assembly station, the treated Metal Rods have to dry and cool down in a buffer for at least 30 minutes. The buffer capacity is 250 Metal Rods.

Seats

The factory is built so that the seats arrive in the same end of the factory as the rods. The seats need no processing before assembly but nevertheless need transport to the assembly preparations. The transport distance for each of the seats is approximately 45 meters (each square in the model layout represents a distance of 1x1m) which is taken care of by an electric truck.

The seats arrive pre-packaged in a box containing five seats. To load the truck, the operator needs to get out and remove the box from the seats and load them onto the truck. The seats are then transported to a queue before the assembly. At the queue, the operator needs to take the chairs apart and manually lift them into place.

- The loading process takes 45 seconds
- The unloading process takes 45 seconds
- The truck moves at a speed of 2 m/s
- The truck acceleration is 0.5 m/s^2
- The truck deceleration is 1 m/ s^2
- The queue before the assembly has a capacity of 10 seats

Sorting before assembly

The assembly process is fully automated. Due to the automated station, the products have to arrive in a particular order (seat, leg, leg). The sorting is taken care of by a PLC which decides when two conveyors joining into one are allowed to move.

- The leg conveyor after the buffer is 6 m
- The straight conveyor from the queue is 2 m
- The following curved conveyor has a radius of 3 m
- The combined conveyor is 5 m

Assembly

At this station the Seats and Legs are assembled. The resulting product is a complete chair. After assembly, the machine sorts the products depending on type to two different conveyors due to different packaging procedures for the two chairs.

- The assembly process assembles two legs and a seat into a finished chair.
- The process is normally distributed with a mean of 120 seconds and a standard deviation of 12 seconds.
- After the assembly, the finished product is transported lying on the side (dimensions: Length 1 meter, Width 0.5 meter, Height 0.5 meter).
- After the assembly, there are two 3 meter long *accumulating* conveyors leading to each packaging station.

Packaging

The final station in the factory is packaging of finished chairs into boxes. Each box holds 3 finished chairs. The box is then placed in the finished goods area waiting to be delivered to customers.

- Manual packaging starts when 3 chairs are available at respective station.
- Boxes are assumed to be always available at the stations.
- Manual packaging (requires operator), for 3 chairs in total, follows a Normal distribution: mean 300 s, standard deviation 30 s.
- After assembling 20 boxes, the operator is allowed to take a coffee break of ten minutes.
- Only one type of chair can be assembled at each station.

Manning

Today there are three operators working in the factory.

Scrap rates

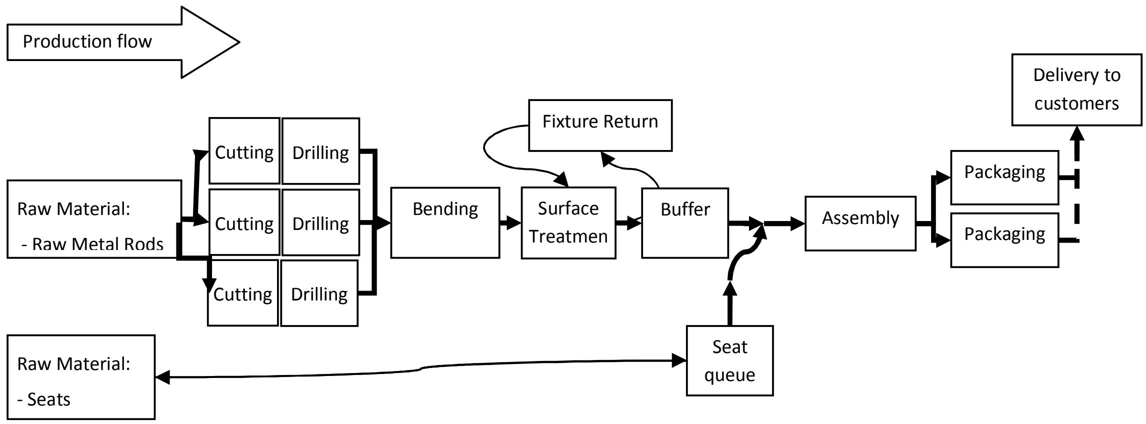
To simplify matters, 100% process quality is assumed, meaning that there are no scrap rates (due to low product quality) to be considered for this production system. Machine breakdowns are included as described in this document.

Other information

If you feel insecure on how to interpret the input information above, please make your own assumption. You can of course also ask the supervisors for guidance.

Appendix I - Production flow & material dimensions

Each connection between operations is represented by a conveyor.



Material dimensions

Raw Metal Rod

Length:	4.5 meters
Width:	5 mm
Height:	5 mm

Metal Rod

Length:	1.5 meters
Width:	5 mm
Height:	5 mm

Fixture

Length:	0.7 meters
Width:	0.7meters
Height:	0.15 meters

Appendix II, Possible investments

Conveyor	Dollar
per meter conveyor	500
Change type of one conveyor from non-accumulating to accumulating	2000
Increased speed on all conveyors with 20%	4000
Cutting	
Identical set of new cutting equipment	18000
Decreased cycletime on all cutting machines with 20%	21000
Increased MTTF on all cutting machines with 40%	5000
Decreased MTTR on all cutting machines with 40%	5000
Drilling	
Identical set of new drilling equipment	19000
Increased drilling speed on all machines with 50%	6000
Increased MTTF on all drilling machines with 40%	3000
Decreased MTTR on all drilling machines with 40%	4000
Bending	
Identical set of new bending machine	22000
Reduce cycletimes on all bending machine with 20%	6000
Increased MTTF on all bending machines with 40%	5000
Decreased MTTR on all bending machines with 20%	4000
Surface Treatment	
Per additional fixture	3000
Automatic loading/unloading, reduced handling times with 50%	10000
Speed up fixture conveyor system with 20%	5000
Assembly	
Reduce cycletime on Assembly operation with 50%	20000
Further reduce cycletime with 20%	11000
Identical set of new assembly machine	29000
Packaging	
New coffee machine (reduced break, 50%) and bigger cups (every 40th cycle)	3000
Lift assistance equipment for manual packing, decreases cycletime with 50%	17000
Identical packaging machine	28000
Truck	
Decrease loading time with 30% by changing demands on supplier	4000
Decrease unloading time with 30% by changing demands on supplier	4000
Double maximum speed of truck	8000
Double acceleration by training truck driver	3000
Increase load quantity of truck (cost per extra seat)	700
Further decrease loading time with 25%	5000
Further decrease unloading time with 25%	5000
Manning	
Hire one new operator	18000

If you find out improvements which are free of cost please make realistic assumptions and use as needed.

Appendix B – Simulation case evaluation – Unit 1

What was your general perception of the case? (Hard/fun/interesting/useful)

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____

How you find the work procedure with both a case description (conceptual model) and a software guide? (Difficult/logical/confusing/etc). How could/should it be done differently?

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Have you got stuck while working on the case on your own to such an extent that you have been unable to continue without asking a course mate or us? If yes, then on what part and why?

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____

If you would only have received the documents (the case description and the software guide to construct your basemodel) and were only allowed to ask questions twice a day on phone/skype/email/etc, do you think it would have taken you much longer? Would it have been possible?

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____

Do you have any other thoughts? Should we have done anything differently in your opinion regarding the case?

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Please finally rate the following statements accordingly, where

1 = I completely disagree
2 = I partially disagree
3 = No opinion
4 = I partially agree
5 = I completely agree

The 10 supervised hours was enough to finish the basemodel and provide enough assistance for my FinalModel-related questions	1	2	3	4	5
I have worked alot on the case outside the scheduled hours	1	2	3	4	5
I understood how my model worked when I built it	1	2	3	4	5
I now (after the presentation) understand how my model works	1	2	3	4	5
I got insights in simulation in the course which can be useful in my future career	1	2	3	4	5
I am able to construct a similar simulation model from a case description only (conceptual model)	1	2	3	4	5
I have adequate knowledge within Enterprise Dynamics to be able to try to perform a real study	1	2	3	4	5
I think that the people responsible for the case assignment have been satisfyingly committed to the course	1	2	3	4	5
I think that building the model was fun	1	2	3	4	5

Thank you very much!

T&S

Appendix C – Simulation case evaluation - Unit 2

This is the survey that was handed out to unit 2. It was written in Swedish and is depicted below in its original form.

Simuleringsutbildning

Vad tyckte du om utbildningens innehåll och upplägg (föreläsningarna, caset, uppgifterna)?

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Ur en utbildningssynvinkel, hur tycker du att arbeta med både en konceptuell modell och en mjukvaruguide fungerar? Kan det göras annorlunda och isåfall hur?

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Om du enbart fått dokumenten (den konceptuella modellen, mjukvaruguiden och experimentguiden) för att bygga upp din BaseModel och bara haft möjligheten att ställa frågor två gånger per dag via elektronisk kommunikation, tror du att uppgiften tagit mycket längre tid att slutföra? Hade det varit möjligt att slutför a den?

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____

Har du några övriga kommentarer? Kunde något i utbildningen gjorts annorlunda?

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____

Var vänlig rangordna följande påståenden enligt:

1 = Jag håller inte med alls
2 = Jag håller delvis inte med
3 = Jag har ingen åsikt
4 = Jag håller delvis med
5 = Jag håller fullständigt med

Tiden avsatt för handledning var tillräcklig för att slutföra min FinalModel	1	2	3	4	5
Jag har arbetat mycket med övningsuppgiften utanför utbildningen	1	2	3	4	5
Jag förstod hur min modell fungerade när jag byggde den	1	2	3	4	5
Nu efter presentationen, förstår jag hur min model fungerar.	1	2	3	4	5
Jag kom till insikter I simulering under utbildningen som kan bli nyttiga i min fortsatta karriär	1	2	3	4	5
Jag kan konstruera en model utefter en konceptuell model enbart	1	2	3	4	5
Jag har tillräckligt med kunskap I Enterprise Dynamics för att försöka mig på en egen simuleringsstudie	1	2	3	4	5
Jag tycker att de ansvariga för utbildningen haft ett tillfredsställande engagemang	1	2	3	4	5
Jag tycker att det var roligt att bygga modellen	1	2	3	4	5

Tack så mycket!

S & T