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Improving Process Quality and Efficiency in an Engineer-to-order Company

- A case study of the Quotation- and Order Delivery Processes

Master of Science Thesis in Quality and Operations Management

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Abstract

Today's increasing global competition has put substantial pressure on existing industries and businesses, forcing them to cut costs in order to stay competitive. This is a trend that increased substantially during the last years, for capital goods industry as well as for engineer-to-order companies. An Engineer-to-order company is defined as when the entire developing or designing of a product is made after receiving a customer order. This is often the case for highly customized products with low quantities.

From a historical perspective, main focus to stay competitive have been to improve efficiency and quality by optimize the product development and production. The early coordination between marketing/sales and manufacturing is a relatively unexplored area, when finding correlation to efficiency/productivity and quality upstream the process.

The purpose of this thesis is to identify what factors in the quotation process and order delivery process that influences process quality and efficiency in an engineer-to-order company. In order to identify these factors, a case study of an engineer-to order company have been conducted with four internal cases and one external.

During the analysis, the outcome from the case study and interviews with stakeholders could be grouped into five sub-processes. The activities within these sub-processes influences part or the entire value chain from an efficiency and/or quality perspective. These sub-processes were; Capturing process, Quotation process, Hand over process, Order Delivery process and lessons learned. Within each of these some improvement areas could be identified. When analyzing these improvement areas deeper, it shows that many of the quality and efficiency problems identified has its root cause already in the front-end process. This includes the capturing process, the quotation process and the hand over from sales to project manager/engineering.

The major factors influencing process efficiency and quality can be categorized into; 1. Organizational matters, such as internal and external communication, and cultural differences & objectives, 2. Customer specification, the specification creates much uncertainty due to lacking/changing/unclear input and 3. Process Management, how the processes are defined, implemented and measured with representative KPIs to find correlation between certain activities in the process and how this influence quality/efficiency and cost aspects.

Keywords: *Engineer-to-order, process efficiency, quality, Quotation process, Order Delivery process*

Table of Figures

Abbreviations and descriptions

BOM	Bill of Material
COFQ	Cost of Poor Quality
Capturing process	Opportunity identification prior the tendering
Efficiency	"Minimization of waste and maximization of resource capabilities, in order to deliver quality products and services to customers, and improve quality and productivity" (Shaffie et al, 2011)
Engineer-to-order	When the order point of a product is already when developing or designing the product. This is a Pull-type production, just making the product if there is a customer demand
ETO	Engineer-to-order
FES	Front End Sales, link between customers to factories
Front-End	Refers to the initial stages of a process, responsible for collecting input from the customer and processing it to a specification, that later phases of a process can use
Hand over process	Is when the manufacturer receives a formal order from customer, and the project manager takes over the responsibility and calls to the project kick-off meeting
KPI	Key Performance Indicator
NCR	Non Conformity Report, this is used to report all divergent activities in the quotation- and order delivery processes
OpX	Operational Excellence
Order delivery process	Include all activities from hand over, design process, supply chain, production and shipment
Process	"A network of interrelated activities that are repeated in time, whose objective is to create value to external or internal customers" (Bergman & Klefsjö, 2011)
Quality	"The quality of a product is its ability to satisfy, or preferably exceed, the needs and expectations of the customers" (Bergman & Klefsjö, 2011)
Quotation process	The quotation process in this case study is defined as the activities that take place from receiving a request for quotation (RFQ) until notification by the customer of award or opportunity lost
RFQ	Request for Quotation, when customer asks for a quotation
Tender	An offer or bid given to the customer

1 Introduction

This chapter aims to introduce the research area of process efficiency and quality in the development process of new products in the so called engineer-to-order (ETO) businesses.

1.1 Problem background

During recent years many technology companies that produce complex products have experienced an increased global competition. These products are often engineered or designed after the point of sale, called ETO, and therefore requires a large amount of specific knowledge in order to be customized.

These industries have traditionally not experienced any fierce competition but have instead been relatively unthreatened due to the difficulties for competitors to gain sufficient knowledge to enter the market. The pressure from customers has also been low as the customers have not had the possibilities to change supplier easily. This has led to industries where not much focus has been put on optimizing processes or costs.

As today's trend, with increased global competition is valid for most manufacturers of capital goods the development is similar throughout many different industries. Hicks et al (2000) describe how the evolution of the competitive context in recent years has led firms to operate in an increasingly global and uncertain environment. This have made it crucial for companies to emphasize more on the concept of customer-driven manufacturing, making the firms able to deal with more and more differentiated product features, tight delivery performances, low costs and customer demands. Business process efficiency is a critical way to improve margins and allow more flexibility in pricing.

This thesis will present a case study of a company in the ETO business, producing complex products that require a high degree of engineering and customization for each unit can improve its process efficiency and quality. This covers the processes all the way from when a customer request for a quotation until order delivery.

During the last couples of years, the ETO industry has, as many other industries for complex products, faced a more difficult business environment due to an increased global competition. New actors have entered the business mainly in China and Korea where the domestic competition has increased both rapidly and substantially, due to improvements in various aspects like technology and cost.

The traditional initiatives to increase the competitiveness have to a very large extent been focused on two main areas which are also confirmed by Cooper (1994). Firstly, focus has been put into optimizing the design of the product in order to use less expensive materials to be able to keep the margins when reducing the price. Secondly, is that the production has been improved in order to reduce production time and increasing the robustness of the production process leading to cost savings. This has generally been done through implementation of Lean Production which aims to reduce waste, and Six Sigma that focus to detect and remove defects in

production. The argumentation for why this focus have been spent on production can be seen in e.g. Cost of Poor Quality (COPQ), increased number of test failures, but also re-work and changes throughout the production chain. However, taking into consideration the interaction and dependency production have to other functions, such as engineering and sales, much COPQ in production have its root cause already in the initial stages of the processes, i.e. in the interaction between customer-sales-design, see Figure 1.

This early stage of the value chain is often named Front End and includes the activities taking place prior the product development, responsible for collecting input from the customer and processing it into a specification used by later phases of the process. Front End starts already in the quotation process, when making a tender design to a customer. In Figure 1, the quotation- and order delivery process is presented, with involved functions.

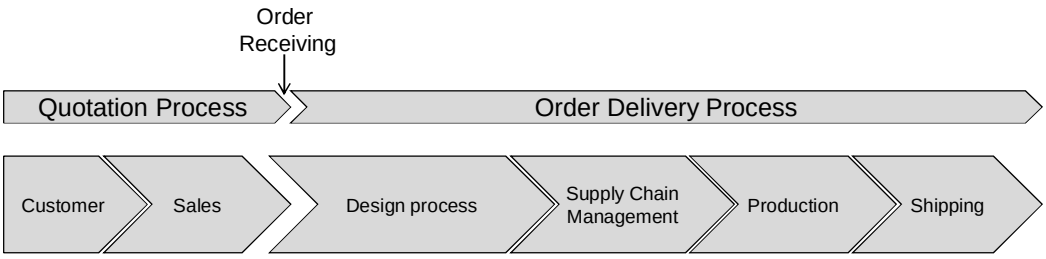


Figure 1 shows the interaction between quotation process and order delivery process

In comparison with the optimization spent on the product quality itself and the efficiency improvements in production, the coordination taking place in the quotation- and order delivery processes have generally not been the target for as much research or improvement work. Both external communication with the customers and internal coordination between marketing/sales and manufacturing is relatively unexplored areas within ETO companies, even though it has been seen that it influences the product success to a large extent. (Konijnendijk, 1993; Konijnendijk, 1994; Zorzini et al 2008; and St. John & Hall, 1991).

This thesis aims to found factors in the value chain affecting process quality and efficiency, with the focus on early interaction between customer and factory.

1.2 Purpose

The purpose with this thesis is to identify what factors in the quotation process and order delivery process influence process quality and efficiency in an engineer-to-order company. A major focus will be put on the early processes, such as quotation process in order to understand the impact on the rest of the value chain.

1.3 Research questions

From the purpose two research questions were developed.

Research Question 1:	*How can the Quotation- and Order Delivery processes in an engineer-to-order company be described from a quality and efficiency perspective?*
Research Question 2:	*Which are the major factors in the Quotation- and Order Delivery processes that influence process efficiency and quality?*

1.4 Delimitations

Main focus for this thesis will be the early processes in the value chain, since the quality of the input to this process affects all steps taken afterwards. It have also been found in literature that the early coordination between functions affect the product success and this was also confirmed after initial discussions with key resources in this project.

However, there is still of interest to understand process efficiency and quality from a broader perspective to determine if the early processes' impact. For example, the biggest amount of COPQ found in the specific ETO Company today can be located to the production leading to a need to incorporate all functions all the way to production in this thesis to understand the situation.

Customers or suppliers will not be part of this thesis, leading to that all factors found to influence efficiency and quality is based on the experience, preferences and knowledge within the cases studied.

Improvement areas and factors influencing efficiency and quality will be presented as well as recommendation of how to improve the current situation. An eventual implementation of improvements will not be included in the scope of this thesis. Neither will other supporting functions that might affect the process, such as Human Resources (HR) and Information Systems (IS) be part of this research.

2 Methodology

In this chapter the chosen strategy and design of the research will first be described. Afterwards a more detailed description of the research design will be presented; with the different phases of the project, including relevant methods, presentation of samples and decisions taken during the project execution. A discussion concerning the ethical concerns and trustworthiness aspects of the project will be held.

2.1 Research Strategy

This project focus on process efficiency and quality in quotation- and order delivery processes in an ETO company. To be able to describe what factors that influence the efficiency and quality mostly, a case study will be conducted at an ETO manufacturer. This company represents the general characteristics of an ETO company, (see 3. Theoretical frameworks for explanation), assuming that the result can be applicable on other ETO companies as well. However, conclusions are based upon the findings and the setting of this company.

The chosen research strategy will take inspiration from grounded theory, meaning that an iterative approach will be used. This by going back and forth between data and theory in order to generate theory from collected data that is systematically gathered and analyzed during the research process. (Bryman & Bell, 2011).

This relates to the initial theory study done on the topic, where it was recognized that relative little of existing literature concerns to the chosen purpose. Instead of confirming a theory or hypothesis, which would be the case for a deductive strategy, this qualitative research emphasizes to understand the meaning of the gathered data and information in a deeper sense. The execution of the research has been inductive, meaning that theory will be the main outcome from the research. (Bryman & Bell, 2011).

The expectations with this research was to find factors in the quotation- and order delivery process that influence the process efficiency and quality and give recommendation of how to improve the situation. To understand the situation better, quantitative data will work as support and supplement to the qualitative data gathered via interviews, when applicable and able to get.

2.2 Research Design

A research design provides a framework for the collection and analysis of data, and since this project will deal mostly with qualitative data, a research design handling loads of data was chosen. Case studies are according to Yin (1984) a good strategy for taking care of much qualitative input and Eisenhardt (1989) refers it as a way to develop grounded theory.

A case study, compared to other research designs, focuses on a bounded situation or system. This study aims to produce general findings valid for ETO companies in general by conducting a case study at an ETO manufacturer. The findings will also work as a platform for future quality improvements taking place within the company.

Even though case study will be the main design, inspiration from benchmarking will complement the study. This assesses the performance of various aspects of an organization's processes and systems, to be determining which of its activities that is strong or weak (Lapide, 2005/2006). By comparing different cases against each other, common issues and challenges can be found and best practices can be transferred within the organization.

There exists different types of benchmarking, for this study the two major ones of interest are internal Benchmarking; Comparing a process with the same process in another place, department or company within the company group, and benchmarking on competitors; Comparing a process with an equivalent process at a competitive company. (Hollings, 1992)

The research design, that combines case study and benchmarking resulted in six major phases, where most focus have been spent on data collection and analysis, see Figure 2.

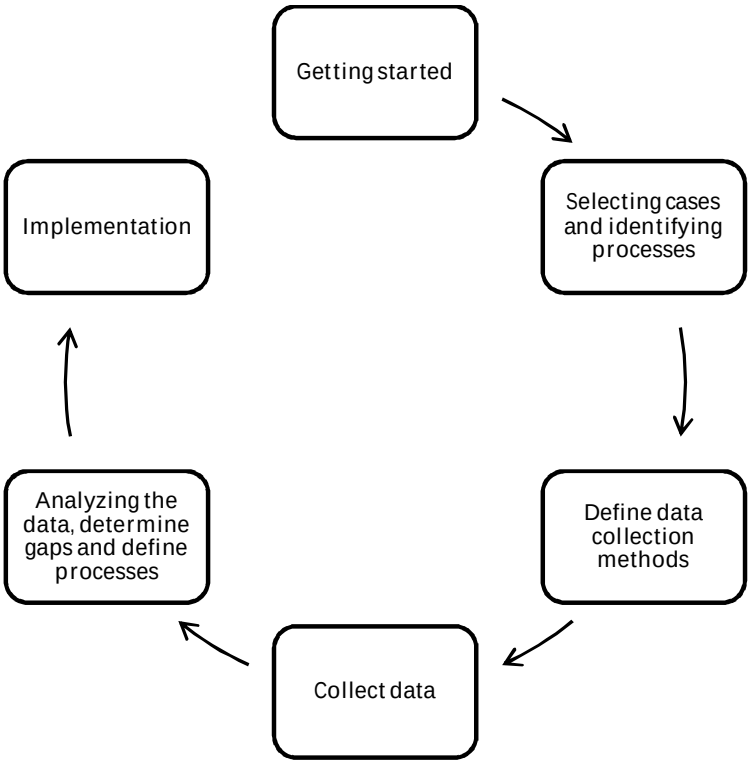
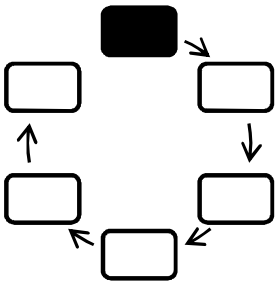


Figure 2 The different phases of the project execution

2.3 Getting started (1)



For a case study the first thing that should be defined is the research questions and scope. Having a well-defined focus is crucial to collect specific kind of data systematically; otherwise you risk to be overwhelmed by the volume of data. Still the research question may shift during the research depending on the findings. The investigator should formulate a research

problem and possibly specify some potentially important variables with reference to literature. (Eisenhardt, 1989).

The first thing done was to understand how the quotation- and order delivery processes at the manufacturer's plants and documentation looked like.

2.3.1 Initial discussions

The project started with the initial main focus on the engineering function and how quality and efficiency could be improved here. After initial discussions with key people that have good understanding of the entire processes, it was clear that the greatest improvement work that could be done was to focus on the front end processes. The reason for this was that improved process quality and efficiency level here will affect the entire value chain, since it was seen that many of the root causes had its origin here. This made the purpose and research questions change during the project, to the current ones, focusing on the quotation process and hand over process. The focus for the project had at this stage moved from engineering function per se, to the coordination between customer-marketing/sales-manufacturing (engineering and production).

2.3.2 Case product characteristics

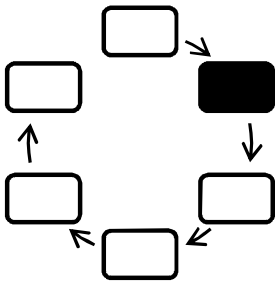
The world's first product of this kind was built already in the end of the 1800's. Today, this product type is used in a broad variety of applications over a wide range of industries and markets all over the world, where the product often is part of a bigger system, dependent and integrated with other parts of the system.

The market for this product type is matured, with not many technological or product innovations taking place. This is a product that have looked more or less the same over 100 years, leading to low technical change, considering the huge size of the market. The life length of this product is long; often the average life time is up to 30-50 years, with a substantial investment cost for the customer. The security requirements are extremely strict, where every industry buying this product has their own standards that need to be fulfilled in the design.

The product is a completely customized product, unique for every customer and order, meaning that a product development process is taking place for every product to fit each customer's need. The interaction between customer and factory is via the sales organization, mostly the local Front End Sales (FES) that acts locally in each region and market.

2.4 Selecting cases and identify processes (2)

Adebanjo (2001) is defining the first step taken in a benchmarking study to be planning, including the identification of business process or function to be benchmarked. This step could be linked to Camp's (1989) first four steps; select subject, define the process, identify potential partners, and identify data sources.



In this phase the samples was defined to be included in the study. This is important when building theory from case studies. Cases may be chosen from many different aspects like replicate previous cases or provide examples of polar/extreme types. Random selection is not preferable. There is no ideal number of cases, but with fewer than 4 cases it is difficult to generate theory with much complexity. (Eisenhardt, 1989).

In this study multiple cases was chosen, and they can be seen as representative or typical cases, even though, or perhaps because of that the difference between them can vary quite much. By having a cross sectional design, meaning a case study with many cases, general findings can be found.

When having grounded theory as research strategy, the first step, presented by Bryman & Bell (2011), is to organize a theoretical sample. Compared to statistical sampling, which is looking for accurate evidence on distributions among people, theoretical sampling is done in order to discover categories and their probabilities and to suggest the interrelationships into a theory (Bryman & Bell, 2011). According to grounded theory there is a great deal of redundancy in statistical sampling, while theoretical sampling focus on sample what is relevant and meaningful, in order to reduce wasted time by hearing the same stories over and over again.

2.4.1 Selected cases

According to Eisenhardt, (1989) between 4-10 samples are recommendable when making a case study or benchmarking study. Four internal factories where defined already from start to be included in this study, these where later changed due to different circumstances to the final four ones presented below.

When defining the samples to be included, it was of high interest that the plant had both high management commitment and also a value adding background to the project with their experience and faced challenges and opportunities. In the end, four internal samples were defined representing different cultures, types of products, history and issues faced in the past.

2.4.1.1 Case 1: External

Beyond the four internal samples, one external case was chosen to serve as a benchmark. This company makes large diesel engines to ships, a product that is highly complex and with both standardized and customized products in the product range. This makes them have both an ATO process and ETO process in parallel. The latter one similar to the process of making the product made at the ETO manufacturer in the case study. (North Europe)

2.4.1.2 Case 2: Internal

The first internal case defined, was important due to the fact that management support and commitment in the beginning was of great importance. The involvement from this factory was high and the project could be supported even more since a representative from the Operations Excellence team, also working as a support for this project, was located there. This factory deals with complex products,

with customers from all over the world, and face slightly different situations compared to more mainstream factories. (North Europe)

2.4.1.3 Case 3: Internal

The second internal case has a more or less standard product portfolio, and has been struggling the last years due to the high global competition in the area of more standardized products. Still it is important to understand that every design of a new product still is customized but not in the same complex way as for the first case. This is a new and modern factory, where much of the management for the product is located. (South Europe)

2.4.1.4 Case 4: Internal

The third internal case was not producing exactly the same range of products as the rest of the internal samples. They use another design platform for the product design compared to these factories. Last year this factory has also had some orders from that product range as well, since they have the capabilities to produce them. Main reason for visiting this plant is their interesting background in the interface with the local sales organization for one part of their market. (Asia)

2.4.1.5 Case 5: Internal

The fourth internal case and fifth sample all together is a factory producing both the product type as the other factories and a more standardized product made in higher volumes and less customization. They started to produce the product of interest not that long ago, leading to an experience level that is below other visited factories. During the history they have faced quality issues that they now started to overcome in a successful way. (Asia)

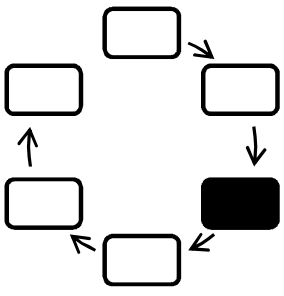
2.4.2 Selected interviewees

In addition to the case studies at different factories, interviews with other key people were a major data source. These where people that either was defined already in the beginning in the project, as people having good insight in the processes or people that was recommended during the project to be included due to their insight and knowledge related to the area.

2.4.3 Internal documentation and standards

The second step in this phase was to identify and understand the processes included in the study. Initial understanding was built on internal documentation that was studied, complemented with held discussions, see Appendix.

2.5 Define Data collection methods (3)



Typically multiple data collection methods are used in case studies, where qualitative data are useful for understanding the underlying relationships revealed in the quantitative data. (Eisenhardt, 1989). During the project three main data sources have been used, interviews and discussions, internal

documents and standards and external literature and theory, where the major focus has been put on interviews.

2.5.1 Literature studies

In the search for relevant literature some keywords have been useful, both individually and combined with each other; ”Engineering”, “design process”, ”Quotation”, ”Order Delivery”, “process”, ”Product development”, “front end”, “Engineer-to-order (ETO)”, “efficiency”, “quality”, and “manufacturing-marketing interface” is some of the most used phrases.

Databases from Eidgenössische Technische Hochschule (ETH) in Zürich, Switzerland and Chalmers University of Technology have been used, combined with e-journals, articles, books and course material distributed at Chalmers. Using references from useful articles and papers have also been of great value in order to find relevant literature.

2.5.2 Interviews

Most of the data in this project have been gathered via discussions and interviews, both in person and via telephone. Almost 50 interviewees have been conducted in this study, leading to an extensive set of data and below are the different types of interviews used, presented.

Unstructured personal interviews

In an unstructured interview, the interviewers do not follow a strict structure of questions, but instead have only one or a few questions for the interviewee, making the interview more like a conversation (Bryman & Bell, 2011).

Interviews of this type where mostly held in the beginning of the project when trying to understand the business, and also during the two first benchmarking visits when the study’s scope still was not completely set and defined.

Semi-structured telephone interviews

A semi-structured interview is referring to a situation where the interviewer has a set of questions to be answered by the interviewee. Still, the sequence of questions can vary depending on the discussion; this makes the interviewer able to change direction of the interview and to follow up with probing questions during the interview. This method is attractive because of the flexibility that it allows (Bryman & Bell, 2011).

A telephone interview can be beneficial to use when resources are limited. The disadvantage compared to personal interviews is that it can be hard to ask complex questions over the telephone and the interviewer has less control over the interview situation (Ingelgård, 2010).

Many of the interviews and discussions held with key interviewees not directly linked to one of the visited plants have been held over phone. This since people involved in the project are located all over the world. The following structure was then used:

- Introduced the project, my background, expectations, timeline of project etc.
- A general discussion related to the area, supported with specific questions and topics that was found to be relevant
- Looking for improvement ideas and main issues according to the interviewee
- Summarized the discussion
- Ask for any further questions or ideas

Semi-structured personal interviews

The benefit with using a personal interview is that the interviewer can observe body language and more easily interact with the interviewee. Also, the interviewer has better control of the interview situation (Bryman & Bell, 2011).

This kind of interviews was mainly used during the second half of the data collection, both for visits and when meeting key people in person. The reason for this is that the purpose and scope of the project got clearer during the project execution which enabled more structure in order to check and confirm areas previously found interesting, instead of finding new ones. The agenda of the discussions where similar to the semi-structured interviews held via telephone, see Semi-structured telephone interviews.

2.5.3 Participants Observations

An observation involves studying people in their natural habitat with a common focus on the culture of a group in order to understand the reality of the situation better. An observation makes it possible for the researcher to better understand use of words and to get other information that the person under study takes for granted and does not speak out verbally during an interview (Bryman & Bell, 2011).

This method was mainly used during the benchmarking visits, both when going out in the production for understanding the complexity and business better, and for observing the interaction between people during interviews when more than one interviewee participated. Here cultural differences could be seen and hierarchy could in some cases affect the interviewee in their willingness to give their opinion.

2.5.4 Research ethics

There are four main ethical issues that need to be taken into consideration when conducting a study (Bryman & Bell, 2011):

- What harm can come to participants?
- Is there a lack of informed consent?
- Does the study involve invasion of privacy?
- Have the research participants been deceived?

Harm to participants

Harm can be interpreted in broad terms, including both physical and psychological harm (Bryman & Bell, 2011). In this study no physical harm has come to the participants, however since questions during the interviews was related to relationships, communication, and knowledge level in different functions some

participants might have felt singled out as the cause of some disturbances in the processes, leading to psychological harm. On the other hand, discussions were never concerning individuals, but a more comprehensive discussion related to the various functions' influence on process efficiency and quality.

Lack of informed consent

Informed content is when the research participant has enough information to make a sound judgment of whether or not he/she wants to participate in the study (Bryman & Bell, 2011).

During all interviews, an introduction to the research topic was held, informing about the project background, expected outcome, and other involved parties. This made the participants understand the situation and also have the opportunity to ask questions if any ambiguities. However, no interviewees were included solely on voluntary basis, instead they were all encouraged from management to participate, which can raise the question if someone potentially would have wanted to refuse to participate. On the other hand was mainly all interviews held without management involvement, making the interviewee able to raise concerns, unclear points or questions.

Invasion of privacy

Bryman and Bell (2011) is describing that invasion of privacy is very much linked to informed consent, and as discussed above it is not clear if the interviewee would refuse to answer or participate since the management expected their involvement. Still no questions were on a personal level, and since the interviews was semi-structured, it was often the interviewee that steered how the questions would be addressed in the discussion.

Deception

Deception in research is when a researcher presents his or her research as something it is not. In order to clarify the purpose of the research and the role of the researcher a presentation was always held before an interview.

2.5.5 Trustworthiness

When judging the quality of a study, reliability and validity are often used in that discussion. When conducting a qualitative study, the concept of trustworthiness is often used when arguing for validity and reliability. Trustworthiness is consisting of four criteria, and has been used as a base of this study. The criteria and the related questions are as follows (Bryman & Bell, 2011):

- Credibility – *How believable are the findings?*
- Transferability – *Do the findings apply in other contexts?*
- Dependability – *Are the findings likely to apply at other times?*
- Confirmability – *Has the investigator allowed his/her values to intrude to a high degree?*

Credibility

Credibility is related to how well the results presented reflect the reality. After initial discussions with the contact person at the ETO manufacturer it was decided to not record the interviews, this since it was risk to meet resistance at the factory and also that people would not be as honest, knowing that the interview was recorded. On the other hand were all initial interviews and two first visits conducted together with an internal resource from the manufacturer, so all gathered information was triangulated after interviews in order to guarantee that the interviews was interpreted in the same was.

To confirm all interviews and conclusion made during the research, all data and input was went true at least two times, in order to see the material with new eyes. When interviews were held only by one researcher, the outcome from the interviews where discussed with another resource to clarify the findings.

Transferability

Transferability is meaning how well the findings can be useful in other contexts. This research is based on much qualitative data based on almost 50 interviewees input, leading to a thick description.

The whole meaning of this thesis is to make conclusions relevant for other ETO companies as well. To secure that the findings is not only relevant for specific ETO manufacturer, one additional external sample was included in the case study to work as a benchmark but also to confirm general conclusions found in an ETO company. Also some of the interviewees were representing other backgrounds than just for the investigated ETO product.

Dependability

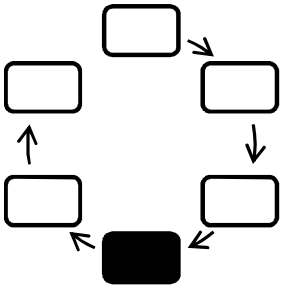
Dependability involves documenting reasoning, where peers should be able to audit the work process. The execution of the project was defined in the beginning of the project, with a detailed time line and schedule of which factories to include in the research. This made it possible for involved parts to affect and update the work progress if necessary or needed.

Confirmability

Confirmability is relating to not letting personal values affect the findings. This is a risk in all research since you as a researcher never can be completely objective. It is also a risk to be influenced by interviewees that talked more than others, this was something that was recognized to affect the outcome, which made in principle all interviews be held with one person at the time.

During the project execution the findings was presented to several involved people to make clear that findings was not contradicting with general opinions within the company, and if that was the case, this data or input was controlled once again.

2.6 Collect data (4)



When entering of the field, a constantly overlapping between data collection and analysis is necessary, for example field-notes like an ongoing stream of conscious commentary about what is happening in the research. This involves both observations and analysis. It has been important to write all impressions down, since it is hard to know what kind of impressions that are useful and not. For these kinds of studies it is also legitimate to add data collection methods during the study, since the goal is to understand and reach depth in each study and not present statistics about a set of observations. (Eisenhardt, 1989).

During the entire project execution a project diary have been used, where important data, question marks, decisions etc. was write down. This was also something that was useful to go back to when something was unclear or checking what was decided to be done at what time.

Bryman & Bell, (2011) is describing the iterative process in grounded theory, after sampling, by coding, theoretical saturation and constant comparison. This means that data collection and analysis always goes hand in hand. The meaning of theoretical saturation is that the researcher continues to sample theoretically, until a certain category is saturated, and new data seems to emerge.

This was also the case during the project; from the beginning the idea was to include one additional internal sample. But after conducted the four other internal visits, it could be seen that much of the data and input repeated the same story and some clear categories had already emerged.

2.6.1 Data collected

In this project several different sources of data have been used. The main input is qualitative data from interviews with both key people on a Business level, with a broader perspective, and more locally at different factories. The latter interviews have been both with employees from different functions in the delivery chain connected to a specific factory, and managers on a higher level that have good insight in the process. The common factor for all interviewees are that they all have insight in the quotation- and order delivery processes in the ETO manufacturer in general and many times the engineering function in particular.

Internal documentation and standardization have worked as reference material for internal benchmarking and for finding gaps in existing processes. One external benchmark visits have been used to see if another ETO company faces the same challenges in the functions as for the rest of the samples.

Literature has worked as a framework and reference when evaluating the outcome in the existing processes. By comparing empirics with literature, improvement areas could be identified but also well working processes could be defined and confirmed.

The main data input will be from primary sources, complemented with secondary data, such as literature and internal documentation.

2.6.2 External benchmarking

To understand if other companies in an ETO business face similar issues related to quality in Engineering, an external benchmarking-visit was performed, this to find improvement ideas, but also to work as a benchmark for the internal samples.

The visit consisted of a half day of semi-structured discussions with the Development Engineer and the Design Manager at the factory site, also including a factory tour.

2.6.3 Internal Benchmarking

Four internal factories were visited during the project to find challenges and opportunities related to the topic. This was also a way to confirm similar issues faced in the organization but also to look for improvement ideas and best practices.

The product produced in the different factories are slightly different compared to each other, which is important to have in mind since this affect both the processes and tools used and sometimes even the type of issues that the factory face.

At each factory visit a two day workshop was held, starting with a kick-off meeting at the factory, presenting both factory history and the project. This to make everyone to start to think about the challenges and opportunities related to the project, but also to make each discussion more efficient by not presenting the project individually for each interviewee.

Discussions where held with representatives from each function in the order delivery process, exactly which positions the interviewees held varied between factories and is therefore presented for each factory. The interviews lasted between 1-2 hours per function. For the first two internal case visits, the nature of the discussions was mostly unstructured, in order to have an open mind and understand the main issues without preconceptions. For the last two factories visits much understanding was gained both from previous visits, but also from additional interviews. This resulted in more semi-structured interviews, with clearer topics to discuss and data to collect.

On the afternoon the second day, a conclusion meeting was held where main findings were presented, both to confirm but also to share the outcome between functions in order to learn and raise a discussion. During the external visit and two first internal visits all interviews where held by two interviewers that independently of each other took notes. After completed interviews it was triangulated in order to guarantee that the input was understood in the same way. This was also a good way to increase the amount of input and details to be captured.

For the last two visits all interviews where held only by one interviewer and discussion points and required data/statistics where asked for on beforehand.

Case 2

This visit was done together with an internal resource within the Operation Excellence team. The following functions were included in the discussions: Marketing & Sales, Project Management, Engineering, Mechanical Engineering, Operations, and Quality.

Case 3

Also this visit was done together with the resource from the Operation Excellence team. At the second visit the following functions were included in the discussions: Marketing & Sales, Sales (Quotation), Project Management, Engineering (Planning and Scheduling), Supply Chain Management, Operation Manager, and Quality & After Sales.

Case 4

This workshop was help only by one interviewer and following functions were represented: Sales including electrical designer (makes tender design), Project Manager including mechanical designer, Quality manager, Operations, Material/SCM.

Case 5

Only one interviewer held this workshop and discussions. For the last visit the following functions took part in the discussions: Sales, Project manager, Planning, Engineering manager, designers/engineers, Quality manager also for engineering, Purchasing and SCM.

2.6.4 Cultural influence and differences

It was also of interest and importance to understand how and if different cultures affected the way the organizations worked. So even if the main purpose with the visits was not to see cultural differences, they were notified in order to understand the complexity in which a process can be adopted or not.

2.6.5 Interviews and discussions with key people

Most of the interviews have been unstructured or semi-structured telephone interviews, when possible the interviews have been held in person. Most of the telephone interviews were held together with an internal resource.

The structure of the discussions was that firstly the researcher's background was presented and then the project, with its purpose and expectations, time line and other involved persons. After this the expectations of the interview was presented, if that was the case, and also if the interviewee had any questions related to the understanding of the project. See 0 Interviews for when and with whom interviews were held.

2.6.6 Internal documentation and standards

It exist extensive amounts of internal standards and documentation, dealing with how these processes should be managed, created during the last 5-10 years. These have been very valuable for understanding the processes, issues and opportunities in

a deeper sense. These have also been used to confirm findings and understand what kind of actions that have been done prior this project.

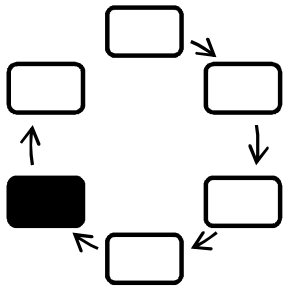
The three main areas studied from the different reports were related Quotation Process, Front End Sales Process and the Order Delivery process, including the production process and Gate model. Most of these documents were introduced in the beginning of the project, but some new presentations and reports where introduced during the project execution as well.

2.6.7 The result, an iterative process

Since the research strategy is based on grounded theory, an iterative process is applied in the data collection and analyze phase (Bryman & Bell, 2011), therefore the result will be presented in a structure that is based on the first findings from the analysis. The result will be presented based on five major sub processes describing the value chain. Every sub process then has areas that are of interest when describing process efficiency and quality.

One of the main challenges within qualitative research and the analysis connected to it is that it rapidly generates a large amount of data. There is few well-established and accepted rules how to analyze this qualitative data, and how to manage this is based on broad guidelines. Qualitative approaches is often described as iterative, meaning that it is an interaction between the collection and analysis of data, meaning that the strategy of how to make the analysis also affect the way the data is collected. (Bryman and Bell, 2011).

2.7 Analyzing the data, determine gaps and define processes (5)



The second step in a benchmarking study according to Adebanjo (2001) is the analysis, referring to the actual collection of data and analysis of performance gaps. The relating steps that Camp (1989) presents are collect data and select partners, determine the gap, and establish process differences.

When making a case study, three major steps can be located to the analyzing phase, a cross-case analysis, adding literature and when to reach closure. (Eisenhardt, 1989).

In grounded theory, Bryman & Bell (2011) present that there is a constant comparison going on in order to see patterns so categories and concepts can emerge from the data collected. Concepts are described as phenomena that are being labeled, and frequently found, and where members in the organization studied can recognize and relate to it. A category on the other hand can include two or more concepts and represent a real-world phenomenon. A category is on a higher level than the concepts.

As a starting point a cross sample analysis comparing the different cases against each other was done, this to find the factors for improvements and describe the processes

as it is today. Secondly this has been evaluated against theory in order find what is written in literature. This has then worked as a framework for future improvement ideas.

2.7.1 Cross sample analysis

When analyzing the data, a use of divergent analyzing techniques is preferable. This is the hart in case study research with the aim of building theory. This is also very difficult since the volume of data can be extreme. By logging the data this can help in the search for relevant input in the analysis phase. By doing a cross-case searching, it forces the investigator to go beyond initial impressions, through the use of structured and diverse lenses on the data. (Eisenhardt, 1989).

2.7.2 Comparison to literature and internal documentation

Secondly literature has been enfolded, comparing with conflicting/similar literature. This is essential when building new theory, a comparison with emergent concepts, theory or hypotheses found in literature. That's why it is crucial to consider a wide range of literature, both literatures that support and conflicts with the findings are important. Especially the latter one can be of high interest if arguing the right way. (Eisenhardt, 1989).

Lastly, reaching the closure, when to stop adding cases is when the iteration process with incremental improvement to theory is minimal. (Eisenhardt, 1989).

2.7.3 Analyze methods

No predefined model for analyzing has been used in this research. Instead have coding being helpful; meaning that data is broken down into components, that is also a key process in grounded theory (Bryman & Bell, 2011). The fragments evolved from the coding have then been clustered and grouped in order to see patterns and build concepts, influenced by the affinity method, see description below.

Affinity diagram

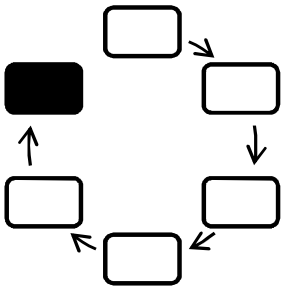
Affinity diagram is a method to analyze large amounts of qualitative data, by organizing ideas and data into groups. By fragmenting the information and data into small pieces that then group it together, based on their relationship, in order to find the meaning behind the messages and understand how several fragments develop into larger concepts. (Bergman & Klefsjö, 2003).

An affinity diagram incorporates the following three steps:

- Data compilation: Notes are taken during the interview and later complemented with additional information when the recorded interview is listened through.
- Fragmenting of data: All interviews are read through and interesting statements and quotes are extracted from the interviews to form separate fragments.

- Bottom-up sorting of information: The fragments of data are sorted into in small groups in order to create meanings. Several groups are later connected to create a bigger picture of the information developed.

2.8 Implementation (6)



Adebanjo's (2001) third step in a benchmarking study is action, when to communicate the findings, set targets and implementation of specific improvements actions. Camp (1989) is presenting similar steps, target future performance, communicate, adjust goal and implement.

An implementation based on the result will be outside the scope of this thesis. Still, the conclusions and recommendations from the project will work as a reference for future creation of guidelines for implementation.

Activities like training, follow-up of the implementation, process ownership and how to work with continuous improvements are all areas that need to be discussed and managed when implementing a new model or process. Also a plan dealing with implementation resistance and how to overcome issues like this needs to be considered before enforcing a change in the organization. Change management is a science on its own and its difficulty should not be underestimated.

As a last step of a benchmarking study, the result needs to be reviewed and lastly recalibrated (Camp, 1989). Adebanjo (2001) link this step to the identification of learning points, evaluation of the benefits of the process and the continuous monitoring of improvements.

There will be a continuation of this project to define and structure the quotation and hand over process, a project that started based on the outcome from this study. The aim within that project is to increase the process efficiency and quality during the entire value chain. The result from this project will first be implemented in two pilots and if successful, a global roll out will take place in 2013.

3 Theoretical frameworks

In order to understand and analyze the collected data a theoretical framework that covers the scope of the research purpose is necessary. The theoretical framework will be built in such manner that it supports the structure of the research questions.

The theoretical framework will firstly describe the meaning of a process, efficiency and quality, and then move over to front end activities and the characteristics of an ETO company into detail. The last part covers the quotation- and order delivery processes, from a theoretical perspective, see Figure 3, including the activities that take place in these processes, i.e. interaction between marketing and manufacturing.

Lastly the product development concept will be elaborated by introduce Lean product development and Design for Six Sigma.

Figure 3 Correlation between quotation process, order receiving and order delivery process

3.1 Process Efficiency and Quality

In this section the essence of what is meant by process, efficiency and quality will be elaborated.

3.1.1 Process

Bergman & Klefsjö (2011) define a process as a set of interrelated tasks that together transform inputs into outputs whose objective is to create value to external and internal customers. The purpose of a process is to satisfy customers, while using as little resources as possible. Further Bergman & Klefsjö (2011) has identified three types of processes; Main processes, also referred to as operative processes or core processes that have the task to satisfy and fulfill the needs of the external customer. Support processes is an internal process that provide resources and support for the main processes and Management processes' task is to make decisions on targets and strategies of the organization.

A central factor in process management, to succeed with implementing improvements in activities, is to have a holistic view of the processes. When doing improvements, following aspects should be taken into consideration; *efficiency*, how well the processes are utilizing the resources in the organization to deliver and produce results, *quality*, meaning the capability to satisfy customers' needs and expectations, and lastly *adaptability*, how well the processes can be adapted to changed prerequisites. (Bergman & Klefsjö, 2011) For this thesis the two first

concepts have been of great value to identify what factors that a process needs to focus on when creating a new process.

3.1.2 Efficiency

An efficient operation strives to minimize waste and maximize resource capabilities, in order to deliver quality products and services to customers, and improve quality and productivity. (Shaffie et al, 2011). Efficiency is described as the choice of alternatives which produces the largest result for the given application of resources, meaning the greatest benefit for the cost invested. Efficiency is defined as a measurable concept, determined by the ratio of output to input. (Mintzberg, 1982).

Drucker (1967) defined efficiency as doing the things right, highly linked to how well resources are utilized within a company, and how to eliminate non-value adding activities in order to cut costs and shorten process lead-times. This thinking is highly linked to the concept of Lean and waste reduction. See chapter 3.6 Lean Product Development for what is categorized as waste in Lean Product Development.

Within the principles of Lean, process efficiency can be estimated by using cycle time. For lean manufacturing, efficiency is described as Value Added Time divided by Total Time. (Alastair, 2005).

3.1.3 Quality

Bergman & Klefsjö (2011) define quality as a products' ability to satisfy, or preferably exceed, the needs and expectations of the customers. In order to satisfy both external and internal customers, such as employees, a business process needs to be executed with a high and predictable quality. Grigori et al (2001) describes external quality as the one perceived from the customer in terms of better and faster service, and internal quality as perceived by the service provider in terms of lower operating cost. Further they state that the critical issue in managing business process quality is to analyze, predict and prevent deviations from the desired or acceptable behavior.

One of the most common methodologies used, when coming to process quality is Six Sigma, that aims to reduce defects. See chapter 3.7 Design for Six Sigma (DFSS), how this thinking can be transferred into the product development process.

3.2 Front End activities

Not that long ago the global demand for ETO products exceeded the total production capacity which meant that the need for building customer relations were not that important as it is today. Ideas were developed internally by a company and then validated through customer screening and product testing (TenStep Inc., 2005). Kim et al (2010) states that the dynamic changes in the global business operations are especially emphasizing needs for a much higher level of early collaboration between marketing and production functions to respond to customer's demands quickly with high satisfaction. It is reported that by improving the upfront homework in the pre-development phases, the market success rate will be improved for a product development project (Cooper, 1994), but too often there is a desire to do the

development before proper time is spent on the homework (Carbone & Tippett, 2004).

The Front End activities are defined as the activities taking place prior to the product development, see Figure 4Figure 4.

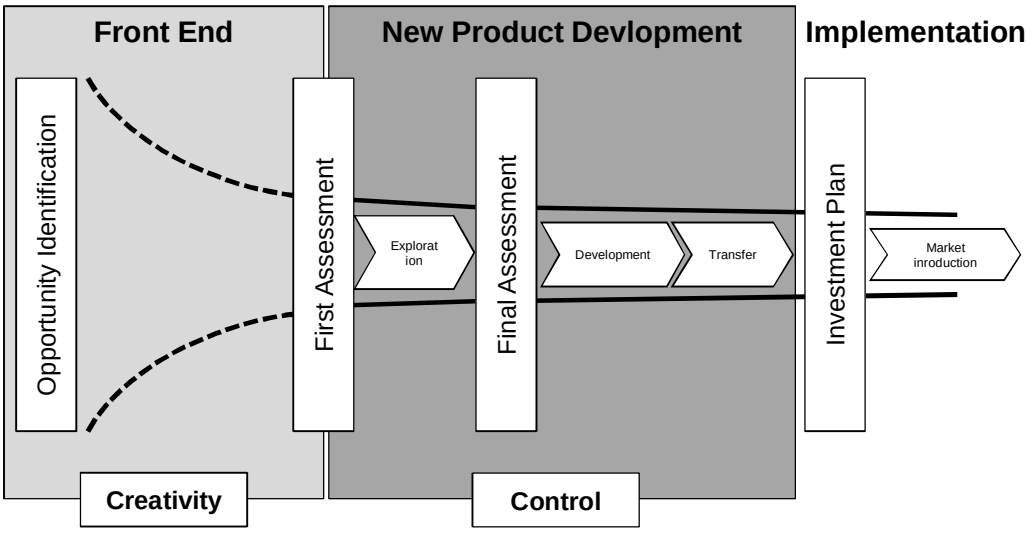


Figure 4 Front End correlations with the product development process (Soens, 2009)

Wheelwright and Clark (1992) show that managers involvement in a product development process is typically focusing on the actual development and when producing the product. This since it is often at this stage the problems are detected, even if the root causes are created in an earlier stage of the process. In these earlier phases, called conceptual and preliminary design, see Figure 5Figure 5, the engagement from management is normally not very high, despite the fact that the biggest commitments in terms of cost is made already here. This is very important to keep in mind since the commitments done at this stage often are the starting point for problems occurring during design development and production.

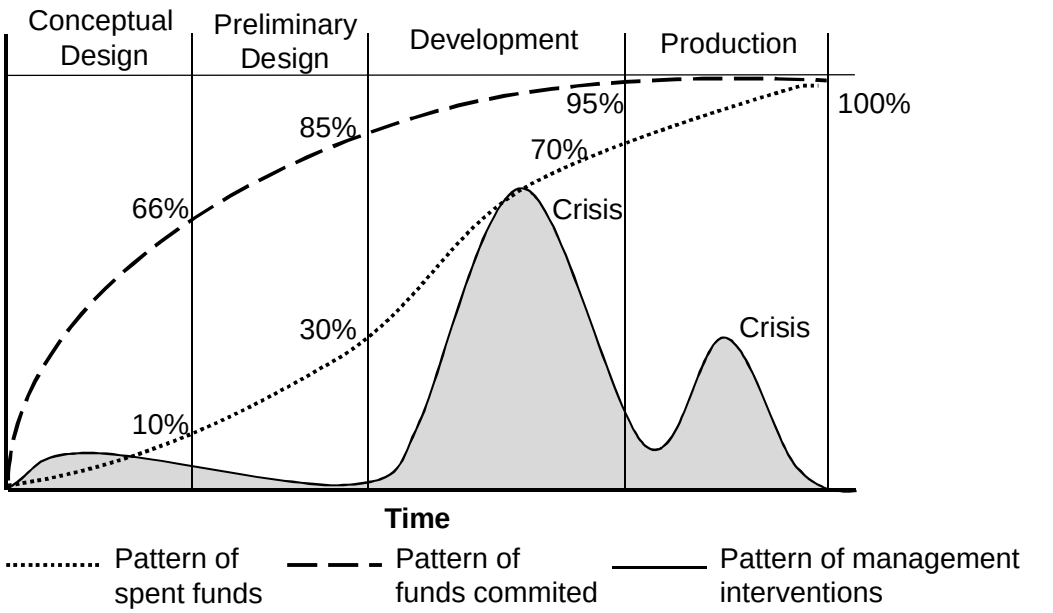
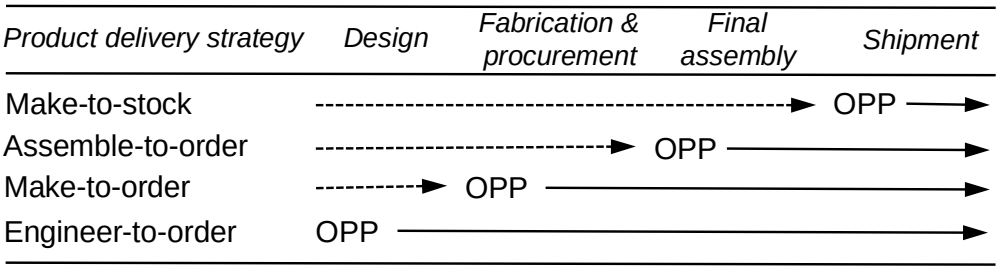


Figure 5 Management involvements in the product development process mostly focusing on development and production, since crises often appears first here (Wheelwright & Clark, 1992)

3.3 Engineer-to-Order (ETO)

There are many different ways and models how to order a product. In Figure 6, some different cases can be seen (Olhager, 2003). Make-to-stock is when the product is already made, and as the name indicate put on stock until the demand occurs and the product get shipped. Assemble-to-order (ATO) is a strategy where already manufactured parts get assembled to a certain extent of customization, when the order is received from customer. This is relative similar to Make-to-order, with the difference that the product gets completely manufactured when the order is received making it completely customized, but not as fast to manufacturer as Assemble-to-order products.

The last strategy goes even further back in the delivery process called Engineer-to-order, this is when the entire developing or designing of the product is made after receiving a customer order, which often is the case for highly customized products with low quantities. This is a Pull-type production, just making the product if there is a customer demand. (Asprova, 2012).



OPP – Order Penetration Point

Figure 6 The time the order is made from customer, affects the product delivery strategy

In an ETO company the products are engineered and produced according to a customer specification, making these companies having both a very specific sales process and production process. (Konijnendijk, 1994). Examples of ETO products could be airplanes, construction projects and ships.

The main characteristics of an ETO product are described by Berstrand & Muntslag (1993) as the important role of the customer order, the customer-specific product specifications and the product and production uncertainty.

When having an ETO approach within a company, there will be a high level of participation from customers' side both in the design and manufacturing process. Multiple parties need to be coordinated and collaborate to make reality of the complex product, where challenges and difficulties tend to occur during the way. This means that ETO companies have very demanding marketing/manufacturing coordination needs, where it is not enough to coordinate timing and volumes as for more traditional businesses, but also the actual product specification. The better an ETO company can translate this specification into feasible parts and constructions, the better it will perform. (Konijnendijk, 1993).

Looking at the sales process in an ETO industry, it is much more time consuming and involves more resources compared to a standardized product. For the engineering and production processes, specific skills and craftsmanship is required and the parts and components used in the product are often expensive and highly engineered. To coordinate these different processes, a specific coordination mechanism is required where to balance customer requirements with production capabilities for each customer. (Konijnendijk, 1993), see Figure 7.

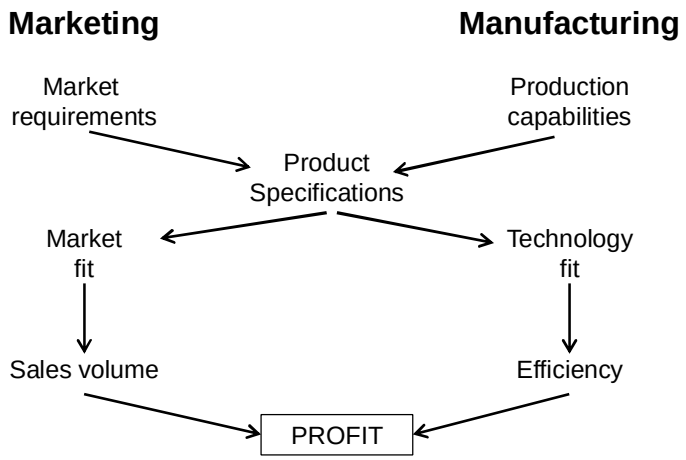


Figure 7 Interdependence in product specification (Konijnendijk, 1993)

Hvam et al (2006) states that increasing competition challenge industrial companies to reconsider their way of doing business to reach success. For industrial companies, dealing with "one-of-a-kind" products, such as an ETO company, three main competition parameters have been identified; (1) a shorter lead-time for quotation and order fulfillment, (2) the ability to meet customer requirements, both in terms of functionality and quality of the products and (3) an intense price competition.

The initial product specification in the quotation process has a major impact on the optimization of the product, and disposes a large part of the total cost. Decisions taken early in the specification process dispose 80-90% of the material- manufacturing- and engineering costs making it crucial to have the specification valid and correct, see Figure 8. (Hvam et al, 2006).

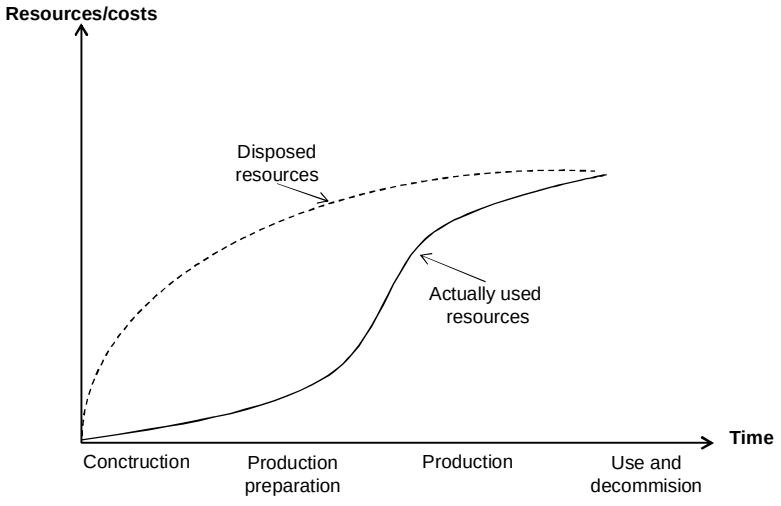


Figure 8 The majority of the resources are disposed in the early engineering phases (Hvam et al, 2006)

3.4 Quotation

The quotation process is when a company make tenders to its customers and compete to win the order. The quotation can be divided into two stages, where the first one relates to the activities taking place before the customer request for quotation (RFQ) and includes the opportunity identification; this is presented as the capturing process. Secondly, is when making the quotation design and is defined to start when the company receives the request for quotation (RFQ) until the customer decides to make an order or not.

In Figure 9 below is the correlation between quotation process and order delivery process presented.

Figure 9 Correlation between quotation process, order receiving and order delivery process

3.4.1 Capturing process

This process aims to understand the market and identify opportunities. Customers buying a typical ETO product are often unfamiliar with the product and uncertain what product that fits their needs. Customers want to consider several suppliers' options and therefore want all potential suppliers to write quotations so they can compare and then decide where to place the order. (Konijnendijk, 1994). This makes it important for an ETO company to identify these opportunities before the actual request is placed in order to understand how customers' judge and evaluate different bids against each other.

Van der Meijden et al (1994), state that conflicts often occurs between demand forecasts, helping sales and marketing to reach their targets, and demand forecasts, supporting manufacturing to produce right amounts of products, at right time, to a minimum cost. This gap is a serious problem, especially in industries with production lead times much longer than customer order lead times, which is the case for ETO products. To overcome this, a close coordination between sales and manufacturing is needed to create one common forecast.

If the quotation-to-order ratio is low, there exist a huge opportunity for improve the efficiency, either by increasing the ratio or by cutting costs associated with developing the quotations (Hvam et al, 2006).

Capturing customer needs

Henry Ford once said: "If I had asked people what they wanted, they would have said faster horses". This quote refers to the fact that the customers do not always know what they need, just what they want.

Cooper (1994) said that the number one success factor is a unique superior product, that is differentiated and that delivers unique benefits and superior value to its customer. To deliver this, you need to be market-driven, customer focused and have a strong market orientation.

"It is the customer who determines what a business is. The customer is the foundation of a business and keeps it in existence. What the customer thinks he is buying, what he considers "value" is decisive – it determines what a business is, what it produces and whether it will prosper." (Drucker, 1967).

According to Ulwick (2002) a common mistake companies do in their pursuit to satisfy their customers is to ask them what tangible solution they want. This is an unsuccessful way to approach the problem since the customers do not know the companies' capabilities, i.e. what it could do. Instead, companies should ask the customers for output, what they expect from the product, and let the firm's R&D department be responsible for the innovation process.

3.4.2 Quotation process

The quotation process can be divided into three sub-processes: Request for quotation (RFQ), quotation preparation, and quotation evaluation, see Figure 10. In the manufacturing industry the quotation preparation is very important since it precedes the order preparation. What have been quoted concerning price, quality and delivery time will affect the final business success. This makes it essential to have access to detailed information as early as possible in order to base the quote on data that represent the actual product to be delivered. The cost calculated in the quotation must satisfy customer in order to get the order but on the other hand guarantee product profit for the company. (Elgh, 2012).

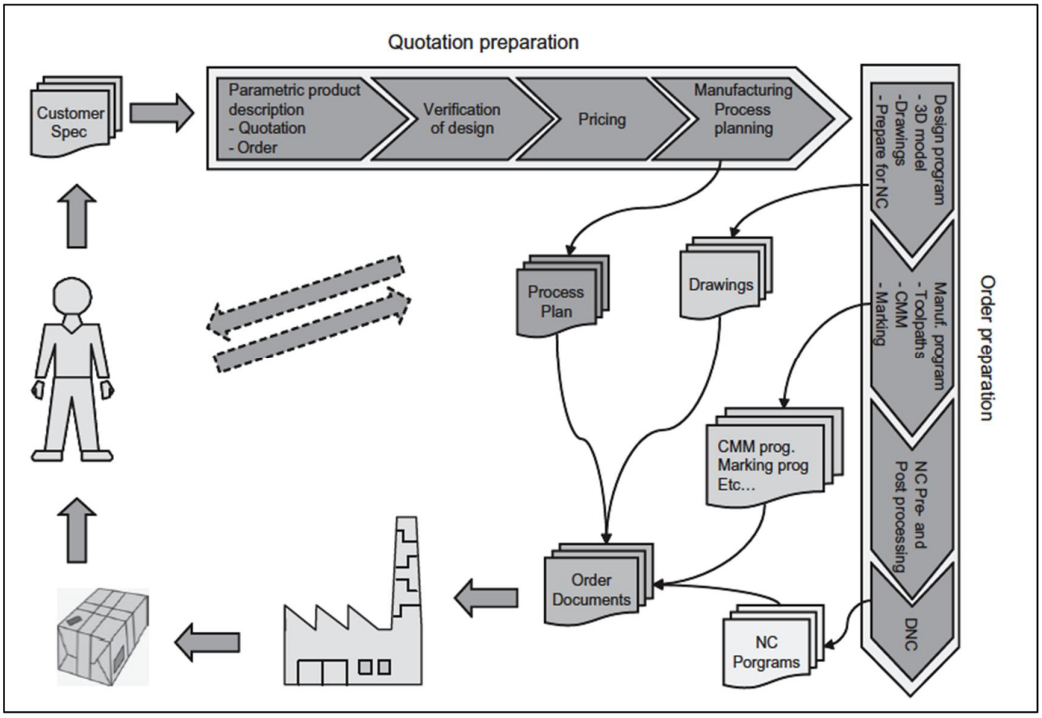


Figure 10 Information flow during quotation and order delivery (Elgh, 2012)

To cover for the extra cost the uncertainty in the quotation specification can generate, extra margins is sometimes added on the price suggested to customer. This is however not always that smart since increased price reduce the probability to get the order. (Konijnendijk, 1994).

Elgh (2010), Tham (2007), and Forza & Salvador (2000) all discuss how to make the quotation process more automatized; by introduce a product configuration system with a product platform for variant designs. Kwong & Tam (2002), present an artificial intelligence technique; case-based reasoning that aims to assist design engineers by using previous successful design cases and store them in a case library. Implement such a system, would make it able to respond quickly to customer with competitive prices and increase the hit rate, hopefully leading more quotations to proceed to order design. Having this system in place requires a rich history of designs to be able to meet each customer specification.

The increasing worldwide competition reduces the margins, putting a higher demand on the quotation process to estimate right costs. To be efficient in this process and reach a high level of accuracy, the quotation process needs to be formalized by defining input and output to the process, identify sub-processes and resources. But also support and tools needs to be developed and implemented to succeed with this. Not having a documented and structured process, or even worse, an ad hoc process, increases the risk to deliver the product to an inaccurate cost, destroying the margins. (Elgh, 2012).

The more a risk or uncertainty can be reduced already during the front end phase of the product development process, the lower the deviations from front end

specifications during the rest of the project execution phases will be, leading to higher product development success (Herstatt et al, 2003).

Zorzini et al (2008) argues that the quotation process for ETO companies have a large impact on company performance. This since the bid preparation done in the quotation is a multi-stage decision, involving complex trade-offs with demanding inter-disciplinary teamwork in order to prepare attractive and reliable bids. By setting short and reliable due dates the situation can be improved, however this requires a continuous coordination during the quotation process between marketing and manufacturing. Most models that exist today are not suitable for complex production systems, as for an ETO company, and available literature does not describe the practices used by firms today sufficient.

Elgh (2012) points out a few issues related to the quotation preparation, these issues were found very useful when comparing the cases in the analysis chapter.

- Long lead-time from RFQ's to returning bids
- Low level of accuracy in the material cost estimation and process time estimation, leading to a low level of accuracy in the overall cost estimation
- Not synchronized information, data exists in more than one place
- Process to complete material planning and the process planning are in parts unstructured and not documented
- The rules (i.e. knowledge) applied in the process is not formalized and documented
- The tasks are completed mostly manually, and can therefore be afflicted with personal judgments giving non-identical results
- The required input and their format have not been standardized

Konijnendijk (1994) presents an overview of the steps in the buying process and correlating steps in the selling process. When the order is placed this do not stop the flow of information in the product specifications, instead a second flow that lead to the final quotation is now taking place. Even after the sale is closed the flow of specifications does not stop, which can be seen in the time-consuming information processing that take place in the selling process of an ETO product. It takes long time before everything is clear about what the customer will order or not and what the needs are. Uncertainty regarding the specifications is high, typically all the way through to the production process.

Wortmann (1995) discusses that for ETO production, it should be allowed that basic information is incomplete, partly inconsistent, or not up-to-date. This since engineers creating the customer-specific solutions only uses this data as reference data. However, Konijnendijk (1993) discusses that this lack of information creates a situation of high uncertainty. Konijnendijk (1994) states that most controllability and uncertainty problems can be solved at the cost of lead-times. But keeping lead-times short is crucial and a tradeoff situation that handles the two sides are necessary.

3.5 Order Delivery Process

The order delivery process includes all activities from receiving an order until the product is delivered to customer. The first sub-process in the order deliver process is the interaction between marketing/sales and manufacturing, at the order receiving point. After this the design of the product is made in the product development process.

Few research studies have been conducted on the order delivery process of making this specific product. Several authors have on the other hand in a more technical manner described how the optimal design should be, by using mathematical models or software program to produce manufacturing specification.

3.5.1 Hand over between Marketing/Sales and Manufacturing

Parente et al (2002), states that the quality of the internal relationship between production and sales heavily affects the customer satisfaction for ETO products. Cameron & Braiden (2004), states that customers are seeking lower prices and reduced lead times, which requires improved manufacturing efficiency, which forces companies to improve the integration between design, manufacturing and procurement functions.

O'Leary-Kelly & Florens (2002) found that the impact of the integration of manufacturing and marketing/sales decision on organizational performance is moderated by a firm's business strategy and demand uncertainty. Having a cross-functional integration among these different functions is crucial to overcome barriers. This is also stated by Wheelwright and Clark (1992).

Coordination between Marketing and Manufacturing

Konijnendijk (1993), Konijnendijk (1994), and St. John & Hall (1991), discusses the importance of mechanisms to coordinate the decisions and actions between marketing and manufacturing. St. John & Hall (1991), discuss three mechanisms; control procedures, planning processes and committees/task forces, and by simultaneously use a variety of these a significant decrease in interdepartmental disagreement could be seen.

Konijnendijk (1994) discuss the interdependence of marketing and manufacturing in ETO companies and the coordination requirements needed. Four coordination characteristics is presented; processes, structure, culture and objectives that influence the coordination, where some if affecting more than others.

In a ETO company two processes is in place in parallel, the selling process and the buying process, where the selling process is characterized as time-consuming information processing. New information starts flows in even after quotation since the product is not fully engineered at that point. It takes a long time before everything is clear what the customer needs and whether they will order or not. This leads to an uncertainty regarding both the specification and sales volume. Early coordination between marketing and manufacturing is extremely important since

manufacturing already at this stage have to quote production costs and lead-times of the potential order. (Konijnendijk, 1994).

Second coordination characteristic, structure, is related to the set-up of the operation that is mainly dealing with craftsmanship without big impact of economics of scale.

By culture Konijnendijk (1994) means that having different cultures within marketing and manufacturing can lead to a strained communication and barriers. The two functions has develop differently, due to the fact that manufacturing focus on details and technological input, while sales focuses on the performance and price delivered to customer.

The objectives between marketing and manufacturing are often different and contradicting. Konijnendijk (1994) present turnover as the objective that is most shared. In order to bring the objectives together three major coordination subjects are presented; specifications, volume and mix and lead-times.

Further Konijnendijk (1994) discuss that the customer specification must be balanced with production capabilities, and is divided into two stages, quotation specification and order specification, where the first one is a way of giving potential customer guidance and a cost estimation. Volume and mix is mostly related to capacity planning, while lead-times is discussing the use of setting due dates for a specific customer order.

3.5.2 Front End of Product Development

According to Khurana & Rosenthal (1997) managers have identified the front end as being the greatest weakness in product innovation. This since quality, costs, and time frame to a large extend will be defined here for a product development project. Cooper and Kleinschmidt (1994) showed that “the greatest differences between winners and losers were found in the quality of execution of pre-development activities”. However, Carbone & Tippett (2004) present that few studies of the front end of product development on specific industries and new products have been conducted.

Designing an ETO product can be seen as a new Product Development project for more or less each product, due to the high level of customization and low level of re-use of previous designs. Herstatt et al (2003) have in their research seen that the uncertainties affected by market or technology successfully could be reduced during the early stages of the project, in the “fuzzy front end”. When comparing Japan and Germany they found two different approaches where Japanese companies emphasized more on planning and strict control to avoid deviations from the front end specification. The German companies did not focus that much on planning, instead they integrated relevant function such as R&D, marketing, sales, production or customer service already from the beginning of the innovation process to ensure that all critical information were taken into consideration already from the beginning. Both these methodologies had, according to Herstatt et al (2003), generated similar results of project success.

In a product development process, relevant information needs to be gathered to reduce uncertainties and risks. The more this can be reduced during the front end of this process; the lower is the deviations from front end specifications during the following project execution phases, leading to higher rate of product development success. (Herstatt et al, 2003).

3.5.3 New Product Development Process

Many authors have come up with product development process definitions, for example Wheelwright and Clarks (1992), see Figure 11 and Eppinger and Ulrich (2004), Figure 12. But for complex products, like ETO products, these descriptions are not that well defined, especially not for the early interface between customer and factory.

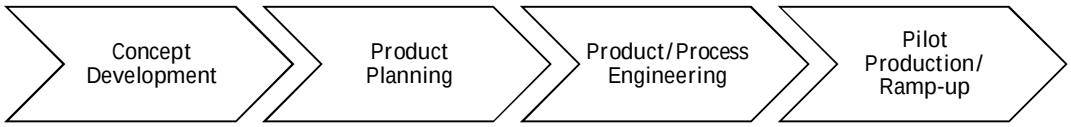


Figure 11 Wheelwright and Clark, New Product Development phases

Figure 12 Eppinger & Ulrich, New Product Development

Wheelwright & Clark (1992) presents and describe the product development funnel, were ideas enter the front end segment, pass through development segment and in the end release to market.

The front end segments can shift in number and nature depending on the model used by the organization, and are often further broken down into phases or gates. All products do not need to pass through the entire development process, due to financial, technical, or market reasons. (Carbone & Tippett, 2004). The existing models for New Product Development have many good points but in many instances they lack the details required to manage the front end. (Carbone and Tippett, 2004).

3.6 Lean Product Development

The philosophy of Lean production aims to reduce waste in production. Lean product development (LPD) is when applying lean principles to product development. This is a cross-functional activity that seeks to uncover product knowledge in the hand over between different functions (Bergman & Klefsjö, 2011). It is a dynamic process that makes it easier to follow the moving target (Wheelwright and Clark, 1992).

LPD emphasizes on understanding the customer through a number of different tools like Quality Functional Deployment (QFD), Kano model, Voice of customer, and Benchmarking etc.

Alfredsson & Söderberg (2010) consider following activities as waste in product development:

- Chaotic work environment – constant interruptions
- Lack of available resources – resource bottlenecks
- Lack of clear prioritizing of projects / tasks
- Poor communication across functional barriers
- Poorly defined product requirements
- Disruptive changes to product requirements
- Lack of early consideration of manufacturability

Additional wastes in processes are:

- Too many gate reviews
- Too many process mandated activities
- Process drains time from value creation
- Process is difficult to scale down
- Phases/gates distort the critical path

These kinds of wastes can be seen in complex projects in order to gain more control, but in the end it leads to less value-adding time spent on the actual project.

3.7 Design for Six Sigma (DFSS)

DFSS aims to prevent problems like defects and failures instead of just fixing them by going upstream to the product development process. It tries to recognize those decisions that affect quality and cost, and gets the product right the first time already during research, design or development phase. This compared to traditional Six Sigma that mostly focus on production. (Huber & Mazur, n.d.).

The Six Sigma approach was developed in the late 1990s by General Electric and Motorola as a way to assure both customer satisfaction and competitiveness. Quality was defined as a number of defects or failures in the product, service or process. Six Sigma is roughly equivalent to 3.4 defects per million parts, and by controlling the variation of a process and keep this limit, this will also be within the acceptance tolerance for customers. (Huber & Mazur, n.d.).

The problem solving approach linked to Six Sigma is called DMAIC, standing for Define, Measure, Analyze, Improve and Control. The approach of DFSS is called IDOV; see Figure 13, including; Identify, Design, Optimize and Validate. (Huber & Mazur, n.d.).

Identify	• Identify customer and product requirements • Establish the business case • Identify technical requirements (CTQ variables and specification limits) • Roles and responsibilities • Milestones
Design	• For each CTQ, Identify Design Parameters • Prioritized Product Design Characteristics • Transfer Function(s) • Preliminary Design Risk Assessment • Performance/Process Scorecard
Optimize	• Process Capability Studies • Reliability Studies • Capability Flow up • Optimal Design • Tolerances on X's • Complete Scorecard
Validate	• Capable Product and Process • Sensitivity Analysis • Assess Performance, Reliability, and Risks

Figure 13 IDOV methodology used in Design for Six Sigma

3.8 Gate model

One of the most recognized gate models in New Product Development is the Stage-Gate model by Robert G. Cooper. It consists of five stages presented in Figure 14. The idea behind the stage gate model is to making essential "go" vs. "kill" decisions, engaging the customer in the pre-development discovery phase, evaluating your product portfolio and accelerating speed-to-market (Cooper, 2001). All this in order to make a more efficient process that delivers outcome that the market wants.

The decisions taken at each gate is based on the available information at that time and includes risks, resource availability and how well it fits to the business case. At these gate reviews, often different criteria's needs to be fulfilled which can be categories into must meet requirements, that can be controlled by a checklist and should meet requirements that are highly desirable.

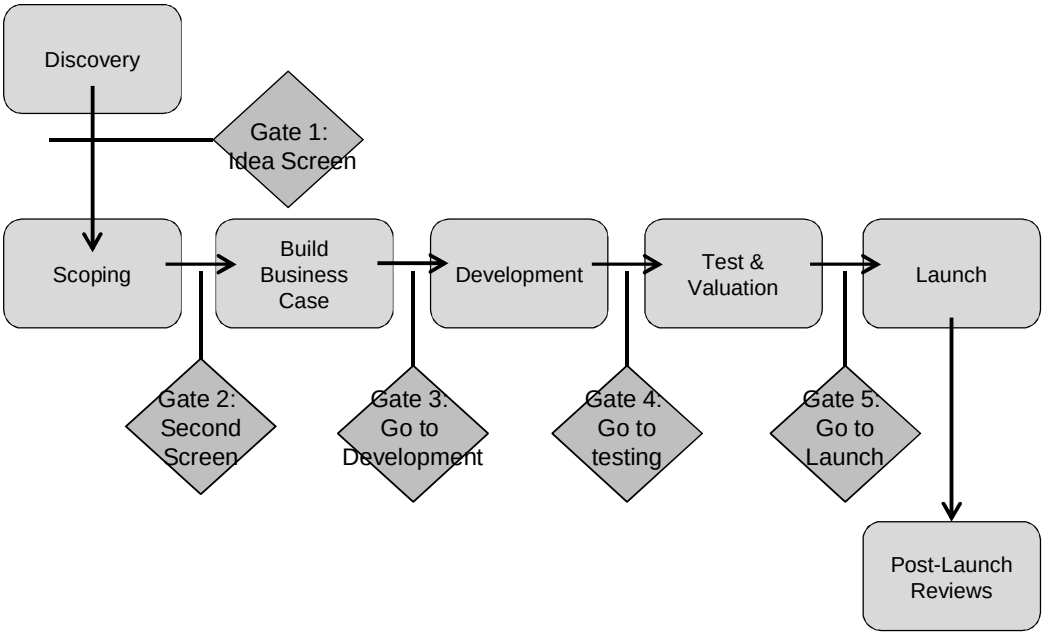


Figure 14 Stage gate model by Robert G. Cooper

4 Case results

The first research question "*How can the Quotation- and Order Delivery processes in an engineer-to-order company be described from a quality and efficiency perspective?"* aims to describe the existing processes and how they correlate to process efficiency and quality. In order to answer the question, each case will be presented according to the five sub-processes presented below, see Figure 15.

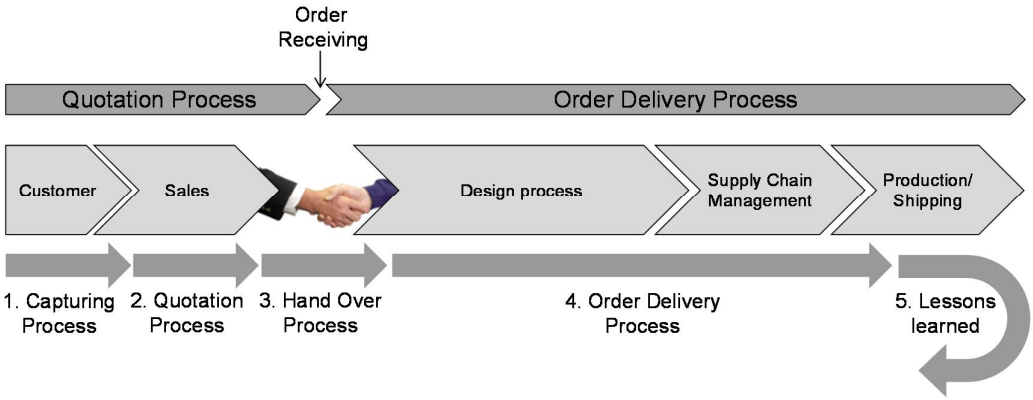


Figure 15 The five sub-processes which the result will be presented according to

1. Capturing process: Activities taking place before Request for Quotation (RFQ).
2. Quotation process: From receiving the RFQ, until customer decides to make an order or not, is normally managed by Front End Sales (FES).
3. Hand over process: When customer decides to make an order. Project is transferred from Sales to the Project Manager at the factory .
4. Order Delivery process: Includes all steps from receiving the order to delivery.
5. Lessons learned: How to work with and incorporate continuous improvements in the processes.

4.1 External case

One external benchmarking case was executed, where all sub processes described above was not discussed as they were not perfectly applicable to this case.

4.1.1 Case 1: External

The discussion did not go into details related to process efficiency and quality, but was more a broader discussion about engineering management process and how to measure quality in an engineering process with certain KPIs.

Capturing process, Case 1: External

It was stated that the sales persons should know the internal customers' needs better, in order to deliver right products.

Quotation process, Case 1: External

The development engineer from the external sample company had also conducted his master thesis at the company recently, where an estimation of increased time spent on quotation, showed that this could lead to reduced time spent on engineering activities/re-work/failures later in the project. This increased empathize on quotations made the whole project more efficient, since time spent on re-work and revisions later in the project could be reduced. In the end, this would also lead to cost savings.

The company had two different products, for which they made quotations. The first one called Non-standard Requirements (NSR) where the engineering function makes unique drawings and customizes the product for each customer. This is typically for an ETO business and comparable to the internal samples used. On the other hand they also have "standard" products.

Each customer often buys more than one product at the time; this is different compared to the internal samples where most customers only buy one or two products.

The input from customer side that should be included in the quotation process is standardized, and it depends from case to case if the input is sufficient depending on if it is a non-standard or standard requests.

Hand over process, Case 1: External

All information is shared by common platforms between functions, and in order to guarantee right information flowing through the functions, a "best before date" for customers to provide right input and specifications is set. This date is set by counting backwards from either "on-line", when the production starts, or when the product is supposed to be ready.

Order Delivery process, Case 1: External

The engineering function rarely has contact with the end customer during the project execution. It is also stated that re-work problems are very costly, leading to an approach where more time should be spent in the beginning of the project, but also on the design in order to reduce re-work. Increased level of checking is also desirable in order to reduce re-work. See Figure 16.

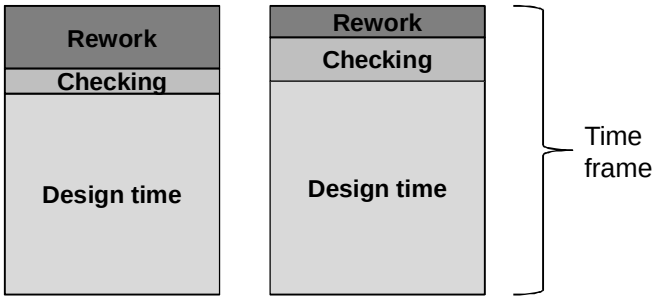


Figure 16 correlation between times spent on design, checking and rework

Lessons learned, Case 1: External

If a product that is nonstandard shows to be an interesting business case, they introduce the product as a standard product. They also continuously work with updating drawings of standard products if a more satisfying design solution is found, this in order to deliver higher quality and keep costs down.

4.2 Internal cases

Four internal cases was part in this study, where each case represents a factory. The result from each case is a summary from all interviews and received data. Sometimes interviewees had contradicting opinions, in those cases; all opinions will be presented but not judged. When interviewees are referring to the case manufacturer company, this will be presented as “company X”.

All result presented in this chapter is based on the interviewees opinions. The main focus is to describe the existing situation in the quotation- and order delivery processes based on all involved functions experience and knowledge. Many times problems and challenges described are linked to improvement solutions. All improvement suggestions presented in this chapter for each case comes from the interviewees at the factory and are not a result of any analysis of the gathered information.

4.2.1 Case 2: Internal

The first internal sample, have a slightly different situation compared to the other factories visited, this since they produce mostly special and complex variants of the products, putting higher demands on the engineering.

Capturing process, Case 2: Internal

In order to reduce much of the re-work, number of revisions, late changes and COPQ seen in value chain today, it is important that the sales organization early identifies customers’ needs, and then guide the customers to what product they should buy. Many times are the needs not corresponding to the wants specified in the specification, making it important to have a close collaboration with the customer in order to produce what the customer values and expect. A customer relationship, with good communication increases the understanding for both parties and reduces the uncertainties, giving a better knowledge about the requirements that the customers’ expect. On the other hand the customers understand what quality and deliverables that they pay for.

Quotation process, Case 2: Internal

Request for Quotation
The product portfolio at this factory is partly unique compared to other factories, leading to specific knowledge and competence not found at other plants. When the customer request for quotation (RFQ) for a product, this request is send to the factory serving that market, see Figure 17. Sometimes, that factory in last minute realizes that they do not have the competence to make the quotation design that they accepted to do, then transferring the request in last minute to this case factory. This leads to frustration and time pressure, making it difficult to make a proper design, with right estimated costs. The time spent on a quotation today is between one day and two weeks.

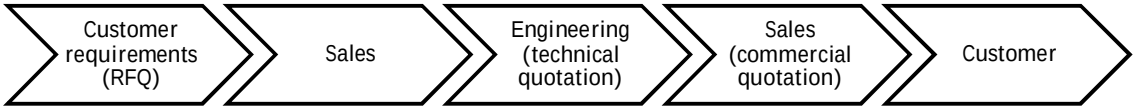


Figure 17 How the process looks like when receiving a RFQ

Customer specification

The customers often have a hard time to specify exactly what they want from the product. Sometimes since the product is integrated in a bigger system, where it needs to compensate and integrate with other parts of the system. Other times low technical knowledge and understanding from customers side makes it is hard for them to specify their wants, which complicates the creation of a standardized template. Everything cannot be written down in a technical specification, some things cannot be understood by the customer until the product is finished, which makes it difficult for designer to include everything in the drawings and make an accurate design compared to the final product. Unspoken requirements and wishes are often built into the specifications and are hard to interpret or understand for the designers, which is the case both for quotation design and order design.

According to engineers is the main reason for making wrong drawings leading to many revisions, is that relevant input is missing in the specification. The designers have not realized that information is missing when starting with the design, or can the specification be overloaded with information, making it time consuming to go through everything in detail. This ends with design mistakes, expensive to change, and leads to re-work afterwards.

Front End Sales (FES)

Today, half of all orders go via an internal system integration that combines products from the company into a whole solution that the customer buys. The other half goes via the sales organization FES, acting locally on each market or region.

One big challenge in the quotation process today, is FES lack of knowledge about the specific products, where the individual skill differences are big. This leads to much frustration from engineering side, since FES does not have the competence to clarify all details or filter the specification on relevant input.

Hand over process, Case 2: Internal

Kick-off meeting

When a customer decided to accept a quotation design and place an order, the project execution handling is handed over to a project manager. When the project manager received the project responsibility from sales, this person set up a kick-off meeting. The aim with this meeting is to clarify all issues and uncertainties that exist when starting with the order design. The electrical engineer is the only one that has read the customer specification at this stage, in order to raise all question marks up to discussion. However, is this not always done properly and there exists a wish to define and prioritize how this should be organized in order to cover all important aspects.

Project management
The project manager needs to have a good understanding for both marketing/economic and engineering activities. All communication between engineering and end customer should be managed by the project manager. However, the communication between engineers and project managers is not always that good, and there exist resistance from project managers to recommend changes to customer that designers suggest. It is not clear with all aspect how the interface between sales/FES and project manager should look like either, making the responsibility unclear and fuzzy.

There is a wish from project management side to have better technical support from engineers, one idea was to divide this support into two parts, one part supporting in the project and customer interface, and one part for production and material.

Customer relationship
It is not always easy to clarify all question marks in the specification with end customer; some markets are harder than others. Today it exist many layers between factory and end customer, see Figure 18, making it hard come directly into contact with the customer and understand what they actually needs. It is also common today that customers use consultants to handle the process from the customers' side, increasing the complexity of the communication. Having a direct contact and closer relationship between engineers and end customer would be of high value during the whole process and also whished by the engineers.

Technical communication is easier when having system integration orders (internal customer) than dealing with an external end customer.

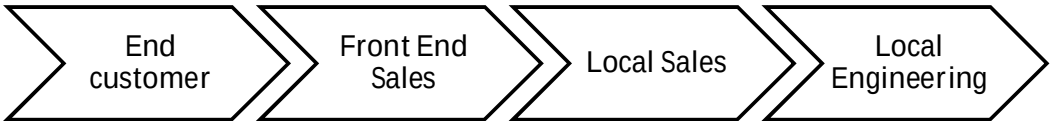


Figure 18 Involved parties in the communication

Tools and platforms
The platform for sharing project documents, has extensive amounts of information where only sometimes the most important input is filtered out, making it hard to discover the important details when making the design. There is also a problem with documents that have bad quality due to being copied many times.

Order Delivery process, Case 2: Internal

Design process
The order design process is today the bottleneck in the value chain and a typical project has many changes during execution; see Figure 19 for correlation between quotation design and order design. The output from the design process is drawings, Bill of Material (BOM) and visual 3D-models for complex orders.

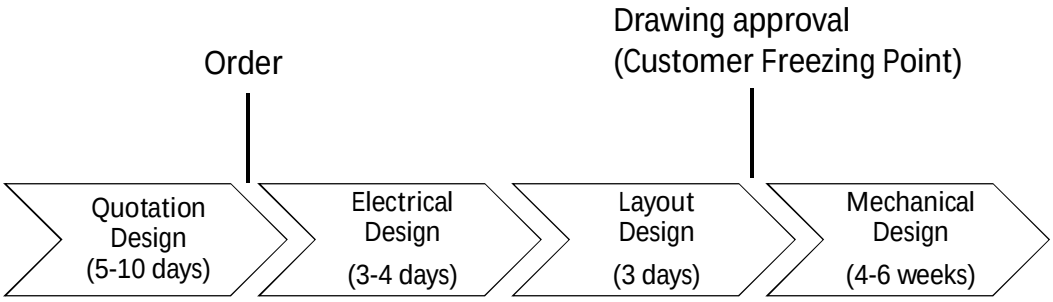


Figure 19 Relationship between quotation and order design

Customer approval

When customer approved the drawings, this is called the freezing point see Figure 19. For 40% of all orders today, the drawings are not approval in time by customers. This affects activities scheduled to take place after the freezing point, such as mechanical design. Many orders are not only delayed in time for the approval but also have changes after this point, which is hard to predict even though the existing gate model. After the freezing point electrical engineers should move on to next project, but re-work of old orders take times and hinder engineers to proceed. The response time for customer to approve drawings is set to two weeks, but often it takes more time due to bureaucracy in some regions. This leads to that mechanical designers starts with basic design before freezing point, but not with detailed drawings since risk for re-work by doing so.

Engineering

The engineers, beyond ordinary work, also support other factories within the company in the making of complex design. It is not always the same engineer making the quotation and order design leads to extra time needed to overtake the work executed by others. Every designer is scheduled to certain projects, in order to limit their maximum work load, still the designers are under high pressure, and especially mechanical engineers are overloaded.

Prioritization of activities

Engineers distribute their time between many different activities where production support is the most important one, since delays are costly. This takes approximately 20% of engineers' time. Order design has then higher prioritization than quotation design, since the real commitment with the customer is when making the order design. This sometimes leads to missed quotation design and therefore also future lost orders. Except from these activities, answer to customer questions needs to be done and takes time.

Material/Production

An estimate is that 70% of all production failures today have its root causes in previous functions, such as engineering. Issues created in engineering take much more time and resources to fix, since these mistakes can result in wrong production method, compared to the ones created in production. Every week there are cases where the input from engineering to production was not sufficient, leading to delays and need of support.

Before releasing drawings to production they should be cross checked by another engineer, to reduce time consuming errors occurring later in the production. When production starts there are not many changes from customer side; still there is some after customer testing leading to re-work. Mismatch between customer expectations and delivered product is often realized at this point.

Gate model
In January 2012 this factory updated their gate model and moved some gates downstream, this to integrate engineers and project management earlier in the process since this was seen as important to reduce uncertainty.

Some opinions was that the gate model should be adapted according to today's reality since that will not change, having two different gate models for utility projects and more complex projects, that needs much more checkpoints and control. The gate model should also better be communicated to end customer, to make them understand the importance to keep deadlines, such as customer approval. This to not miss the production slot resulting in delayed delivery dates.

Lessons learned, Case 2: Internal

The feedback loop after delivery needs to be better and a cross functional meeting to learn from mistakes and increase learning potential is desirable. This is important for update design instructions and technical guidelines, which is not done today. There is a wish to work more with continuous improvements instead of firefighting, i.e. without a systematic way to improve, which is the case today.

Today there is no use of complaints from customers, and for complex/special products, similar design is often made over again, reinventing the wheel and the level of re-use should therefor increase. Mechanical Engineers could for example have weekly meetings with production to learn, and reduce the risk of making a design that is difficult to produce.

4.2.2 Case 3: Internal

This factory produces products within the standard range, leading to a higher competition that for more complex solutions. However the product is still completely customized for each customer.

Capturing process, Case 3: Internal

Long term relationships with customers are important for producing what customers' needs; this puts pressure on sales to build this relationship also with new customers.

In rare cases sales go and meet customer and discuss before a request for quotation (RFQ) is made in order to influence how the specification should look like and understand what factors that are important to take into consideration. Since new markets and customers are more complex to deal with than existing ones, it is important to understand the customer and its specification, since this is more a guideline than a complete truth.

You also need to understand the competition and make external benchmarking in order to stay competitive. Technical wise "company X" is on top, but there is a price gap to competitors, making it important to understand the customers' judging process and what creates value for them. Today's expectations from customers are higher on "company X", when it comes to quality aspects than for competitors.

Quotation process, Case 3: Internal

Lack of process
Today there is no template in place of how the quotation process should be managed in terms of responsibility or building customer relationships. This often goes back to the personal skill level of each sales person. There is a wish to have one common way and structure how to work within the entire process, from quotation to delivery. Where checkpoints and milestones that enforce right quality input to the process and efficiency is important factors.

Request for quotation (RFQ)
It is sales responsibility to check if the RFQ fits the factory's competence before accepting the quotation. After this one electrical designer makes the quotation design, which takes approximately one day per quotation. It is no time pressure to manage this, but it is hard to keep up motivation for engineers just making quotation design.

Customer specification
To clarify the customer specification early in the process, engineering should be involved at an earlier stage than what is the case today and interact more with the customer. The reason for this is to guide customers but also put some pressure on them to come with all input, in order to reduce the number of late changes. Today it is hard for engineers to get into contact with technical skilled resources from customer side during the whole project execution.

Front End Sales (FES)
Most of the order from this factory is via FES and only few internal integrated orders, where there is no difference in how the communication looks like between the two. It is stated that a having a good relationship between internal sales at the factory and FES improves the communication between the two.

The skill level that FES has about the product range and applications is often too low, where the individual knowledge level of FES affects the trustworthiness internally by designers. Low competence creates issues in an early stage; FES is taking risks that they are not responsible for and are not measured on factors correlating to quality, resulting in distance between functions, since different objectives. On the other hand is there a need and wish for designers to respond faster to FES requests as well.

The communication between the end customer and engineering, via FES do not always work that well, according to engineers. For complicated design the local sales goes directly to end customer and ask and even engineers sometimes clarify directly with the customer. This is easier on some markets than others.

Margin slippage
The quotation design today many times deviates from the final product produced; leading to material slippage, i.e. more material is used in the final product than calculated for in the quotation design. This too optimistic quote put pressure on engineering when making order design not to lose margins. The highest COPQ at this factory is material slippage. A better match between calculated and real costs is required in order to keep up the margins.

Hand over process, Case 3: Internal

Kick-off meeting
Today the time that elapse between different milestones and checkpoints in the design process is adjusted during the kick-off meeting. A special kick-off meeting just for active parts, have also implemented with a specific checklist in order to guarantee the quality and reduce errors.

> *"The information flow must be improved, both when it comes to speed and quality" (interviewee at case factory 3)*

Project management
The technical knowledge for project manager (PM) and Sales is many times too low, creating a demand for a technical support. This could be a project engineer that combines technical product specific knowledge and knowledge about the customer. Another comment was that the relationship between PM and engineers must be improved, with clarified roles and responsibilities.

Customer relationship
Today's communication with end customer is many times complicated, with many layers on involved parties in between and the chain of activities from when customer request for a quotation to product delivery is long and complex. Direct communication between engineers and technical skilled people from end customer,

is desirable for clarifying simple issues and ambiguities, where today everything has to go via the project manager.

Order Delivery process, Case 3: Internal

Customer approval
One big issue today is that customers do not approve drawings in time, combined with many changes after this point, leads to re-work that hinders engineers to continue with other planned activities. The standard customer approval period is planned to take two weeks, but could be between 1-5 weeks.

Design process
The high competition on the market for this type of product today creates a beneficial situation for the customer to put pressure on the manufacturer and make them take costs for late changes. A cost the customer should take due to late changes or changes in specification. It is common with smaller changes from customers side after the product testing in production, something that this factory just started to be measure in order to see how much time that is spent on these changes.

In today's design process there are four checkpoints or milestones, linked to the gate model, where the design of active parts have a good quality control. But it exist a wish for more and better checklists and design rules to be implemented in order to prevent engineering mistakes.

Engineering
The engineering department today uses insourced engineers to handle the pressure, which works well. The bottleneck in the design today is mechanical design; this since customer changes takes extra time during design that especially affects mechanical designers planned activities.

Prioritization of activities
Prioritize orders and how to manage their time is today an issue for the engineering department. Today they need to support production some hours each week combined with designing for quotations and final orders.

Material/Production
One quality problem seen in production today is poor drawings with inconsistence and conflicting data, often leading to frustration in production. The production process is robust with formal control points with quality cards and checklists.

There exist no systematic way how to hand over drawings from engineering to Supply Chain Management (SCM). The Bill of material (BOM), the list of material needed in production to build the product, is prepared when the confirmation from customer is sufficient, a relative subjective and vague definition. Some material is ordered already before customer approval in order to not delay production slot.

The communication between Supply Chain Management (SCM) and engineering, related to how to make a cost efficient is not sufficient today. SCM thinks that they

should be more involved in the work of creating guidelines of how the design should be executed, to reduce the risk of making a design that is impossible to produce.

Gate model
The existing gate model, including all milestones in the order delivery process, should be better communicated to end customer to make them understand the importance of keeping deadlines. A missed customer approval can lead to delay in production, which is affecting both internal processes and customer satisfaction.

When making a more complex design, this process should have more checkpoints correlating to the gate model. Better checklists is also required in general, today's output from engineering to production have missed information, wrong data, and missed material etc. Having more frequent cross checking, where a second engineer control the design, is not seen as efficient since it is easy to slip, one idea is to use a team leader instead when making the design reviews.

Lessons learned, Case 3: Internal

The feedback loop that comes from customers and the service division should be more utilized in order to improve and work with continuous learning's. After delivery, the project should be evaluated by a cross-functional team and raise the question if the way of executing the project and design could be improved until next time.

Another feedback that should be better evaluated is the reason for why the factory did not win a certain order. By better follow up this, it could help to improve the situation with low hit rate.

A more frequent use of non-conformity reports (NCR), the report written when something in the development process is deviating from the specification or normal process, should be taken into consideration when improving the design. Reviewing the NCRs is important for not making same mistakes over again. The numbers of NCR today is not that high but have big impact on time since it often takes much resource to fix these issues.

4.2.3 Case 4: Internal

This factory is the only one producing a certain kind of product within the product range, included in this project. The design platform is different at this factory compared to the other internal samples factories visited.

Capturing process, Case 4: Internal

One opinion is that management does not care about tendering, even though most value is created here and the prerequisites for winning an order. Some tenders have too high cost compared to what the customer is willing to pay for, which raises the question if the quality is too high, in relation to what customer needs and are willing to pay for. This situation put high pressure on sales to understand and capture customer data, needs and requirements better and have a more proactive communication and evaluate what is important for that customer or not.

Sales must identify tender opportunities better, low vs. high end quotations, and when possible make budget quotations. They also need to be better on selling in another solution to the customer, than the one they specified. The reason for this identification is to actually deliver what the customer needs and wants to pay for, and not what they specified in the specification, since this is not always correlating.

New customers sometimes want to develop the specification together with the ETO manufacturer in order to learn about the product. This is a good opportunity for them, both to get good quality input regarding the demanded product but also make our design as standard for the company. Understanding the customer and external processes leads to better prioritizing and less re-work.

> *"We spoil our customers by making too much engineering even though customers' is not willing to pay for it" (interviewee at case factory 4)*

Quotation process, Case 4: Internal

The general opinion at the factory is that it is better to spend more time in the beginning of the project, instead of fixing these issues in production. This by asking more questions to customer in the beginning of the process, but on the other hand not hinder customer to change either, that is a trade-off that needs to be managed.

Request for Quotation (RFQ)
An average tender today have three revisions and almost all tenders are re-done to some extent since data and input in the specification is updated or changed. This uncertainty is even higher with new customers. The factory has for the moment one electrical design resource making all quotations for all sales persons.

Customer specification
The customer specification is a big challenge to operate and deal with, it is often very complex and to overcome this, sales must support the customer to specify as detailed as possible early in the process. Deign based on new customer requirements that have not been made before is a growing problem and many times

customer do not specify until late in the process what they want, leading to qualified assumptions and in worst case re-work.

Everything is not specified by the customer in the beginning of the process, since the product many times is part of a bigger system, compensating for other involved parts. This makes the customer referring to the substation specification, instead of specify every detail in their input. Since designers do not have time to go through the entire substation specification, they make assumptions. Another reason for unclear specification is that the customer has not finalized the technical specification, meaning they are not able to specify all details.

Understanding the customer specification right is seen as hard, often there are misunderstandings, in worst case the designer did not understand some things at all or even interpreted wrong. Instead of going back to customer and clarify these details, the designer makes assumptions, many times leading to a non-accurate tender cost.

Engineering

One opinion regarding the engineering is to put more emphasize on the quotation and place the best skilled designers here. On the other hand, others states that doing this might lead to more test failures and higher margin slippage since the best competence should be within order design where we made the commitment to customer. The opinion is that the customer will change their mind anyway during the process, so it is no meaning to spend too much resource on the quotation.

To reduce the uncertainty related to specifications and input when making design, the designers should be included in the early customer meetings together with sales. By integrate designers and customers more during tendering, “company X” could both learn and help the customer what they need and on the same time develop a close relationship.

Having a direct engineer-to-engineer communication, between factory and end-customer, is something that would be appreciated from designers perspective, not only during quotation, but for the entire project. This is done sometimes today and is really efficient when it comes to clarify unclear details.

The communication between internal sales and designers at factory is seen as good but between FES and designers, the understanding is low. Different cultures and structure in the functions, affect the relationship. FES for instant do not care about resource issues within engineering, they just want to please the customer, leading to frustration between the two functions.

Front End Sales (FES)

The knowledge level about the product is not sufficient within FES, making it hard for them to understand and judge the customer specification. However, another opinion is that FES understands the local customer well, and that that is the most important thing. One suggestion to make the situation better is to nominate resources in FES focusing on this type of product.

One way of improving today's relationship between FES and internal sales at factory is to invite FES representatives to the factory to increase the knowledge and understanding between the two. Target for FES should not only be number of won orders, also a quality perspective, where a KPI that covers this should be introduced.

One market linked to this factory, have their FES to make the tender design themselves, still the number of changes in these projects is not less than for other projects even though the communication with the customer is better. This shows that it is not only knowledge issues that create late changes in the process.

Hand over process, Case 4: Internal

Kick-off meeting
After received an order, Project Manager must set up an internal kick-off meeting within three days, this is not enough time for the electrical designer to read and go through the whole specification in order to raise all questions to customer. It is also quite common that the customer have not specified everything before kick-off meeting, by letting the customer attend these meetings much of uncertainty can however be reduced.

Project management (PM)
The project management at the factory suggests that a technical support committed to help the PM in the communication with customer would be very helpful, this since the knowledge level of PM sometimes is not sufficient.

Customer relationship
Having early discussions with customer is important for clarifying the project set-up; it was also discussed if penalties for late changes could be one solution to reduce the re-work level. Customers' mindset is that they can wait to specify requirements until last minute since the delivery time is so long and by wait get the best price and quality. This leads to much late input from consultancy or customer side.

Order Delivery process, Case 4: Internal

Design process
Sometimes designers start with order design without clarified everything in specification, this since the scheduled time for making an order is pressed. It takes around three weeks to make the drawings, but due to queue of orders, customer receives the drawings after three months. Even though the input to engineering should be 100% clear when starting with order design, this is rarely the case. Half of all orders need to be revised or updated during the design process.

Customer approval
It is not always designers wait for customer approval before starting with next step in the design process, often customer takes more time for approval than planned, then a spoken agreement is common not to slip in schedule and miss production slot. After customer approval there are not many changes in the project.

Engineers

The pressure and stress on engineers is often high, which requires high motivation in order to make the designer to stay. Attract young generation of new designers is also a big challenge. To motivate people and increase the quality level, training internally combined with work training abroad is used to gain experience and understand customer better.

Since changes of drawings in production leads to high extra costs, designers many times chose to not revise the design at this stage, even though it would be necessary to do so, this since they are afraid to get accused to create trouble. This is a mindset that needs to change, by communicate that the changes comes from customer and not the engineer, the understanding from production might increase. A fact that is supported by the statistics of many changes that is done for every project, there it can be seen that 70% of all changes come from customer side.

Prioritization of activities

The prioritization for designers needs to be clarified in order to better manage their time. Customers are today dissatisfied with long response time from factory side, this since high work load for designer makes them take long time to answer the customer. There is also frustration related to long response time from engineering to both suppliers and internal sales as well. Today the highest prioritization for designers is production support, and secondly existing orders, and last quotations.

Material/Production

Many drawings is today unclear when they reach production, 20-30% of all orders needs support by designers in production and in many cases internal and external design does not match in production, something that a design review with a CAD model could have prevent.

Late changes also affects purchasing and production, as much as 60% of material is bought before customer approval, meaning that changes to high extend affect material purchase and today 10% of all order material is wrong in production.

Gate model

Existing internal checklists is not followed in design reviews today, designers do not come to design reviews, where the existing gate model is defined on a too high level.

Lessons learned, Case 4: Internal

The feedback loops need to be improved in order to not repeat same mistakes again. After delivery today, there is a cross-functional project review meeting including quotation designer, order designer, sales, PM, project controller, SCM and production, in order to learn by previous learning's.

Better evaluation of the gap between tender and final design is a great opportunity to improve and learn. Today's deviation in margin slippage is communicated to the tender designer with the purpose to learn and not make same mistake again. Once a week the factory have a meeting where they discuss risks with current projects and NCR learning's. Still, revise and update checklists, listen better to customer feedback

and encourage engineers to work with continuous improvements could be done more and better.

4.2.4 Case 5: Internal

This factory is, compared to other factories producing this product relative new, leading to less experience of the business.

Capturing process, Case 5: Internal

To give correct cost calculation in tendering, sales must increase their understanding of the market and competition and improve the communication with customer already before RFQ, something that is not working that well for the moment. By understanding what customer needs the quotations can be better and more accurate. Today extra margins is added on basic tenders, because there is a fear of losing revenue otherwise, this can vary 40-50% from real cost, leading to lower chance to get the order.

Quotation process, Case 5: Internal

Customer specification
Sales must start to integrate more with customer to clarify needs and requirements. By having a checklist for critical items, and point out clearer responsibility during the quotation process, this could be improved. Engineering finds it hard to read and understand the customer specification, where the designer interpret wrong or language issues makes them not fully understand what data that is lacking; this increases the risk for late changes during project execution.

Understanding unwritten expectations from customer, and special requirements, is another area that the designers found hard. One example is that some industries do not specify their specific standards that are required, in the specification since they believe that these are obvious. Sales must inform and communicate if it exist special requirements.

Other reasons why designers struggle with the specification is that customers have too low technical knowledge, making them disable to clarify everything. Some specification is not updated with new global standards valid for an industry, like oil and gas, which needs to be discussed with customer before changing. New customers have a hard time to specify what they want, leading to many changes during the process.

Front End Sales (FES)
FES do not have enough knowledge about the product, still they can recognize key data. FES target and objective is also different compared to the factories, making them frustrated since they do not understanding each other.

Hand over process, Case 5: Internal

Kick-off meeting
The kick-off meeting held when receiving an order should be held together with all involved parties of the project, which is not the case today. The time between order

receiving and kick-off meeting is short, not making it impossible for the electrical designer to go through the material and raise all questions that is needed to be clarified with customer and Project Manager. A more robust process of how to evaluate the specification is needed, today almost one third of total orders are not clear with main items. For repeat design old NCRs and drawings should be taken into account, this is not always the case today.

Project management (PM)
The knowledge level and confidence needs to be improved both for PM and Sales representatives, and PM should be integrated in project already during quotation to improve the quality of the project execution.

Customer relationship
Speaking directly with customers is today hard for the designers, due to factors such as language barriers, and consultancy that make it hard to communicate and get data directly from end-customer. Communication between customer-FES-internal sales is a bigger challenge than the communication between Internal sales and designers.

Order Delivery process, Case 5: Internal

Design process
The final design do not always correspond to customer expectations, this is disclosed during customer testing which often result in re-work for the factory. It is judged to be hard to predict in advance what in the specification that could lead to problems during project execution.

Today's system for sharing documentation and information about projects must be improved, today there are much double work and issues with wrong revision of the drawings sent to production and customer.

Engineering
Attracting resources with right skills and knowledge to the engineering department and then keep them motivated is a huge challenge today. You need as a designer, to have knowledge and experience from different markets in order to understand how to deal different specifications. The numbers of design tools used is putting high pressure on engineers today.

Language skills is another problem that exist today, engineers do not have enough knowledge in English, making it hard to understand the specification and face and talk directly to end-customer, especially for export projects. Training both in language and how to interact and understand the customer, combined with personal skills training is something that is of high interest, not only for designers, but also for sales and project managers.

Prioritization of activities
A clarification and prioritizing for designers' activities need to be set between; production support/tender design/order design/communication with customer is needed. Respond time from designer to customer is very long, since they are busy with other orders, having a better prioritization could improve the situation.

Material/Production
Wrong revisions of the drawing that are launched to production and mistakes discovered that leads to re-work are two common problems in production. Also incorrect transport drawings made today leads to wrong shipments and extra costs.

Gate model
The only design review held today with checklists is before releasing the drawings to production. This is not always done properly, and it is very common that this is slipped. There is a need to have a more robust process with design reviews and checklists with better discipline. There also exist wishes to have design reviews with end customer, since this generates a more robust control.

Lessons learned, Case 5: Internal

Sharing experience and networking more between functions and factories is crucial, when entering a new market where another factory already is located and deliver products, this experience must be better shared.

After delivery a project review should be held in order to capture lessons learned and not make the same mistakes over again. When the factory receives a request for repeat design, meaning that a customer comes back and want one more product of a design that they already ordered once, quality function or responsible should look at old design/NCR for that order and lift eventual finding's for discussions during kick-off meeting. This is not the case today, the storage of old project data is not structured leading to hard times to find right revision of drawings.

FES does not provide data of why factory missed order, which is of high value for designers to improve to next time.

4.3 Cultural differences found between samples

Even though it was not in in the scope to determine and evaluate the cultural difference affected the process efficiency and quality, some observations was made during the visits influencing the organizational set-up.

For the first case in north Europe, the hierarchy was flat and production and designers could easily talk to each other if any concerns in production or with design, where engineers often visited the production to discuss design matters. For the second visit at a factory in south Europe it was a clearer barrier between production and engineers, where designers rarely went out in the production unless production needed support. For the third case in Asia, some indications of hierarchy could be seen, both between blue and white collars, but also between functions.

For the last case in Asia, it was firstly hard to make them express their opinions and feelings regarding the different topics in order to not lose their face. Meaning that they did not want to confess or raise issues if anything in the processes or communication did not work that well. In these cases, examples when things did not work that good, from other factories where given in order to reduce the resistance or fear of the interviewee. This mindset is probably influencing also the internal communication.

4.4 Result from Interviews with key people

In this section the result from all additional interviews and discussions held will be presented. This is the result from a wide range of different people's knowledge, ideas and experiences, making the result sometimes inconsistent or conflicting.

Most of the interviewees are not connected to a certain plant, but instead have global roles representing the global business for this product range. In total 17 interviews were held with people with this type of roles.

4.4.1 Capturing process

Since the hit rate in an average factory today is low with big improvement potential, this means that much of the job put down on creating quotations is done for nothing since it is not leading to an order. Some quotations should clearly not be done and the process for deciding this is today somewhat chaotic. The focus must be better and the number of quotations reduced. Quotation shall not be done on the "quote and hope"-basis that it in many cases is today.

The question of why certain orders are lost must be asked more frequent in order to improve the situation in combination with getting to know the customer better and understand customer's decision-making process. What is creating value for them, and what are they willing to pay for, when understanding this, designers can make "right" quotation depending of what customer find valuable. Today the manufacturer company is highly competitive in quality but not in price.

Improving product competitiveness and produce what customer needs, not what they want must be worked with and understood in an early stage. Sales/FES must use more value based selling, and talking to customer before customer request for quote (RFQ). It would even be preferable to let the designer meet the customer at this stage as well in order to guide the customer in their judging process, and communicate to the customer the advantages of high quality and make them realize why they should pay a premium.

Building a clear marketing process, and set up a capturing team, is of major importance to understand the customer judging process. One project running at the ETO manufacturer currently, focusing on making the information better in the early process, that have created cost savings up to 20%.

One way of becoming more competitive regarding price, could be to separate orders into low vs. high end market, this could lead to lower costs and in the end lower price for customer. However, other interviewees say that the quality might suffer if prices are pushed down too much.

4.4.2 Quotation process

Lack of process

Management must understand that most of the value is created in the quotation process; cost spent on the quotation is today small compared to the value it generates for the business. A cross functional team between the top management representing the complete product range and FES should define the quotation

process, what checkpoints that is needed and what education that is needed in order to follow the process.

Define and structure a process for quotation that fits the business, with measurements and KPI to see correlation to quality/costs for the rest of the value chain, and resources, competence and responsibility is of highest prioritization. Without a defined process with correlating measurements it is impossible to work with continuous improvements. By creating a quotation process with corresponding milestones a more systematic approach of doing quotations can be achieved, resulting in better input when making the design and therefore being more competitive. It is also important to communicate this process to everybody involved and affected by it.

Templates and Checklists

The starting point in the quotation is to understand what questions that are needed to be asked to customer in order to make a good design. One way of doing this would be to have checklist of what kind of relevant data that is needed to do a tender at all. By defining what questions that needs to be asked to customer in a model or template this can help to manage the relationship and communication between sales and customer in a satisfying way.

This kind of checklist would be used by FES, which today has the major contact with customer in this early stage. One risk that was discussed by doing so is that the knowledge level in FES is too low to judge the quality of the input, and understand if it is sufficient for designers to base the design upon.

It would also be valuable to have an internal checklist at the factory when making the order in order to make it in the most appropriate way. This could be used in combination with quality cards, meaning that somebody needs to take the responsibility over the decisions made and "sign-off" in order to proceed in the process. These quality cards are already used in production in order to guarantee the quality.

Quotations

An average factory for the product range generates between 1-2 tender designs per day, according to some people that is too many. More time should be spent on each tender in order to increase the quality of each tender, instead of doing more quantities.

One interesting idea how to generate faster quotations is to create a configurator tool to make standardized quotations, based on previous designs.

Customer specification

The input from the customers today is often poor, which results in the designers doing assumptions, which in the end leads to not satisfied customers. Much data without importance is handed over to designers and many times the low technical knowledge by customer makes them use consultants. Sometimes the customer does not know themselves why the specifications look like they do. More attention must

be spent on getting right data at this early stage, and also be stricter against the customers in explaining what the factory needs delivered on time.

Uncertainty must be reduced so that designers can make the quotations that the customer needs, which leads to two questions that need to be understood; What is the customer demanding in specification? Secondly, what are we obliged to do? By having a close relationship between Sales and customer this can be understood.

Engineering

In order to make a good quotation a high level of competence is needed, but it is hard to attract experienced designer to make tenders. Some people is saying that putting the best skilled designers in quotation leads to "quote and hope", and that it is FES' job to evaluate and understand what quotes are judged upon, not placing the most qualified resources there in order to make qualified assumptions on a poor specification.

One thing that many interviewees suggested is that designers must integrate more with customers in this early stage, but also during the rest of the order process. It has been seen that language is an issue in this communication, and also a reason for designers not interacting with the customer.

Front End Sales (FES)

FES is lacking competence to sell this kind of product; they do not have enough engineering skills. Some interviewees thinks that FES does not fit to sell this complex product, on the other hand others says that this current setup with FES have better understanding of the market than it was before. Still there is big difference between FES in different countries. One idea was to create a special sales force within FES just dealing with this product.

Today's situation leads to low trust from designers side to FES, since they cannot deliver good information to engineering and do not look into the input from customer good enough, instead they hand over too much data. Despite this, it is important that designers trust FES when they communicate customer feedback and complaints. Today FES claims that designers do not respond fast enough on their questions, and vice versa.

Today the way of measuring FES and Sales is not related to quality, more to number of orders received and margins, not delivering the prerequisites to designers for them to deliver high quality in the next step. This makes FES unable to ask the right questions to the customers, and also hard for them to judge and understand all input in the specification. Some opinions are that this leads to that a changed interface between customer and "company X" is needed in order to get input to high quality to designers making the design. By having FES into more customer contact and listen better and more careful to them during the entire process this could be improved, and a better relationship can be built up.

Sales do commit to customers that is not communicated, or poorly communicated back to designers. This leads to misunderstandings between the functions and the factory have a hard time to deliver what sales promised the customer. One idea,

discussed during the interviews, to prevent this, is to send FES to the factory for training. Combined with integrating with different functions at factory the understanding for each other could increase.

Higher accreditation before taking on a job should be implemented, an FES person must either know the customer very well, then it is not that important to have full insight in product, or vice versa.

4.4.3 Hand over process

The order handling and the responsibility in the hand over is not clear today, hand over documents and checklists that should be handed over between Sales and Design should be defined and implemented in the process. One way to increase and clarify the responsibility could be through quality cards, such as the ones used in the production. The internal communication and understanding with clear responsibility must be defined. One drawback with this according to some is that designers already today are under high pressure and do not want to sign and take the responsibility, this will make it even harder to attract engineers to the role.

Customer interaction
A borderline of who is the responsible to manage customer needs in the hand over process is seen at the factory. The communication at this stage with the customer must be more proactive with better use of continuous communication. Much of COPQ comes from poor communication between customer and factory; increased communication would decrease re-work and mistakes and in the end reduce the COPQ. By having direct communication between technical functions from customer and factory side this could be improved.

More pressure must be put on the customer and it must be communicated that order design will not be done until defined specific input is included in the specification. By presenting and explaining the gate model this could help in the explanation of why it is important to keep schedule not to miss production slot, leading to longer deliver time.

Project Management (PM)
The communication between designers and PM are not always good, the responsibility and understanding for each other is not satisfying.

Kick-off meetings
The kick-off meetings should be held with all involved functions, preferably also invite the customer to this internal kick-off in order to get right data and clarify things directly together and not clear all the questions via PM or Sales. At this stage also old NCRs should be raised by the quality function.

4.4.4 Order Delivery process

Design process
One major issue today is changes of drawings, and understanding why these exist is of high importance. One way to reduce the uncertainty during the process is to have more customer meetings, which could be held via video conference or telephone

meetings. There is a need to find KPIs for measure design fulfillment of specifications, something that the factory has not succeeded with so far. Putting up a timeframe when information should be delivered in the process both for FES and designers are something that should be investigated further.

Engineering
Some critique that relates to the factory side and designers is that they do not pay enough time to understand the customer and their specification. This could be prevented by increased communication between factory side and end customer. Another issue in engineering is to find right resources that have the right skillset for making the work; training should be standard for new electrical engineers when starting in the company.

Prioritization of activities
A better prioritization between order types and activities must be defined and clear. Disturbances in production take much time today. The factories need to react faster in communication with the customer (FES), today customers ask for drawings but the factories cannot provide these on time.

Material/Production
One common issue in production is the number of changed drawings. A closer collaboration between production and designers is also desired to prevent designs that are difficult or impossible to produce. In some cases the production starts without customer approval in the design process.

Gate model
Many interviewees raise the question if existing gates in the order delivery process is sufficient as it is easy to slip gates and take shortcuts combined with an unclear responsibility for making quality checks. This since keeping production slot is of major importance. For each gate there should be checklists and quality cards, the idea of adapting the gate model depending of the complexity of project was raised.

The use of existing checklists is not always sufficient. One opinion is to make checklists mandatory or skip them, something in between would not be clear. Easy and straightforward checklists that could look different for different projects, consisting of maximum two pages are preferable. There are also cultural issues where some countries have a harder time to follow checklists than others. Use of cross checking, when a second engineer control drawings, should be implemented during design phase in order to find mistakes already here and not in production.

4.4.5 Lessons learned

Today there is more a firefighting mentality and approach and less of working with continuous improvements. The learning's from previous projects must be better; one example is repeated designs where same mistakes are done over again, this must be prevented by carefully using the captured knowledge from last project. Cross functional design reviews between production and designers for lessons learned, and regular meetings between FES, Project managers, internal sales and sometimes engineering are two improvements ideas on how to continuously work with lessons learned.

5 Analysis

The analysis will be divided into two parts, a cross sample analysis and then enfolding literature. This in order to answer the two research questions *"How can the Quotation- and Order Delivery processes in an engineer-to-order company be described from a quality and efficiency perspective?"* and *"Which are the major factors in the Quotation- and Order Delivery processes that influences process efficiency and quality?"*

The analysis is inductive, meaning that important areas are grouped into clusters, to see patterns and a method of high importance in order to be able to analyze huge amount of data.

5.1 Cross sample analysis

In grounded theory, Bryman & Bell (2011) describe that concepts and categories are generated in the analysis, where a category is described on a higher level, including two or more concepts. Five major categories or sub-processes could be found during the iterative analysis. These are the capturing process, quotation process, hand over process, order delivery process and lessons learned, all including concepts or areas found to influence the process efficiency and quality see Figure 20. A list of all improvement areas and influencing factors found are presented in appendix.

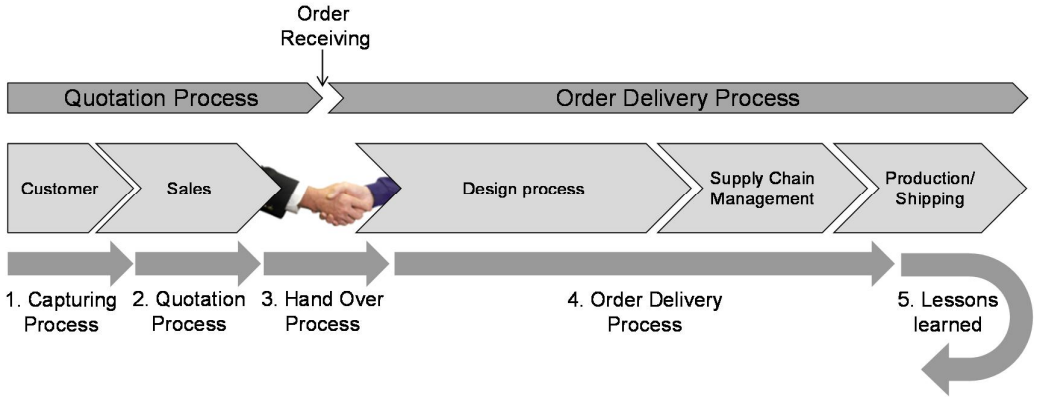


Figure 20 The five identified sub-processes and the interaction with the quotation process and order delivery process

5.1.1 Capturing process

Having a good relationship with the customer is seen as one of the most important aspects in order to succeed to make a product that satisfy the customer and reduce uncertainty. These are factors that increases the efficiency leading to less re-work, revisions, and late changes from customer side. Still, building relationships are hard to manage and in the end it all goes back to the personal ability for each sales person. All cases and interviewees agrees that relationships is one of the key deliverables in order to stay competitive on the marketplace and to understand the specification and in the end satisfy the customer.

The customer specification is seen as one of the factors impacting efficiency and quality most and is strongly linked to building relationships. Understanding the customers' needs gives you freedom with the specification, understanding what aspects that are important and what's not. Improving the capturing and opportunity identification by building relationships and understanding the market competition could improve the probability to make a product that corresponds to customer needs, and by extension win the order.

5.1.2 Quotation process

In the quotation process some major aspect affecting quality and efficiency have been seen in the process itself. This relates to how different cultures and objectives found in the functions affect communication and how the process itself today managing these differences.

The role of FES is seen as a huge opportunity for improvements. Their knowledge level is not satisfying from engineers' perspective, and the reason for this is that FES cannot clarify all details linked to the project at an early stage. The interaction between customer and sales today is not always creating the best conditions for the designer to make a design that correspond to customers' expectations. Many layers of involved parties between customer and designer make the communication difficult. This creates an environment with several organizational matters, including unclear roles, responsibilities, communication that are not supported by a defined process.

The specification is, as mentioned before, one of the biggest uncertainties today, too extensive specifications makes it hard to find all relevant input, however not specified input leads to assumptions, creating risks for re-work, revisions and margin slippage as a result.

5.1.3 Hand over process

Today the kick-off meeting is crucial for clarify the specification with the customer before project execution. Still this process is many times an unclear where responsibilities and roles are not defined and communicated. The project managers' role and competence have also seen to influence the quality due to not satisfying technical competence.

The electrical engineer's responsibility to evaluate and review the customer specification before kick-off meeting is a crucial check that today is under huge time pressure.

Communication is another factor linked to organizational matters and lack of process that influence the efficiency and quality. Mainly referring to the difficulty for the designer to clarify specification queries, both due to the complexity to come into contact with the end customer and then find a person with right competences.

5.1.4 Order Delivery process

The order delivery process includes the entire project execution process, where factors influencing process efficiency and quality could be linked to both external

and internal factors. The external factors are often referred to the interaction with customer and a not clarified customer specification. While the internal factors relates to slippage of checkpoints and milestones, re-work related to mistakes with drawings but also a unclear prioritization of activities for the designers.

5.1.5 Lessons learned

All cases agrees that there must be better feedback use in the existing processes to work with continuous improvements instead of firefighting. Incorporate lessons learned in the existing gate model used in the order delivery process is highly recommended. Having a cross functional meeting after delivery can hinder same mistakes to happen again. This is highly linked to building an efficient process by learning from previous mistakes, delivering products of higher quality.

5.2 Enfolding theory

This part aims to answer a part the second research question *"Which are the major factors in the Quotation- and Order Delivery processes that influences process efficiency and quality?"* by comparing the outcome from the cross sample analysis to theory.

5.2.1 Capturing process

Hvam et al (2006) states that if the quotation-to-order ratio is low it exist a huge opportunity to improve the efficiency. This could be done either by improve the ratio, referred to as hit-rate in the result chapter, or by reducing the cost for develop quotations. Both ways was up for discussion in this study, where improve the ratio mainly focusing on building customer relationships by value based selling. Reducing costs was mostly discussed in terms of create a better screening process within sales, categorize the tenders into either budget quotation or the ones to spend more effort on, this was however not agreed by all interviewees. Increasing the degree of product configuration, as suggested by Elgh (2010); Tham (2007) and Forza & Salvador (2000) where the design is based on old projects, was also up to discussion.

Building relationships and understand what customer needs, was another topic heavily discussed both in literature (Cooper, 1996 and Ulwick, 2002) as well at all cases. Carbone & Tippett (2004) states that "To improve project screening, organizations must first have an idea of what makes a product a success", relating to the topic of understand your market, both in terms of who is your customer but also your competition. Secondly Carbone& Tippett (2004) say that a need of a process that can make use of the information in the front end phases for improved the screening is needed. This have also been seen during the quotation to be an opportunity, how to organize the communication both internally and externally with customers. Van der Meijden et al (1994), state that conflicts can occur internally when marketing and sales' target does not correspond with manufacturing's.

5.2.2 Quotation process

"Having a (Front End) model to use and follow is only one portion of what is needed during the front end. As information is gathered it must be shared across various

groups in the organization using a defined and understood process" (Carbone & Tippett, 2004).

The quotation process is seen as one of the most crucial processes in order to be competitive in today's global context (Elgh, 2012, Zorzini, 2008, Hvam et al, 2006). It is in this process the risks and uncertainties can be reduced (Herstatt et al, 2003) in order to create a competitive tender. This has also been one of the most debated areas during this research, how to overcome uncertainties related to the activities in front end.

Elgh (2012) discuss the importance of having an accurate quotation preparation since it precedes the order preparation, in setting margins and delivery time, making it essential to have access to detailed information. This could however be seen as one of the major challenges today, with a high uncertainty regarding the specification that is also stated by Konijnendijk (1994), saying that flow of information never stops, leading to a time consuming information processing. Wortmann (1995) says that it should be allowed that basic information is incomplete, partly inconsistent, or not up-to-date, since the specification should only be seen as reference data. This leads back to the importance of building customer relationships and understand what the customer needs, something that have been seen throughout all cases as one of the crucial aspects for reducing uncertainty.

To be efficient in the quotation process and reach a high level of accuracy, the quotation process needs to be formalized by defining input and output to the process, identify sub-processes and resources (Elgh, 2012), which is not the case today. The process was often ad hoc and very dependent on the individual sales people's skill and knowledge level. This opens up for a big improvement potential to increase the process efficiency by formalize and define the process.

On one hand Elgh (2012) says that an ad hoc process increases the risk to not deliver a product to an accurate cost, destroying the margins. On the other hand Konijnendijk (1994) agrees that standardization will increase the efficiency but to the cost that it is hard to balance with having a high degree of innovation. This points out how important it is to link the process to the corporate strategy.

Konijnendijk (1994) discuss both the selling process and buying process, where it is important to distinguish between the two when defining and structure the communication and information flow. This has also been seen in the different samples, that the coordination between involved parties is not always that structured, where different function tend to not understand each other. Konijnendijk (1994) raise some characteristics in the coordination between marketing and manufacturing, where culture, structure and objectives explains some of the communication issues seen today. Not having the same culture and objectives creates a barrier between functions and when this is not supported or managed by a defined process, the responsibilities and roles turns out to be fuzzy and unclear.

5.2.3 Hand over process

"In order to create such a model (that ties together information processing with the product development requirements), the organization must first understand the

information required and then create a process to share and use that information so as to improve product market success rates" (Carbone & Tippett, 2004).

Konijnendijk (1994), presents four coordination characteristics; processes, structure, culture and objectives that influence the coordination between marketing and manufacturing. This also the case in this study, where organizational matters includes issues found in structure, culture and objectives. Parente et al (2002), present that the quality of the internal relationship between production (manufacturing) and sales affects the customer satisfaction significantly for an ETO product type. This have also been seen during this research, the coordination in the hand over needs to be supported by a process in order to generate a customer specification of high accuracy that the designer can use when making the design.

Konijnendijk (1993) says that it is a big challenge with the customer specification, and the better the company can translate it into feasible parts, the better it will perform. This was also discussed at one factory, how the specification can be translated into internal language in order to make a good design. Berstrand & Muntslag (1993) pinpoints the important role of the customer order, the customer-specific product specifications and the product and production uncertainty, as characteristics of an ETO company, something that this research can confirm to be found characteristics.

A structured process that support the organizational set-up, to be able to clarify the specification would reduce the level of re-work and revisions, late changes, COPQ and reduce the uncertainty that today is a great part of the situation.

5.2.4 Order Delivery process

The quality and efficiency improvements for the entire project execution need to emphasize on the early activities in the order delivery process, mainly the hand over process.

Prioritization of the designers' daily operations needs to be clarified, in order to make the internal process more clear and efficient. Alfredsson & Söderberg (2010) described some wastes defined in Lean product development as lack of clear prioritizing of projects/tasks, lack of available resources –resource bottlenecks, poor communication across functional barriers, poorly defined product requirements and disruptive changes to product requirements, these are all activities that can be found in today's processes. Creating an inefficient environment not supported by a well-defined quality process to reduce some of these wastes.

The findings in the capturing, quotation and hand over process fits very well with the approach and purpose of Design for Six Sigma (DFSS). The method strives to increase customer satisfaction and competitiveness via preventing problems already in the front end to the product development process. This by getting the product right the first time already in the design or development phase. By implementing the IDOV methodology thinking much of the seen factors influencing the quality and process efficiency would be taken into consideration already at an early stage in the process.

Carbone & Tippett (2004) argues that all products do not need to pass through the entire development process phases or gates, due to financial, technical, or market reasons. This is also something that many interviewees claimed, that today's gate model was described as too formal with many checkpoints, not always contribute with direct value to the involved parties.

5.2.5 Lessons learned process

In order to improve the quality deliverables and efficiency achieved internally, lessons learned needs to be better incorporated in the everyday activities. Reflecting about the learning's after each delivered project to update instructions and share knowledge is a huge potential for improvements.

Continuous improvements are also related to training of people, so they have the right knowledge and skills. This is also something that been discussed at the different cases, how to support the functions, like FES, Project Manager and Designers, to take a greater responsibility and better fulfill the requirements and expectations.

5.3 Improvement areas within sub-processes

Following improvement areas could be identified in the sub-processes when combining and analyzing the result from all cases and interviews held with stakeholders. These improvement areas are both reasons (written in Italic) and results leading to an inefficient process influencing quality, see Figure 21. Some factors are hard to distinguish as reason or result since they might overlap and influence each other.

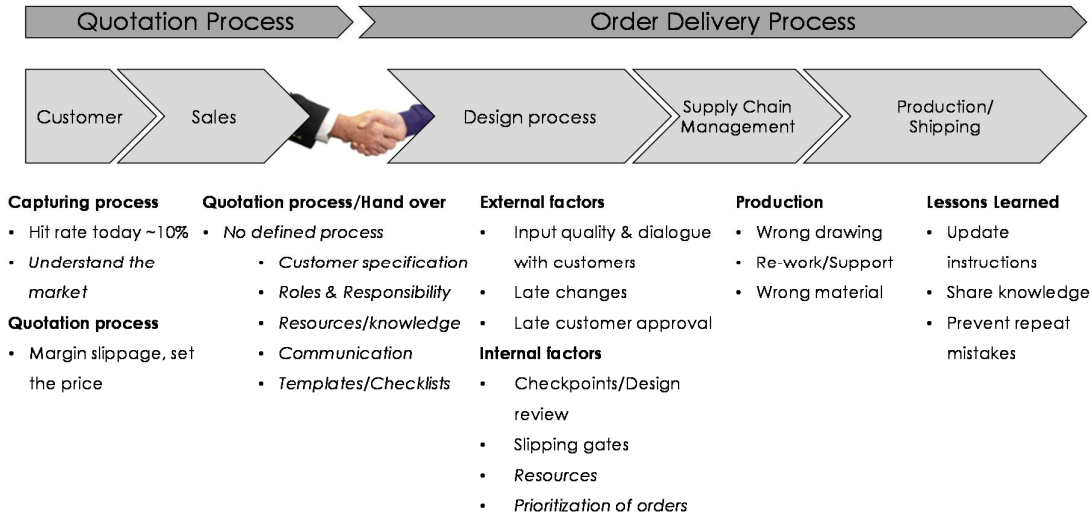


Figure 21 Following improvement areas were found to influencing process efficiency and quality

When comparing the result from the different cases to literature, most improvement areas for increasing the process efficiency and quality could be related to the front end activities, including the capturing process, quotation process and hand over process. This could be related to the quality of the input to the processes, often from customer's side. Not having a process or organization that fully support the

uncertainty reduction at an early stage are the major factors influencing efficiency and quality through the entire value chain.

The capturing process is important in order understand customers buying process and influence the specification and increase the probability to win the order. While the quotation process is more about communication and cultural differences in the organization combine with the uncertainty of an uncompleted customer specification, highly influencing the margins. The hand over process is crucial for creating good prerequisites for the rest of the project execution. Clarify all concerns both externally with the customer regarding the specification and the internal responsibility and roles is a must.

The order delivery process is the process that has been most invested in during the years. The reason for this is that the development and production from a historical perspective been the two areas of interest when discussing efficiency and quality. Gates and milestones is not fully in compliance with the design process, raising the importance to have a process that support the needed quality outcomes from each function. Incorporate lessons learned is one crucial factor to increase the quality and making same mistakes twice.

See Figure 22 for a separation and break down of these improvement areas, linked to whether they influence efficiency or quality, or both.

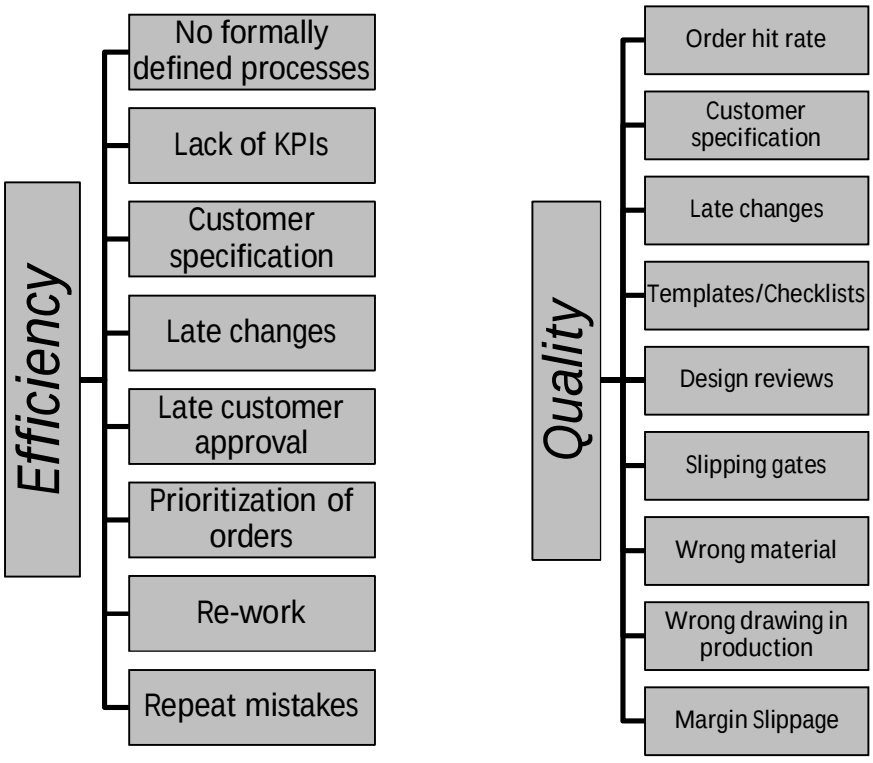


Figure 22 Factors found in the quotation and order delivery processes influencing Efficiency and Quality

5.4 Factors impacting quality and efficiency

Based on the cross sample analysis and theory, some major factors could be identified in the sub-processes influence process efficiency and quality. See Figure 23.

First are the communication problems between functions and how the responsibility and roles are defined. This is of high importance since it was found that the culture in the different functions often differs, which goes back both to a personal level and to the targets and objectives defined for each function. *Organizational matters* are a factor that can be overbridged by training and by increase the knowledge levels, and establish goals and targets that strive for same deliverables between functions. Having an unclear organization leads to both inefficiency, since responsibility and communication is not set and clear, and the objectives between functions strives for different aims. This will also result in poor delivered quality, since the data and input transferred in the organization is not meeting the internal customers' expectations.

Secondly, the *customer specification* is seen as one factor that causes both inefficiency and quality problems and is extremely important in the making of ETO products. Missing input, special requirements and changed input are just some aspects of why the specification leading to an uncertain environment.

Lastly is *process management* that relates to how today's processes are managed. Front End processes including quotation and hand over processes are not formally defined and lacks in KPIs, meaning that the correlation between these activities to cost and quality is not measured today. The order delivery process is defined but needs to be re-implemented when it comes to gates, reviews and checklists. Having a process that not delivers what involved customers, both internal and external, expect generates an inefficient process.

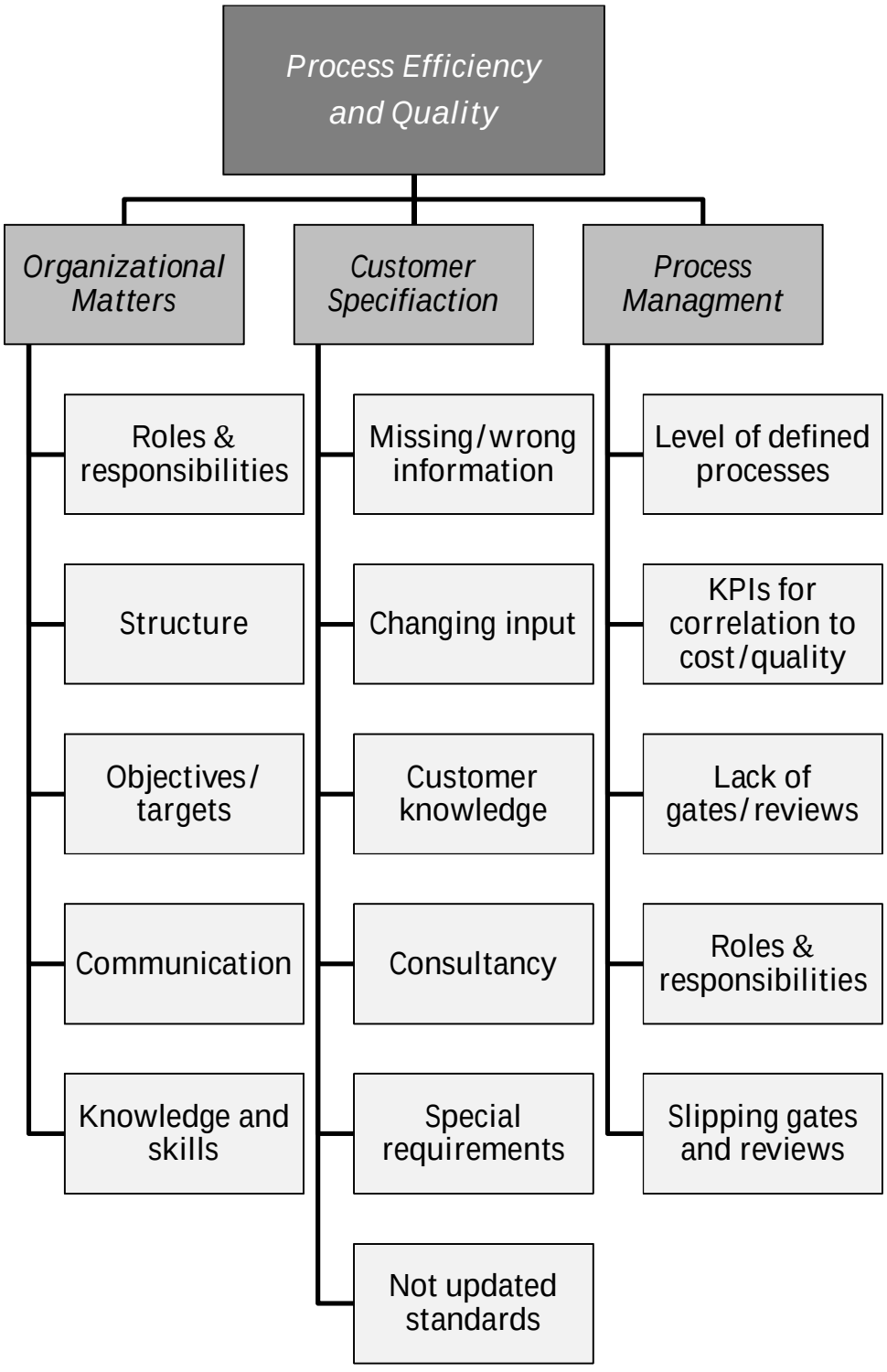


Figure 23 Major factors influencing process efficiency and quality

6 Conclusions

Research Question 1: *How can the Quotation- and Order Delivery processes in an engineer-to-order company be described from a quality and efficiency perspective?*

Research Question 2: *Which are the major factors in the Quotation- and Order Delivery processes that influence process efficiency and quality?*

6.1 Research Question 1

It can be seen that the efficiency and quality success is strongly affected already in the early integration between customer-sales-factory, the front end. Below is the quotation- and order delivery processes described with correlating factors influencing quality and efficiency mostly.

6.1.1 Capturing process

Identify future opportunities are of high importance to understand how to create right quality for the customer and reduce much internal uncertainties linked to the customer. Especially since the marketplace for this product type is getting more dynamic and hard to act on. Understanding the customer must be seen as one of the most importance aspects in order to stay in the market long term.

It would be of high value to define the capturing process and how it would correspond to the company strategy. These activities takes place before a customer send a request for quotation and mostly is about building customer relationships, discover market opportunities, activities that is hard to structure in terms of a process flow. Still, it is of great value and a big opportunity to understand the market and capture a bigger market share.

6.1.2 Quotation process

In the quotation process two levels of processes needs to be defined, to overcome the organizational differences and to increase the efficiency and quality, one formal internal process with coordinating marketing/sales and manufacturing, and secondly a “process” of how to build trust and relationship between sales and customer.

This latter one has been seen as one of the biggest improvement potentials for understanding the customer and their needs and values when it comes to judge the quotation design. Since new customers and markets is becoming more the nature of the business it is highly important to start coordinate this situation.

6.1.3 Hand over process

In the hand over much coordination between functions needs to managed, leading to many organizational differences. The target and objectives between the functions

and the cultural differences is affecting the communication pattern. Since the internal process also must take into account customers external process, a high level of coordination is needed both between customer and sales but also sales and factory.

The hand over process is the most important phase of the value chain when it comes to clarify the specification, therefore the kick-off meeting and the role of the project manager is important to clarify.

6.1.4 Order Delivery process

This is a part of the value chain that been most investigated and defined during the years. In this study it could be seen that the major approach of the order delivery process and the correlating gate model is implemented at least partly at the different factories. Still there exist a big potential to improve this process with robust checkpoints from today. This could be done relatively easy compared to defining new processes such as for quotation and hand over.

6.1.5 Lessons learned process

Dealing with continuous improvements is the heart of building long-.term quality in a company. Everyone involved in the project agrees that it is crucial to keep processes up to date. There was also a frustration from people at the factories working in the processes that instructions and documents were not updated, and previous learning's was not taken into consideration in future projects.

By integrating this lessons learned loop in the delivery process, with natural meetings and closures of project this situation could with high probability be improved. But to succeed with that clear roles and responsibilities needs to be defined, not only suggest that a feedback loop is important. By defining process owners a higher degree of responsibility could be delivered.

6.2 Research Question 2

Three major factors could be identified affecting the process efficiency and quality after the analysis, see Figure 24. That is the organization itself, including factors such as cultural differences and objectives, secondly the customer specification and lastly the process. This is also supported by literature to be factors that ETO companies needs to be coordinated between marketing/sales and manufacturing, and defined.

6.2.1 Major factors influencing process efficiency and quality

On the next pages the three major factors found will be presented into detail.

6.2.1.1 Organizational Matters

The organizational matters found include cultural differences between functions, affecting the objectives but also the structure of the organization. This is mostly affecting the coordination between the functions, influence the communication and responsibility between the different roles. This is also discussed by Konijnendijk (1994) in terms of culture, objectives and structure, and St. John & Hall (1991) by control procedures and planning processes.

6.2.1.2 Customer Specification

The customer specification is often containing some uncertainty, leading to many changes since lack of input, wrong input or hard to disclose the important content since it can be so massive. This has also been seen in literature as typical for an ETO company by Berstrand & Muntslag (1993) and Konijnendijk (1993). Different functions needs to be coordinated in a certain manner in order to reduce the specification uncertainty, where the production capacity and commercial interest needs to match.

Missing information, wrong information, changed input, special requirements, not updated standards in specification are some common issues with the specification today. The specification uncertainty with never-ending information flow is a part of the operational nature of an ETO company, meaning that it should not be prohibited for customer to change or supplement the specification. However, the organization and processes must support and relate to this environment, since this is the nature of the business.

6.2.1.3 Process Management

Last factor influencing on process quality and efficiency is process management, especially in the front end activities, including quotation and hand over, where formal processes are missing. This is also the most important factor to improve, since it can maneuver and support the other two, this is also stated by Elgh (2012).

No formally defined checklists, reviews, KPIs, roles and responsibilities are today standardized globally in a process implemented cross factories. Having an organization where culture and objectives for involved functions are different, this needs to be managed by a process supporting this in order to over bridge the differences. The same can be seen with the uncertainty related to the specification, by having a process that help manage the customer relationship and where the most critical data or input from customer side is recognized, a lot of ambiguities could be eliminated.

By defining the Front end process, including quotation and hand over, much re-work could be hindered and later processes in the value chain would be more efficient and deliver higher quality. And by becoming more aware of how the capturing process affects the possibilities to win an order and build relationships, the satisfaction and perceived quality from customers would increase and the internal processes become more efficient.

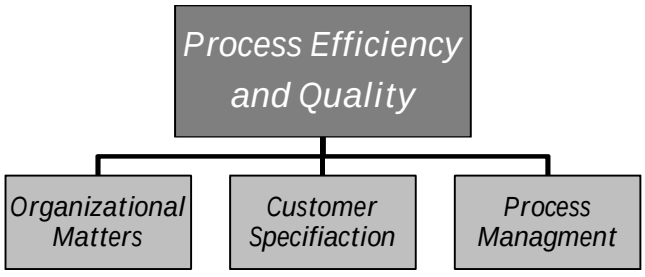


Figure 24 Major factors influencing process efficiency and quality

7 Recommendations to the ETO manufacturer

Following actions are recommended to be taken for each sub process in order to improve the efficiency and quality for the quotation and order delivery processes.

These sub-process with correlating recommendations are divided into two phases as seen in Figure 25, where the recommended initial focus should be put on the front end activities, including capturing-, quotation- and hand over processes. The reason for this is that the root causes for the problems occurring when designing or produce the product mainly has its origin here. Still before a new robust front end process is in place, the order delivery process and especially the design process needs to have quality checks to identify deviations leading to inefficiency and/or quality problems further in the process.

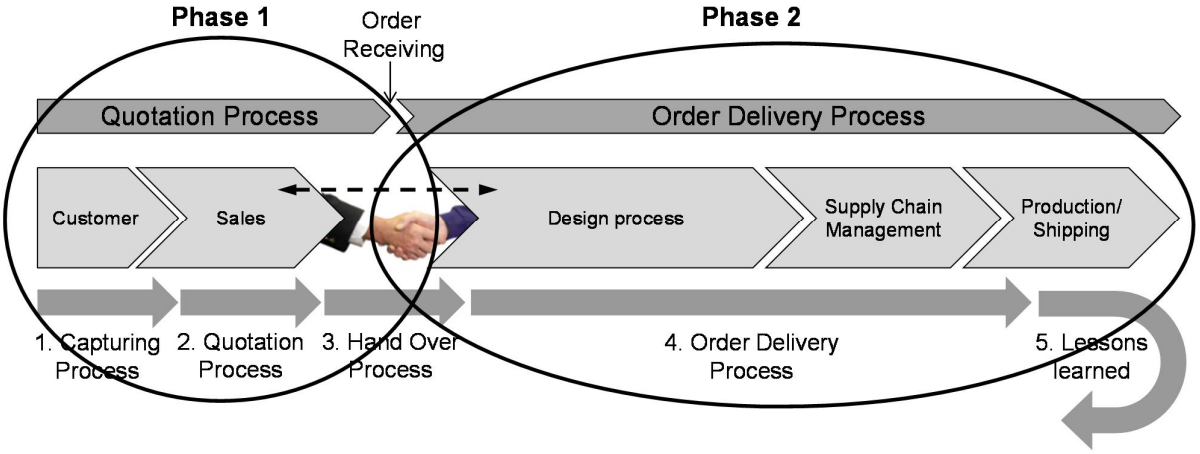


Figure 25 The recommendations is in the first phase to improve the quotation process and hand over process, and afterwards focus on the order delivery process, with updated gate model

7.1 Capturing process

Improvement to be done

On a strategically level the capturing process needs to be defined. Understand the market in that sense that future opportunities should be identified, customer contact must be established to know customers value and judging process and finally understand the competition and what they can offer. Knowing all these factors leads to better market understanding, where a better screening of orders can be done. This will then lead to a better resource use and better probability to make a design that the customer decides to order.

Recommended Actions

- Decide on a strategy how the capturing process should be defined
- Use peer reviews and capture team to see future opportunities
- Sales must identify tendering opportunities at an early stage
- Marketing/Sales must prioritize the projects, so engineering can plan their resources better

- Communicate and support customers in the creation of the specification, they might need something else than they want/ordered
- Make the customer understand what they pay for in terms of quality
- FES/Sales must be trained in value based selling and technical concerns

7.2 Quotation process

Improvement to be done

Define a formal quotation process including KPIs, responsibilities, checklists/reviews, needed input from customer and output delivered to design process for order design. Also a better screening of the RFQ needs to in place, this to prevent that resources are spent on orders with no or low probability to win. By defining this, the chance to design right product to right price to the customer increases which positively affects the order hit-rate. Also better margins can be reached if the quoted design as far as possible is consistent with the final design.

Recommended Actions

- Define a process that should be valid for the entire product range, include milestones and identify critical success factors
- Identify what checklists to be in use (today there exist many different)
- Structure the communication with customer, what input/data is needed for make a tender, template or guide of questions
- Structure all activities that needs to take place
- Define crucial KPIs related to quality and start to measure (for Sales)
- Set up a prioritization for designers, how to manage their time
- Integrate PM and designers already in tendering/quotation to build understanding for customer

7.3 Hand over process

Improvement to be done

Define the process with responsibilities for the hand over from quotation to order design. Identify and define all communication that needs to take place both internally and externally with customer. Integrating the customer more in communication at this stage would reduce much uncertainty related to the specification. Have a better screening of the specification before starting the project execution in order to not miss details or lack data is crucial.

Coordinate the order for all involved functions, also planning, production, Supply Chain Management and Logistics needs to be informed.

Recommended Actions

- Define hand over process by communication, roles and responsibilities, also including which documents that needs to be transferred from sales to factory
    - Set responsibilities for sales, project manager and engineers
- Technical support/engineering support to PM when meeting customer
- A clear specification screening is crucial, preferably translating the speciation into internal language will reduce much uncertainty

- Clarify the contract with customer in order to reduce extra costs for late changes from customer side
- Structure the kick off meeting
    - Responsibilities
    - Include customer for clarification
    - Cross functional, raise all questions at this point
    - Include NCRs for repeat design
    - Marketing/Sales must inform and communicate if special requirements

7.4 Order Delivery process

Improvement to be done

From existing documentation and best practices redefine the gate model with correlating milestones and checkpoints. Today's gate model is on a high level and needs more structure and details. Better prioritizations and continuous trainings needs also to be in place for support to the functions in the order delivery process.

Recommended Actions

- Redefine and update the process and gate model based on existing documentation and best practices found
    - Define milestones and responsibilities
    - Define checklists to be used and when design reviews/cross checking should be done
- How to store project data needs to be investigated, to reduce wrong revisions being used and ease future re-use
- Define KPIs for engineering, e.g. # of changes, # of revisions, leak of gates, late customer approval
- Investigate if the model should be adapted and customized to the complexity of each project

7.5 Lessons learned process

Improvement to be done

In a structured way with clear responsibility and ownership include and bring learning's from previous projects into gate model. Communication between functions and factories are important when working with continuous improvements, leading to better efficiency and quality output.

Actions

- Define in gate model when, how and with whom reviews should be held
    - Implement Cross functional meetings after delivery
    - Design reviews between engineering and production
- Define a process how learning's should be used for updates and audits
- How to include customers feedback
- Use of NCRs
- Margin slippage analysis, difference between quotation design and order design

8 Recommendations for further research

In this chapter some suggested research topics for further studies will be presented.

In general it have been hard to find literature, relevant papers, articles or books dealing with the coordination situation between customer, sales and manufacturing in an ETO company in detail. It has been even harder to find literatures that discuss marketing and sales influence on quality, and how to improve the situation. Based on the analysis done throughout the project some areas of future research areas have been identified.

How to deal with the capturing process including customer satisfaction
It is of importance to understand how a sales organization in an ETO company, producing complex and customize products can capture their market's need better. The global market is becoming more dynamic and uncertain, combined with the importance to have long term relationships to increase process efficiency and quality. This area is recommended to be investigated further.

How to capture customer satisfaction is an area that been highly researched in the area of Total Quality Management, presenting models like Kano model and Quality Function Deployment (QFD). It would be of interest to get more hands-on example of how this thinking could be used in the everyday contact with customer and not only for a one-time study.

Quotation for ETO business
Most literature found focusing on the quotation process for ETO companies today, either present the process assuming that all data needed for making the design, already is of good quality in the specification nor suggest to implement product configuration system, for making quotations to low cost and short time.

Still, how to adopt the quotation process when data and input is not of perfect quality is not well enough researched, and is an area that should be interesting to understand better.

Quotation correlation to quality and project efficiency
One interest area that should be more studied, is the correlation between quotation and quality delivered during project execution, dealing with the question of what KPIs can indicate this relationship. Also how the efficiency is improved by having a thorough quotation process.

How to manage the interface between customer-sales-factory
Many researchers state that it is important to have a close collaboration between functions, especially marketing/sales and manufacturing, still into more details how this could be managed with crucial checkpoints or milestones, responsibilities and communication flow is not defined.

9 Discussion and final reflections

When reflecting upon the results, some things could have been executed differently. The scope has a trade off in order to deliver useful result. By having a more narrow limitation, a deeper analysis with detailed solutions instead of high-level recommendations could have been the outcome. However, excluding parts of the value chain in order to reach this, increases the risk of not identify all correlations and links. Therefore, in this early stage, understand the situation in a broader sense was important to get an understanding to judge where to spend future resources to gain most result.

The purpose of the project is another area that should have been more questioned in the beginning. What was the expected deliverables and what trade-offs need to be made in order to get there. Even though the vision of the project never changed, there exist many ways to reach that, something I should have elaborated more upon.

Large amount of data was gathered and given to me during this project. In a structured way map connections and relationships in a complex environment as an engineer-to-order industry are, have been one of the hardest thing during the analysis. Activities are often dependent on each other and take place in parallel, and when you think you understand, new perspectives are presented. This made the project very dynamic, where it took off in one direction and landed in another, hopefully better.

Looking back at what learning's this project has contributed with last months, it is clear that it has enriched me in many different ways. From an academic point of view this journey, have offered me a great experience but also challenges with changing scope, focus and aim to strive for. Something that taught me the importance of spending time in the beginning of a process in order to understand what you want to achieve. Doing this in an appropriate way will support you during the entire project even though factors change meanwhile, you still have an idea of what you are striving for and why.

On a professional level this project have learned me enormously much, and contributed with experience that is impossible to gain from school. I met so many interesting and helpful persons that helped and supported me during this journey. Running a project by your own has certainly developed me. Sometimes it has been very challenging to manage a project on your own, not always understanding expectations and unspoken requirements that exist within an organization. But when taking all aspects in together, this has been learning for life.

For my personal development, meeting people from all over the world and being exposed for situations you never faced before have been one of the best schools ever. This have encouraged me to believe in my ideas and on the same time be responsive to others' contribution of opinions and knowledge.

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APPENDIX

Interviews

Business Unit OpX manager (2012, February 17). (E. Gustafsson, Interviewer)
Business Unit OpX-team, Operations (2012, February 23). (E. Gustafsson, Interviewer)
Local Information System (IS) manager #1 (2012, April 5). (E. Gustafsson, & J. Torvinen, Interviewers)
Business Unit OpX-team, Quality (2012, April 16). (E. Gustafsson, Interviewer)
Internal Lean Product Development manager (2012, April 17). (E. Gustafsson, & J. Torvinen, Interviewers)
Product group OpX manager, "Product range Y" (2012, April 19). (E. Gustafsson, Interviewer)
Front End Sales representative (2012, April 23). (E. Gustafsson, & J. Torvinen, Interviewers)
Product group OpX manager, "Product range X" (2012, April 24). (E. Gustafsson, & J. Torvinen, Interviewers)
Product group platform manager, "Product range X" (2012, April 27). (E. Gustafsson, Interviewer)
Project manager for internal opportunity identification and capturing project (2012, May 2). (E. Gustafsson, & J. Torvinen, Interviewers)
R&D manager, "Product range X" (2012, May 4). (E. Gustafsson, Interviewer)
Internal OpX specialist (2012, May 7). (E. Gustafsson, Interviewer)
Business Unit OpX manager for another product than the one presented in this thesis (2012, May 15). (E. Gustafsson, Interviewer)
R&D manager, "Product range Y" (2012, May 16). (E. Gustafsson, Interviewer)
Product group Marketing & Sales manager, "Product range Y" (2012, June 5). (E. Gustafsson, Interviewer)
Local Information System (IS) manager #2 (2012, June 6). (E. Gustafsson, & J. Torvinen, Interviewers)
Division OpX manager (2012, June 29). (E. Gustafsson, Interviewer)
Business Unit Information System (IS) manager (2012, July 6). (E. Gustafsson, Interviewer)
Business Unit R&D manager (2012, July 11). (E. Gustafsson, Interviewer)

Case study Interviews

External sample, 20 March 2012
Development Engineer. (2012, March 20). (E. Gustafsson, & J. Torvinen, Interviewers)
Design Manager. (2012, March 20). (E. Gustafsson, & J. Torvinen, Interviewers)

Internal sample 1, 21-22 March 2012
Marketing & Sales. (2012, March 21). (E. Gustafsson, & J. Torvinen, Interviewers)
Project Management. (2012, March 22). (E. Gustafsson, & J. Torvinen, Interviewers)
Engineering. (2012, March 21). (E. Gustafsson, & J. Torvinen, Interviewers)
Mechanical Engineering. (2012, March 22). (E. Gustafsson, & J. Torvinen, Interviewers)
Operations manager. (2012, March 22). (E. Gustafsson, & J. Torvinen, Interviewers)
Quality manager. (2012, March 22). (E. Gustafsson, & J. Torvinen, Interviewers)

Internal sample 2, 2-3 April 2012
Marketing & Sales. (2012, April 3). (E. Gustafsson, & J. Torvinen, Interviewers)
Sales (Quotation). (2012, April 2). (E. Gustafsson, & J. Torvinen, Interviewers)
Project Management. (2012, April 2). (E. Gustafsson, & J. Torvinen, Interviewers)
Engineering (Planning and Scheduling). (2012, April 3). (E. Gustafsson, & J. Torvinen, Interviewers)
Supply Chain Management. (2012, April 3). (E. Gustafsson, & J. Torvinen, Interviewers)
Operations Manager. (2012, April 3). (E. Gustafsson, & J. Torvinen, Interviewers)
Quality & After Sales. (2012, April 2). (E. Gustafsson, & J. Torvinen, Interviewers)

Internal sample 3, 21-22 May 2012
Sales manager and electrical tender designer. (2012, May 21). (E. Gustafsson, Interviewer)
Project Manager and mechanical designer. (2012, May 22). (E. Gustafsson, Interviewer)
Engineering Manager. (2012, May 21). E. Gustafsson, Interviewer)
Quality manager. (2012, May 22). (E. Gustafsson, Interviewer)
Operations manager. (2012, May 22). (E. Gustafsson, Interviewer)
Material/SCM manager. (2012, May 21). (E. Gustafsson, Interviewer)

Internal sample 4, 23-24 May 2012
Sales manager. (2012, May 24). (E. Gustafsson, Interviewer)
Project manager. (2012, May 24). (E. Gustafsson, Interviewer)
Planning. (2012, May 23). (E. Gustafsson, Interviewer)
Engineering manager and two designers. (2012, May 23). (E. Gustafsson, Interviewer)
Electrical designer, Mechanical designer and quality assurance from engineering. (2012, May 23). (E. Gustafsson, Interviewer)
Quality manager and quality assurance for engineering. (2012, May 24). (E. Gustafsson, Interviewer)
Purchasing and Supply Chain Manager. (2012, May 23). (E. Gustafsson, Interviewer)
Internal documentation and standards

Internal standards and documentation

Order Delivery process
Standard Production Processes, 2007-12-12
Standard Front End Processes for “product range X”, June 2009 (Draft)
Standard Front End Processes for “product range Y”, 2010-02-03 (Draft)
“Product range Y” Process and Document Management, 2012-02-13
“Product range Y”_Inputs

Project Management process
Work Instruction for Project Management, 2004-03-04
Project Management Framework, 2011-01-04
PM certification responsibilities
Internal presentation material, March 2004

Quality audits
Quality management audit process, 2007-12-13

Quality checkpoints and Quality cards
“Product range Y” Product Platform, Quality Inspection Cards Users’ Guide, 2010-07-30

Quotation process
Quotation Process for “Product range X & Y”, June 2009

Standards and platforms
Business Platforms and Standardization, 2012-01-27

Test failures summary
Test Failure Reporting and Handling, 2010-05-25
Test failures Status and Actions October 2011, 2011-10-13
Test room Failures 2011, 2012-01-11

Result from internal documentation

In this chapter an overall description of the processes based on internal documentation will be presented to understand the result better. In next chapter will the result from all five cases, including both the external and internal, be presented, reflecting the situation at different plants. Finally, the findings from the interviews held with key people will be presented.

The value chain

To gain a better understanding of the processes for this specific case, the quotation process and order delivery process, including the differences between quotation design and order design, will be introduced based on internal documentation.

The development process of the studied product is done in two main steps by two different processes, see Figure 26. The quotation process, see Figure 27, is when customer looking for tender proposals and makes a request for a quotation (RFQ). Based on this the factory comes back with a price based on the quotation design. Secondly, the order delivery process, see Figure 28, is when customer decides to make an order and the factory makes the final design.

Figure 26 Relationship between Quotation process and Order Delivery process

Quotation process: "The quotation process for this product range is defined as the activities that take place from receiving a request for quotation (RFQ) until notification by the customer of award or opportunity lost." (Standard Front End Processes for "product range X", June 2009 (Draft)).

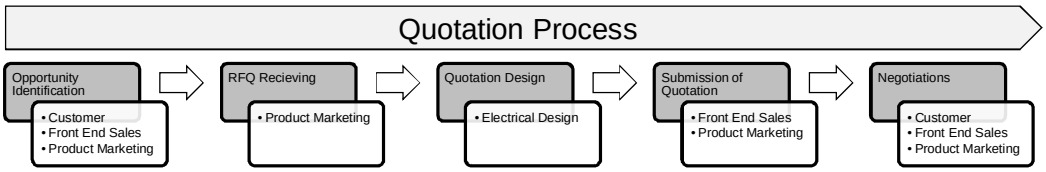


Figure 27 All steps in the quotation process and involved functions

Order Delivery Process: Includes the hand over, design process, supply chain, production and shipment activities. "The order-delivery process must be managed with support from a gate model with milestones. The milestones are the critical points in the process where certain actions should be taken and requirements fulfilled before the process can be continued. Milestones are instrumental in maintaining the efficient use of assets and resources (limiting re-work)" (Standard Production Processes, 2007-12-12).

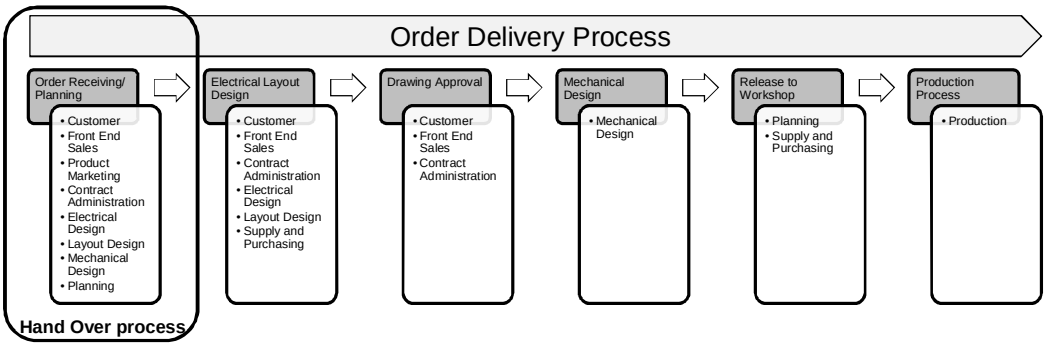


Figure 28 All steps in the order delivery process, where the hand over process is highlighted

Design Processes

Today's design process for the ETO product can be seen as two different phases taking part in both the quotation process and during the order delivery process when making the actual order design.

This is of importance to understand, since the design made in the quotation process will affect the quality of design made also in the order process. In Figure 29 the correlation between the two design phases can be seen.

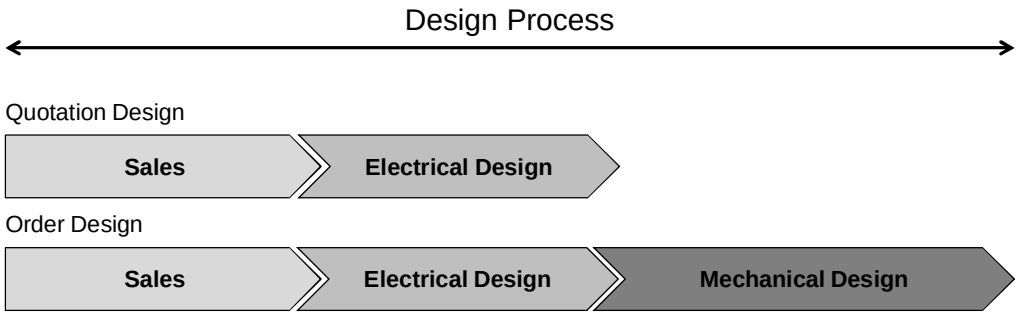


Figure 29 The design process consist of two parts, quotation design and order design

Quotation Design

This is the design based on customer's specification provided when the customer Request for quotation (RFQ). The customer specification can differ in the extent of information provided to the designers. The specification from the customer can be everything from a few lines in a mail to many hundreds of pages of attachments. All information is provided to the electrical designer making the tender design via the sales organization, often FES, who is responsible to judge if the input is sufficient.

The tender design is many times done under high time pressure and with elements of uncertainty. It is mostly consisting of electrical design, and in some rare cases also layout design can be provided to customer if the design is complex or the customer requests the factory to do so.

This design works as a base for making the technical cost calculation leading to the price suggestion to the customer. The calculated cost, combined with commercial cost calculations will then be the basis in the making of the order design, leading to

high importance to get these estimated costs as close to the reality as possible in order to get good margins, but also to provide an attractive offer to the customer.

Order Design

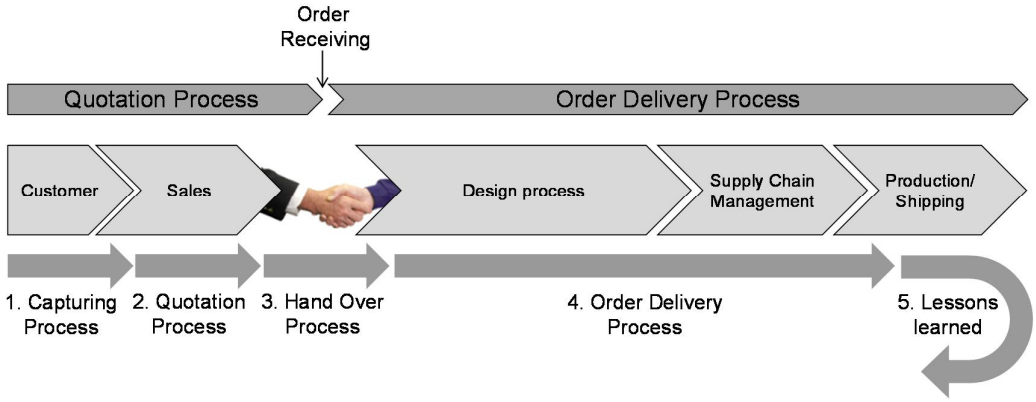
Order Design is the final design made after the factory has received the order confirmation from the customer. Today an average factory making this type of product makes order designs from approximately 10% of all quotations made.

This design is to some extent based on the calculations and design made during the quotation process. But since new input and requirements is often clarified or specified from customers' side at this stage, the design often needs to be revised from the quotation design. In addition to the already executed electrical design, the order design is complemented with layout design and mechanical design.

Gate model

The ETO manufacturer in this case study has a gate model implemented in their order delivery process with seven milestones or gates that aims to secure that all requirements are fulfilled to continue the process. Compared to the stage gate model presented in the theoretical framework, chapter 0, the gates in this gate model aims to clarify and secure necessary steps that needs to be taken and not kill projects. The reasons for this is that it is crucial to guarantee that all relevant input and steps is taken before continue the process. These milestones or gates covers the order deliver process all the way from when the factory receives an order, where the project is handed over from sales to project manager, to delivery and final wrap-up.

Factors influencing the process



Capturing process

- ”Produce what customer needs and not what they want”
- Order hit rate, ~10%
- Understand customer’s decision making process
- Not “Quote and hope”
- Much resources spent on quotation not leading to order
- Better margins if knowing customer judging process
- Opportunity to capture market shares

Quotation process

- No standardized defined Quotation process with responsibilities
- Lack of measurements and KPI in quotation process to see correlation to quality/(cost)
- Specification issues, misunderstand/not understand/unwritten expectations/special requirements
- Competence of designers important in quotation, but hard to attract experienced designer to make tendering
- Customer have low technical knowledge
- Many customer do not know themselves why the specification look like it does
- FES have low knowledge level about the product
  → Not able to ask the right questions to customers, judge/understand specification
- Low trust from designers side to FES
- FES not fitting the complexity of the product
- FES have different target than factory
- Sales do commitments and promise things to customer that is not communicated, or poorly communicated back to designers
- KPI for Sales, orders received and margins, not related to quality
- Hard for designers to understand specification and instructions due to bad language skills
- Exist no written template, goes back to personal skills and knowledge

- 90% of the tenders are re-done (Case 4)
- A normal tender have 3 revisions (Case 4)
- 30-40% of tendering based on assumptions (Case 5)
- Add high margins for basic tendering, this can vary 40-50% from real cost (Case 5)
- Quotation quality is one major issue today (FES person)
- ”30% of Engineers time should be spent on quotations” (Manager for an internal project focusing on better opportunity identification and capturing)
- Specification uncertainty leading to wrong costs and margins and reduce probability to get order (hit rate)

Hand over process

- No checklists or checkpoints in the handover between sales and design
- Responsibility and communication not clear
- No standardized input to design process
- Short time before kick-off meeting to go through material
- Everything is not clear after kick-off
- Consultancy makes it complicated to talk to end-customer
- Communication with customer must be proactive, not come afterwards and explain. Continuous communication
- Order handling is not clear, COPQ comes from poor communication between customer and factory
- Language issue in communication between factory and end-customer
- Too low technical knowledge of PM and Sales
- ~15% late changes from customer side (Case 3)
- KPI; number of changes during the project. Today ~4.25% of all orders are changed, 1.25 comes from engineering itself, 3% from customer →70% of all changes comes from customer (Case 4)
- 20-30% of total orders are not clear with main items when starting with order design (Case 5)
- 50% of all orders needs to be revised/updated (Case 4)
- Specification uncertainty
- 20-30% of orders have changes/re-work/additional work during process/test failures (Case 2)
- Incorrect drawings/miss in specification common causes for NCR in Engineering
- In more than 50% of the cases there are some missing or unclear information (Case 2)
- Unclear responsibility especially in the hand over process
- Order handling and Project management is not clear who is responsible for what
- ” In some regions, we don't have competent project managers which causes challenges”(interviewee)

Order Delivery process

Design process

- Time management, long response time from engineering to sales/customers/suppliers
- Not always wait for customer approval before start with next step
- Many revisions of drawings during customer approval
- Internal checklists not followed in design review
- ”Lack of information in Engineering is a major issue”
- 40% of orders is not keeping freezing point (Case 2)
- ~30% Changes after customer approval (Case 3)
- Engineering changes after customer approval for more than 30% of orders (Case 3)
- Many revisions of drawings during customer approval (domestic ~1 time, export ~5 times) (Case 5)

Gate model

- Different implemented gate models at different factories
- Today people take short cuts and leak gates
- Internal checklists, design reviews not followed
- Start production without approval in design process, since important to keep production slot
- No standardized use of checklists or design reviews

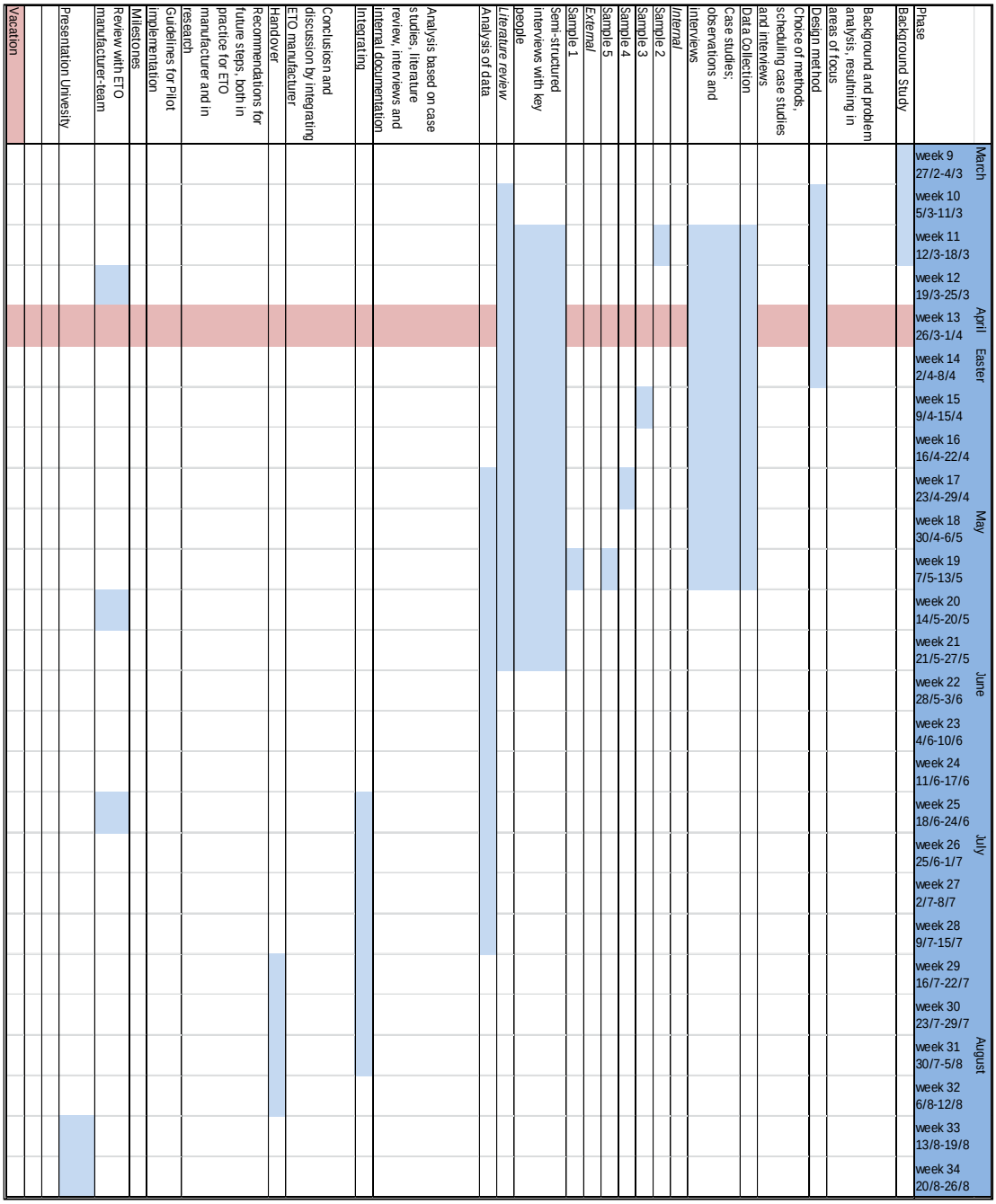
Production/Drawings

- Unclear drawings in production
- Wrong BOM when doing many revisions of drawings
- Internal and external design do not match
- Late changes affect purchasing/production, 60% of material is bought before customer approval
- Transport drawings not correct, leading to wrong shipments
- Design not corresponding with customer expectations
- Many drawings are changed in production (Case 5)
- Internal and external design do not match in production in 50% of the cases (Case 4)
- 20-30% of resources in production is spent on re-work, test failures (Case 2)

Lessons learned process

- FES do not provide data of why factory missed order
- NCR not taken into account for repeat design → doing same mistakes again
- Better learning loop with continuous improvements instead of firefighting
- Hard to find right data from last project design
- No feedback use from Service department
- Making same mistakes over again leading to high costs
- Few updates/audits of instructions or processes

Gantt Chart of the project execution



Major steps in the project execution

Agenda over the visits

		Quality in Engineering							
		Agenda for the visit							
		Day 1					Day 2		
						8:00	9:00	Discussion with Quality manager	
8:30	9:30	General presentation of factory				9:00	10:00	Discussion with Sales manager	
9:30	10:30	Project presentation	Emelie			10:00	11:00	Discussion with Project manager	
10:30	12:00	Discussion with Engineering manager				11:00	12:00	Discussion with Supply manager	
12:00	13:00	Lunch				12:00	13:00	Lunch	
13:00	14:00	Discussion with Engineering manager				13:00	14:00	Discussion with Operations manager	
14:00	15:00	Discussion with Electrical Engineer				14:00	15:00	Time buffer and preparations	
15:00	16:00	Discussion with Mechanical Engineer				15:00	16:00	Time buffer and preparations	
16:00	17:00	Office/Factory tour				16:00	17:00	Conclusions	Emelie