Master's degree thesis

LOG950 Logistics

Engineer-to-order and make-to-order production: a case study

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Preface

This master thesis represents the conclusion of our Master of Science degree at Molde University collage.

First we want to express our gratitude to National Oilwell Varco Molde for giving us the opportunity to write our thesis about their modularization project. We would also like to express a special thanks to Roar Lervik for helping us along the way, for his patience and cooperation.

Furthermore we would like to thank Heidi Hogset, our supervisor, for all the feedback and input during the process of writing this thesis.

In addition, we would like to thank our fellow students for the years spent together and the all the help they have given us throughout this time.

Last and perhaps the most important, we give our deepest gratitude to our families. For their help and support, not only with regards to the thesis but also the support we have received every day.

Abstract

This paper is exploring National Oilwell Varco Molde and their implementation of a new production strategy, which came as a response to new trends in the market. NOV Molde is originally an engineer-to-order company, who produce customized offshore cranes. The new strategy they now are looking into is make-to-order production, and this will meet the demand for less costly cranes.

The focus of this paper is to explore how these two different production strategies might affect each other when operating within the same organization. The initial purpose of the project was to reduce lead-time and cost. NOV's make-to-order project will give customers a new product that operates in an evolving market segment. However, this paper is exploring the possibilities if NOV can take advantages from both strategies.

To compare the differences between these two business models, we have found an average cost and lead-time for an ETO crane, to the forecasted cost and lead-time of an MTO crane. Furthermore, we visualize the differences in a modified VSM to give an overview of how big the actual differences are. To get a better insight to how the operation works, both with consideration to the ETO process and the new MTO project, we conducted several interview with key personnel at NOV.

After thoroughly analyzing the data, the paper discusses and concludes on the research problem. Based on the conclusions, five hypotheses are made for further research on the subject.

Key words: Engineer-to-order, Make-to-order, Value stream map, Supply chain

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List of abbreviations

SCM – Supply Chain Management

ETO – Engineer-To-Order

MTO – Make-To-Order

VSM – Value Stream Mapping

CSM – Current State Map

FSM – Future State Map

NOV – National Oilwell Varco (Molde)

RQ – Research Question

1.0 Introduction

1.1 National Oilwell Varco

National Oilwell Varco Inc. has since 1841 been dedicated to ensuring customers receive the highest quality oilfield products and services. They also provide supply chain services through its network of distribution services centers located near major drilling and production activity worldwide. National Oilwell Varco, Inc. is a worldwide leader in the design, manufacture and sale of equipment and components used in oil & gas drilling and production operations, the provision of oilfield services, and supply chain integration services to the upstream oil & gas industry.
The company has over 60,000 employees globally, where of 16,000 are within rig solutions. Moreover, the company has over 800 facilities worldwide in 60 countries, one of which is Norway. National Oilwell Varco has 3500 employees in Norway, and the headquarters lies in Kristiansand, with branch offices in Stavanger, Molde, Asker, Arendal, and subdivisions in Tønsberg and Trondheim. National Oilwell Varco Norway AS is a subsidiary company fully owned by NOV Inc. which has its headquarters in Houston, Texas.

The increase in product proliferation as a result of meeting ever increasing customer demand for variety is well documented (Forza and Salvador 2002). Customization has also been promoted as a source of competitive advantage. It is such companies' ability to customize their products, differentiating them according to the needs of particular customers, which gives them a competitive advantage (Amaro et al. 1999). In spite of these factors, most of the published research in operations and supply chain management (SCM) has neglected the needs of the engineer-to-order (ETO) sector (Hicks, McGovern, and Earl 2000). Though National Oilwell Varco Molde (NOV Molde) for many years has had success with this business model, recent trends in the market indicate that some measures must be made in order to compete on the same level as before as well as to expand the customer base. So what is a potential strategic move to meet and adapt to these fluctuations in the market? According to the market analysis done by NOV, the trend is indicating a need for standardization and modularization.

The term NOV uses to describe their business model is ETO. However, NOV is now exploring opportunities to adapt to the changes mentioned above. The company's goal is to take back lost market share, increase their sales volume and grow the organization. NOV Molde wants to achieve a reduction in lead time and cost by implementing a make-to-order (MTO) strategy. Therefore, the case study is about a project NOV has initiated as a response to the market changes and the master thesis will explore the development of this project. Consequently, this thesis will use NOV as its case study, and it will be an exploratory research. An exploratory research can be a good method used to illuminate ideas and develop a better understanding for our case study.

There are six different supply chain structures that can be defined to describe the number of possible operations. These are;

- Engineer-to-order (ETO)
- Buy-to-order (BTO)
- Make-to-order (MTO)
- Assemble-to-order (ATO)
- Ship-to-stock (STS).
- Make-to-stock (MTS)

This paper will focus on engineer-to-order and make-to-order production. There is very little if any research on the subject of companies combining two supply chains with both of these strategies, and it is this gap we want to fill. One of the key factors that separate the design management of the two supply chains is the position of the customer order decoupling point (Olhager 2012). On ETO supply chain the decoupling point is located at the design stage. This means that each customer order goes through the design phase of a product. In MTO the decoupling point is located at purchased goods in a supply center, which means the planning is customer order-driven.

Furthermore this master thesis will use Value Stream Mapping (VSM) as a tool to illustrate the current operations at NOV, and compare it to the forecasted operations of the MTO project. By drawing these two maps, we will visualize the improvements, or rather the changes, which NOV want to achieve from the MTO project. Since the ETO and MTO strategy are two different methods to operate by, the changes do not necessarily mean that

MTO is better with consideration to the market. But from an economical cost and lead time reduction point of view, these changes are improvements. The method will however be further explained in the theoretical framework section

1.2 Research problem

Research is defined by Bradley (2007, p. 7) as;

“(…) one of the most useful tools in business, any business. It is the way in which organizations find out what their customers and potential customers need, want and care about”.

The *research problem* is explained by Creswell (2007) as a statement to establish the central direction for the study. We will in this chapter present and elaborate on the research problem. Furthermore, this thesis will try to give an insight into how NOV initiated the MTO project, the existing business model as well as the MTO project itself.

Last summer one of the authors of this thesis had an internship at NOV, and he related several contacts within the company with the purpose of writing the master thesis. After the internship ended, the student contacted NOV in order to agree upon a subject from their operation which could be relevant for a master thesis. As it were, NOV was in the process of planning and launching a project to regain lost customers, expand their customer base, and make the business more flexible to changes in the market. After a meeting with a representative from the company, we reached an agreement with NOV to write a master thesis on the new project.

NOV’s project started as a response to the decline in demand, as well as a result of too small and unpredictable margins on their products. The objective of the project is to make the business more flexible, as well as adapt to the new conditions in the market. It was decided that the thesis would be about the implementation of the new project and how it would interact with ETO as their existing business model. In particular we were to consider and compare the lead-time and cost of their two business models in order to make an assessment on whether they could benefit each other, operate as two different supply chains or if one of the supply chain will be discarded.

As NOV produce customized cranes for each customer, the uncertainty in lead-time and costs are high, and there are several bottlenecks and pitfalls along the way. The biggest bottleneck is located in the design phase of a contract. If the time spent here exceeds what is planned, the rest of the processes stops and the delivery dates agreed upon are hard to make. Furthermore, it is not before the assembly and testing phase that most of the errors, missing parts or delays are discovered. When this happens late in the process it affects the lead-time, and there are higher costs tied to fixing the mistakes as fast as possible.

The project that this thesis examines, in addition to the already existing operation, aims to smooth out the bottlenecks mentioned above, as well as to regain the segment of the marked NOV is losing to their competitors. By introducing a crane based on modules, NOV want to reduce the hours spent designing the cranes, to be able to order in batches to get economies of scale, reduce risk, get standardized modules they know work and how to produce and get routines so that there are fewer mistakes which are only discovered in the later stages of the process. By producing a crane which satisfies these goals of improvements, NOV can manage to move the point in the process where they interact with the customer further downstream. This gives them a business model referred to as MTO.

MTO shares many of the characteristics of engineer-to-order; it is the preferred strategy for customized products or products with infrequent demand (Felea and Albastroiu 2012). Companies that follow this strategy produce a shippable product only with a customer order in hand. This will also help to keep the inventory level low while allowing for a wide range of product options (Felea and Albastroiu 2012).

With all the factors mentioned above in mind, we have produced a research problem which addresses several of the aspects of the two business strategies, as well as to explore an area with very little previous research or literature. The research problem is as follows:

How will NOVs standardized and modulated offshore cranes be different from customized cranes, with consideration to lead time and cost, and can these changes benefit the customized crane?

With this thesis the aim is to see how NOV’s two different business models work on an operational level and compare the processes from a supply chain management (SCM) point of view. To achieve this it is necessary to analyze the supply chain of both types of business models and see whether there are parts that can be adopted to strengthen the other supply chain. The thesis will also look into how the bottlenecks affect the whole operation and how they could be improved. In order to analyze these two supply chains we will use the lean manufacturing tool VSM.

After mapping out the two processes, we will analyze each part of the operation and discuss whether or not it is possible to apply knowledge from one to the other. To help us conclude on the research problem, we have made several research questions. These research questions, and how we ended up with these specific ones, will be addressed in the methodology section.

2.0 Methodology

In this chapter we start by introducing our research design and research quality to make a framework how we want to conduct this research. Then we formulate a few research questions to be answered, in order to conclude on our research problem. We then go on to explain what an exploratory research is since this is the method the thesis use. We end this chapter with our data collection methods.

2.1 Research design

A research design can be explained as the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions. (Yin 2009, p. 26).

Research design is a logical plan for getting from A to B, where A may be defined as the initial set of questions to be answered, and there are some set of conclusions about these questions (Yin 2009).

In other words, research design provides a framework for the collection and analysis of data. It represents a structure that guides the execution of a research method and the analysis of the subsequent data (Bryman and Bell 2011).

Bryman and Bell (2011) write about the nature of business research and that the practice of it does not exist in a bubble. The nature of business research is not isolated from the social sciences and the various intellectual allegiances that their practitioners hold. The diversity between the nature of management and business scholarship has led to considerable disagreement about how its research claims ought to be evaluated. The authors use a point cited from Gummesson (2000) who sees academic researchers and management consultants as “(…) groups of knowledge workers who each place a different emphasis on theory and practice.” Whereas the consultant contributes to practice, the scholar contributes to theory supported by fragments of practice. This master thesis will focus on the latter, since this is an exploratory research were the purpose is to explore an ongoing project at NOV and look into the events.

However, the decision to adopt quantitative or qualitative research will not be enough to undertake a piece of research. According to Bryman and Bell (2011), two other key decisions will have to be made. This, along with other tactical decisions about the way in which the research will be carried out and the data analyzed. These key decisions are the choice about *research design* and *research method*. They may seem much alike, but it is crucial to draw a distinction between them (Bryman and Bell 2011, p. 40).
According to Bryman and Bell (2011, pp. 40-41), whereas *research design* provides a framework for the collection and analysis of data, a *research method* is a technique for collecting data.

This thesis will conduct interviews, regular meetings, examine documents and do content analysis.

2.2 Research quality

To ensure the quality of a research, possibly the key quality control issue deals with the *validity* of a study and its findings (Yin 2010, p. 78)

“A valid study is one that has properly collected and interpreted its data, so that the conclusions accurately reflect and represent the real world (or laboratory) that was studied” (Yin 2010, p. 78).

According to Yin (2010) the validity issue is not limited to a study’s findings. The issue also concerns the description of a field event or of a participant’s views. In other words, these numerous items may consider the facts presented by a study, and all of them require validation.

As written in the research design section, a research design is supposed to represent a logical set of statements. Therefore it is possible to judge the quality of any given design according to certain logical tests (Yin 2003). There are four tests that have been commonly used to establish the quality of any empirical social research. The four are listed below and described to give the reader an understanding of why they can ensure the quality of the research.

- Construct validity
- Internal validity
- External validity
- Reliability

Construct validity can be problematic in case study research. The problems that may occur is that a case study investigator fails to develop a sufficiently operational set of measures and that "subjective" judgments are used to collect the data (Yin 2003). According to his book an investigator must be sure to cover two steps in order to meet the test of construct validity

1. Select the specific types of changes that are to be studied (and relate them to the original objectives of the study) and,
2. Demonstrate that the selected measures of these changes do indeed reflect the specific types of change that have been selected.

Internal validity is the second test that mainly relates to the issue of causality. Internal validity is concerned with the question of whether a conclusion that incorporates a causal relationship between two or more variables holds water (Bryman and Bell 2011, p. 42). If an investigator of a case study incorrectly concludes that there is a causal relationship between *x* and *y* without knowing that some third factor - *z* - may actually have caused *y*, the research design has failed to deal with some threat to internal validity (Yin 2003, p. 36).

It is important to note that this logic is inapplicable to this master thesis, due to the fact that it is not concerned with making clausal claims (Yin 2003).

Another point with the concern over internal validity, for case study research, is that it may be extended to the broader problem of making inferences.

"(…) a case study involves an inference every time an event cannot be directly observed" (Yin 2003, p. 36).

An investigator will infer or conclude that a particular event resulted from some earlier occurrence, based on interview and documentary evidence collected as a part of the case study. Yin (2003) proposes some questions that need to be answered in order to deal with the overall problem of making inferences and therefore the specific problem of internal validity.

- Is the inference correct?
- Have all the rival explanations and possibilities been considered?
- Is the evidence convergent?
- Does the evidence appear to be airtight?

Note that the specific tactics for achieving this may be difficult to identify, especially in doing case studies. Nevertheless there are other tactics of addressing internal validity, such as the analytic tactic of pattern matching, explanation building, rival explanations and triangulation.

External validity deals with the problem of knowing whether a study's findings can be generalized beyond the specific research context (Yin 2003, Bryman and Bell 2011). It is in this context that the issue of how people or organizations are selected to participate in research becomes crucial (Bryman and Bell 2011). The external validity problem has been a major barrier in doing case studies. One of the reasons is that critics typically state that single cases offer a poor basis for generalizing (Yin 2003).

Reliability is the final test, where the objective is to be sure that if a researcher went through the same procedure as described by an earlier researcher and conducted the same case study all over again, the later researcher should find the same findings and conclusions (Yin 2003, p. 37). Reliability is particularly at issue in connection with quantitative research, where the goal is to minimize the errors and biases in a study (Bryman and Bell 2011, Yin 2003).

2.3 Research questions

Research questions can be described as:

"…from the broad, general direction for the study, the researcher narrows the focus to specific questions to be answered" (Creswell 2013, p. 105).

According to Creswell (2013), the research questions assume two forms; a central question and associated sub questions.

This thesis narrows down the research problem into three research questions. The first one refers to the module aspect of the MTO project. These modules will in all likelihood be less costly, faster to produce and more predictable than any new, untested components made for an ETO crane. To analyze and see whether there are parts of the ETO supply chain that could benefit from operations in the MTO supply chain, would help to answer the main research problem of the thesis. To specify on the module-aspect of the project, the following question is asked:

- RQ1: Is it possible to apply modules from MTO in order to improve lead time and cost in the ETO?

In order to view the options the MTO project offers NOV, we direct a question towards the possibilities of a combination of the two strategies, rather than to operate with two different supply chains. This question helps to determine whether or not the advantages discovered in the MTO project can help the company merge the two strategies into one supply chain, which optimizes the market potential. If not merge into one supply chain, see if the advantages of one strategy can be applied to the other to. This way, NOV can offer the customer the best alternative with regards to cost and value, and thus, make NOV more attractive in the market.

- RQ2: With consideration to RQ1, can a crane made with the use of modules as well as customization be offered to the customer?

For the third research question, the focus is on how NOV approaches the bottlenecks of the supply chain. We want to see if there are any changes in the bottlenecks that will reduce the risk, lead-time or cost in the MTO supply chain, which then again could apply to the ETO supply chain. The research question was included due to the fact that by eliminating or making a bottleneck more efficient, the whole supply chain would be improved.

According to Goldratt (1990, p. 123) *"The strength of a chain is as strong as its weakest link",* and small changes in one part of the supply chain can cause massive changes elsewhere (Emmett 2008).

Therefore, uncertainty exists and NOV needs to have countermeasures. This means identifying where the weak parts are and where the bottlenecks are in a supply chain (Emmett 2008).
Though there will always be a bottleneck, it is necessary to make it as insignificant as possible. This way it is easier to cope with it in an earlier stage, so it does not affect the lead time and costs at the end. Because of the changes made about the bottleneck in the ETO supply chain to the MTO supply chain, the thesis addresses this as one of the potential main sources for cost and lead-time reduction. So it is relevant with regards to the research problem, to see if the changes can be applied and potentially benefit the ETO supply chain as well. The third RQ is as follows:

- RQ3: Can acquirements about the bottleneck in the MTO supply chain be applied in the ETO supply chain, in order to move it upstream?

The goal with these three research questions is, as mentioned, to specify different aspects of the research problem to easier draw a conclusion. Also, it is a good way to help enlighten vital points about the research problem on a more detailed level.

2.4 Exploratory research

"Exploratory research is typically conducted in the interest of 'getting to know' or increasing our understanding of a new or little researched setting, group, or phenomenon" (Ruane 2005, p. 12)

An exploratory study is therefore a valuable means to ask open questions to discover what is happening and gain insights about a topic of interest (Saunders et al. 2012, p. 171).

According to Ruane (2005), exploratory research often produces *qualitative data*. This can be evidence presented in words, pictures, or some other narrative form that best captures the research subject's genuine experiences and understanding.
However, it is important to recognize that the term exploratory research should not be solely associated with qualitative research.

The term “qualitative” is sometimes used quite loosely. Therefore it can be helpful to find out what is not a qualitative research.

An article written by Fitzpatrick and Boulton (1994), discusses the qualitative methods for assessing health care. The article state that research based on a small number of respondents should not be considered qualitative just because the sample size is too small in order to be statistically representative of the population. Moreover, a study is not qualitative because it is based on answers to a questionnaire about subjective matters nor because data are collected by personal interview. If such data are to be used, it can be a quantitative study if the data are analyzed and reported largely in terms of frequencies and proportions of respondents expressing particular views (Fitzpatrick and Boulton 1994, p. 107).

“Qualitative research depends upon not numerical but conceptual analysis and presentation” (Fitzpatrick and Boulton 1994, p. 107).

Another description or rather characterization of the term is:

“Qualitative research is best characterized as a family of approaches whose goal is understanding the lived experience of persons who share time, space and culture” (Frankel and Devers 2000, p. 113).

In other words, qualitative research can be characterized in such a way that designs are flexible rather than fixed (Robson 2002). A flexible design may well make some use of methods which results in data in the form of numbers (quantitative) as well as in the form of words (Robson 2002). According to Saunders et al. (2012), exploratory research has the advantage that it is flexible and adaptable to change.

“If you are conducting exploratory research you must be willing to change your direction as a result of new data that appear and new insights that occur to you” (Saunders, Lewis, and Thornhill 2012, p. 171).

Thus, this master thesis will use a flexible design that make some use of methods in the form of quantitative data as well as in the form of words.

There are a number of ways to conduct exploratory research. To do an exploratory research can include a search of the literature; interviewing ‘experts’ in the subject;

conducting in-depth individual interviews or conducting focus group interviews (Saunders, Lewis, and Thornhill 2012, p. 171)

As written earlier, this thesis will conduct interviews and have regular meetings, where we have, through the contact person at NOV, selected which people to interview. There are mainly two reasons for this: (1) Exploratory research usually involves only a small group of people, and (2) these people are almost never randomly selected to participate; the selected respondents that will be interviewed are 'experts' in the subject. The respondents have different responsibilities at different operations related to the ETO cranes and modularized cranes.

We will use a *"semi-structured interview"* in this research. A semi-structured interview is a "verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions." (Longhurst 2003, p. 103).
A semi-structured interview has predetermined questions, but the order can be modified based upon the interviewer's perception of what seems most appropriate Robson (2002). There is also a possibility to give explanations, remove some questions or include additional ones if necessary.
The interviews will be held in English and in Norwegian due to the fact that some respondents do not have Norwegian as their first language.

Through exploratory research, we will try to produce hypotheses in regards to the topic at hand rather than any final answers or decisions.

2.5 Data collection

For this case study there will be two different types of data; primary and secondary data. The primary data is collected by the researchers and the secondary data will mainly be from scientific papers, books and web pages.

2.5.1 Primary data

"Primary data is information collected for a current research problem or opportunity" (Hair et al. 2010, p. 2311).
In other words, primary data is used to describe information that is collected for a specific purpose. Primary data can be seen as more reliable than secondary data, because secondary data is 'old' primary data (Bradley 2007).

If the information is unavailable or has not yet been gathered, the researcher will have to gather it him or herself.

"One of the most challenging tasks for the researcher is collecting original information from the marketplace"(Bradley 2007, p. 112).

There are many different methods to capture data and gain access to it from the respondents. Primary data can be collected through field research, content analysis, surveys, interviews and observations.
To convey justifiable primary data from the field for this thesis, we wish to do interviews, meetings, and analysis of existing quantitative data.

2.5.2 Secondary data

"Secondary data in research are data which have not been collected with a specific research purpose" (Sørensen et al. 1996, p. 435)

As mentioned previously, primary data can be more reliable than secondary data since it is more specific and relevant to the product or service.
However, secondary data should not be given less emphasis when doing a research. According to Bradley (2007), secondary data has various uses: it may answer research questions; it may also help to refine objectives, it may help to design primary research; it can assist in sampling; and it can help to supply pre-codes for questionnaires.

The advantage lies in the costs tied to gathering the data and that the data already exist. Since the data is already there, it is likely to be less expensive than to collect information first-hand. Moreover, secondary data can be effective due to the size of the sample, representativeness and it is often comparable (Bradley 2007).

The disadvantage can be the lack of control for the researched and that the data sometimes can be hard, or even impossible to validate (Bradley 2007).

This thesis will follow the design of a case study. However the research is looking into a problem that has not previously been explored. Or if it has, we are unaware of it.

3.0 Theoretical framework / Literature review

This chapter presents the different theories and literature we apply in this thesis. Whereas some of them are used to as a framework for analysis and discussion, others are explained to support our conclusions.

3.1 Supply chain management

In the 1990's the situation for most organizations, especially businesses, was a period of rapid change. The rate of change did not slow down and is actually increasing in the twenty-first century (Coyle et al. 2008).
The forces of change required organizations to be able to transform themselves to survive in the intensely competitive global environment (Coyle et al. 2008).

And it was during this period an increased focus on the SCM emerged, and organizations started to apply it to improve the operations.
There can be found a great deal of confusion regarding what SCM actually involves. According to Lambert (2008), many people that use the term *supply chain management* treat it as a synonym for logistics or as logistics that include customers and suppliers. The author goes on by saying that others view SCM as the new name for purchasing or operations.

Due to the fact of the confusion regarding SCM, there will also be different definitions. According to Coyle et al. (2008, p. 17), a growing number of terms are being utilized by individuals and organizations that are presented as being more appropriate and/or advanced than supply chain management. One of the reasons may be that some individuals view SCM to be narrowly focused or focused upon supplies and materials, not demand for finished products (Coyle et al. 2008).
Emmett (2008, p. 1) view the term Supply Chain as the:

"(...) the process, which integrates, coordinates and controls the movement of goods, materials and information from a supplier through a series of customers to the final consumer."

According to Christopher (2005), the focus of SCM is on co-operation and trust and the recognition that, properly managed, the whole can be greater than the sum of its parts. Consequently, the definition adopted in his book on SCM is:

"The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole" (Christopher 2005, p. 5).

From this definition the main focus on SCM is upon the management of relationships in order to achieve a more profitable outcome for all parties in the chain.

However, the term "supply chain management" has been widely used, and one can argue that it should instead be termed "demand chain management" Christopher (2005), due to the fact that the chain should be driven by the market and not the suppliers. Moreover, the term "chain" should be replaced by "network" since there will normally be multiple suppliers and, suppliers to suppliers as well as multiple customers and customer's customers to be included in the total system (Christopher 2005).

This paper chose to use the definition from The Global Supply Chain Forum. This is a group "of non-competing firms and a team of academic researchers", that try to improve the theory and practice of SCM. Their definition goes as follows:

"Supply chain management is the integration of key business processes from end-user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert 2008, p. 2).

In other words, SCM deals with business process excellence and represents a new way of managing the business and relationships with other members of the supply chain (Lambert 2008, p. 2). The author also states that SCM is about relationship management. A supply chain is managed, link-by-link, relationship-by-relationship, and the organizations that manage these relationships best will win.

3.2 Vertical integration

When designing a supply chain, strategic concentration is an important issue for manufacturing companies. The definition of SCM brought by Christopher (2005), shows the importance of managing the upstream and downstream relationship with suppliers and customers. To effectively manage a supply chain includes thinking creatively about how to "integrate and perform logistics and manufacturing activities" (Pagh and Cooper 1998, p. 13).

"Vertical integration" is well established as a foundational concept of strategic management (Stonebraker and Liao 2006, p. 36). Vertical integration is the degree to which a firm owns its upstream suppliers and its downstream buyers. When firms integrate upstream, economists call this backward integration; when they integrate downstream, they call it forward integration (Harrigan 1985, p. 399).
According to Guan and Rehme (2012), as a corporate strategy and a supply chain governance strategy, vertical integration relates to organizational economics and strategic supply chain management.

According to Langlois and Robertson (1989), the theory about vertical integration has been present in economic literature at least since Adam Smith's statement that the division of labor is limited by the extent of the market. This approach was the base for George Stigler, who developed the theory that production of new products is more likely to be vertically integrated (Næss and Haneczko 2013, p. 40). Vertical integration can be defined as:

"A variety of decisions concerning whether corporations, through their business units, should provide certain goods or services in-house or purchase them from outsiders instead" (Harrigan 1985, p. 397)

Vertical integration is a way of increasing a firm's value-added margins for a particular chain of processing from ultraraw materials to ultimate consumers (Harrigan 1985).

Vertical integration has, according to Guan and Rehme (2012), traditionally been inspired by altering industry structure and minimizing cost. However, the current popularity of vertical integration seems inspired by something more than just these two explanations. Mahoney (1992, p. 560) argues that the driving forces for vertical integration in strategic and economic theories can be classified into four categories:

1. Transaction cost considerations
2. Strategic considerations
3. Output and/or input price advantages and
4. Uncertainties in cost and/or price.

Harrigan (1985) suggests that firms should adjust the dimensions of their vertical integration appropriate to competitive or corporate needs. Below is a brief explanation of the four dimensions of integration; *stages of integration, breadth of integration, degree of integration, and form of integration* (Harrigan 1985, Stonebraker and Liao 2006).

Stages refer to the “number of steps in the chain of processing which a firm engages in - from ultraraw materials to the final consumer –“ (Harrigan 1985, p. 400). *Breadth of integration* refers to “the number of activities firms perform in-house at any particular level of the vertical chain” (Harrigan 1985, p. 401) *Degree* is the percent of total production exchanged with sister units (Stonebraker and Liao 2006).
The final dimension of integration, form, means ownership or quasi-ownership of the integrative mechanism of control. It is not necessarily a must to own a business unit and control it in order to enjoy the benefits of vertical relationships (Harrigan 1985).

3.3 Engineer-to-order

Companies that use engineer-to-order as their strategy have products manufactured to meet a specific customer’s needs. These products require a unique engineering design or significant customization (Amaro, Hendry, and Kingsman 1999). Each customer order will therefore result in a unique set of part numbers, bill of materials and routing.

Manufacturing companies differ in the way they meet their demand. While some deliver products to their clients from a stock of finished goods, others manufacture only in response to customers’ orders (Amaro, Hendry, and Kingsman 1999). In general, customized products, whatever the degree of customization, can only be made or at least finished to order (Amaro, Hendry, and Kingsman 1999).
However, the level of product customization to offer has direct implications on the delivery lead-time the company can provide (Amaro, Hendry, and Kingsman 1999). The greater the degree of customization the longer the delivery lead-time, since more activities need to be performed after receiving the order (Amaro, Hendry, and Kingsman 1999).

Companies in all sectors are trying to find ways to reduce costs, shorten product development time and manage risk (Hicks et al. 2000). Furthermore, the authors state that the transactions between companies in supply chains are characterized by adding value up through the chain and costs down the chain.

The increase in product variety as a result of meeting ever increasing customer demand for variety is well documented (Forza and Salvador 2002). Customization has also been promoted as a competitive advantage. It is such companies’ ability to customize their products, differentiating them according to the needs of particular customers, which gives them a competitive advantage (Amaro, Hendry, and Kingsman 1999). In spite of these factors, there seems to be limited research into SCM in the ETO sector.

Rahim et al (2003) describes the use of case study research techniques in exploring the use of new product development frameworks for ETO companies. They define an ETO product as a product that is manufactured to specific customer order and to customer specification. New product development in ETO can involve the customer, consultants, contractors and suppliers heavily during parts of the process.

3.4 Make-to-order

MTO, which shares many of the characteristics of ETO, is the preferred strategy for customized products or products with infrequent demand (Felea and Albastroiu 2012). Companies that follow this strategy produce a shippable product only with a customer order in hand. This will also help to keep the inventory level low while allowing for a wide range of product options (Felea and Albastroiu 2012).

According to Morikawa, Takahashi, and Hirotani (2014) MTO manufacturing system suits a demand with high uncertainty, and in a market where the need for customization is represented. Furthermore, by having order-specific operation on several levels, the final product can be customized a great deal while at the same time use practically the same raw materials. In their article, they argue that an option to shorten lead-time when applying the MTO business model is to start production upstream the supply chain before orders are confirmed. The semi-finished goods are then held on stock until an order matches the description.

One article which contradicts the premature production is Zhang et al. (2013). The authors state that a MTO company should only start production after demand is known, and that each item is delivered directly to the end customer. Furthermore, they argue that the MTO approach is best fit for mass customization, where the customer's specific needs are the focus. Lee and Fu (2014) supports this methodology and argues that it is infeasible to build up any sort of inventory on key items. The production must be initiated immediately to meet each unique customer demand.

3.5 Value stream mapping

Value stream mapping is a lean production tool which is used to get an overview of the supply chain in order to identify the different parts of the process that is value-adding and also detect the non-value adding processes. (Rahani and al-Ashraf 2012, Abdulmalek and Rajgopal 2007). After organizing and mapping out the operations, it is easier to locate where changes must be made and to decide upon what kind of methods to use in order to improve the "bottlenecks". There are several tools or theories that can be applied to reduce lead-time and cost. Some theories can be Just-in-Time, Total Quality Management, 5S (Sort, Set in order, Shine, Standardize and Sustain), and postponement. These tools can be used to improve the waste discovered in the Value stream map (VSM) overview. The mapping of the operations is referred to as the current state map (CSM), whereas the desired scenario is referred to as the future state map (FSM). It is in this map the improvements are highlighted and you have visualized the changes that are to be applied (Abdulmalek and Rajgopal 2007, Rahani and al-Ashraf 2012). Both Rahani and al-Ashraf (2012) and Abdulmalek and Rajgopal (2007), divides the VSM into two parts, the CSM and the FSM.

To explain how this paper will apply the VMS tool, it refers to the method described in Keyte and Locher (2004). These authors elaborate on how to build the current state- and future state map. As a frame of the process we use the four steps illustrated in Figure 3-1.

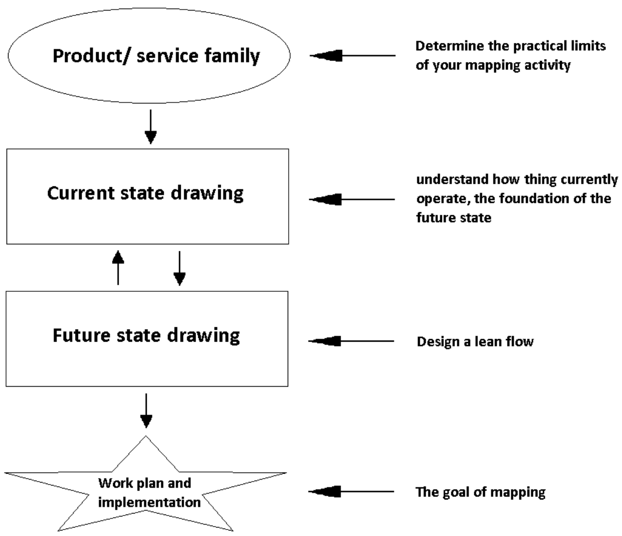


Figure 3-1 VSM process (Keyte and Locher 2004, p. 7)

3.5.1 Product Family Design and Product Platform Design

“The more a company can deliver customized goods on a mass basis relative to their competition, the greater is their competitive advantage” (Davis 1987, pp. 17-18).

In other words, companies that can offer customized goods at minimal extra cost have a competitive advantage over companies that do not.
The main drivers for this type of approach will be listed below. They are taken from a master thesis by Simpson (1998, p. 10):

- Simplify the product offering and reduce variety by
- standardizing components so as to
- reduce manufacturing costs and inventory costs and
- reduce manufacturing variability (i.e., the variety of parts that are produced in a given manufacturing facility) and thereby
- improve the quality and customer satisfaction.

The product family represents the work and a transaction the VSM is going to include and looks further into.

3.5.2 Current state map

After the product/ service family is decided, the drawing of the CSM should begin. The CSM does not provide any solutions or opportunities for the company; it only illustrates the different processes that should be looked into. The purpose of the map is to gather information on the processes and visualize them for the reader. Keyte and Locher (2004, p. 23) describe a six-step process to complete the CSM. These six steps are:

1. Documentation the customer’s information and needs.
2. Identifying the main processes
3. Selecting the process metrics
4. Perform a value stream walk-through
5. Establish how each process prioritizes work.
6. Calculating system summary metrics

Documenting the customer's information and needs

What does the market/customer want? What creates value for the customer and what requirements does the market demand?

Identifying the main processes

In this part the creator of the map identifies the main processes for the company and makes "boxes" for each one of them. The reason for this is to see where in the total process they are as well as to get an overview of which operations are to be addressed. It is important not to include a lot of unnecessary "boxes" and all of them should be relevant in either the CSM, or the Future State Map.

Selecting the process metrics

Selecting metrics is an important part of the VSM. Some of the different process metrics mentioned in Keyte and Locher (2004, p. 25) are:

- Time (process time, lead time and value-added time)
- Typical batch sizes or practices
- Demand rate
- Percentage complete and accurate
- Reliability
- Number of people
- Inventory

Perform a value stream walk-through

This step is highlighted as the main event for creating the CSM. The creator should to any extent try to do a "walkthrough" of the value stream from start to end. By observing each process the creator is enabled to identify what data and information is needed.

Establish how each process prioritizes work.

This step emphasizes how the work is prioritized. In this case this step is less relevant, but from a theoretical view, the creator of the map should look at how each process from each step prioritizes the work. Examples on ways to prioritize are first-in first-out, alphabetical, due date or size.

Calculating system summary metrics

In the final step, the metrics are summarized to get a total for the entire value stream. It is common that time, such as lead-time, is represented as a line at the bottom of the map. Furthermore, the quality and cost metrics are summarized and represent the total "value" of the whole operation.

3.5.3 Future state map

The goal with the future state map is to focus on the direction in which the company wants to be heading. It is the potential new design for the value stream and it is intended for identifying changes and improvements. After finishing the FSM, it should show an ideal, though an achievable future state. To get to this state, the company must prepare a work plan which explains how the goals are to be reached.

3.5.4 Work plan and implementations / changes

The work plan should include a description of the required changes which is needed in order to realize the FSM. These changes are often referred to as "kaizens". Kaizen is derived from Japanese, and is a term for emphasizing "continuous incremental improvements"; to achieve the goal of creating more value and to strive for perfection (Keyte and Locher 2004, p. 8). When developing the work plan, the changes that are to be implemented should be elaborated on and explained so that they are understandable for the external reader. This way, the implementation should go more smoothly and everyone who is incorporated in the process understands what is to be done.

3.6 Mass customization, modular product design and postponement

According to Jiao et al. (2007), manufacturing companies have been given much attention towards mass customization. Mass customization aims to satisfy individual customer needs by introducing product proliferation while taking advantage of mass production strategy. Manufacturers have been trying to expand their product lines and to focus on differentiation of their product offerings, because this may stimulate sales and generate additional revenue.

The key to mass-customizing effectively is postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network (Feitzinger and Lee 1996, p. 116).

Companies need to reconsider and integrate the designs of their products, the processes used to make and deliver such products, and the configuration of the entire supply network. If done correctly, companies can operate at maximum efficiency and quickly meet customers' orders with a minimum amount of inventory. The products can become more attractive by these methods, but when variety keeps increasing, they should be aware of the *law of diminishing returns*, which suggests that the benefit does not last long (Jiao, Simpson, and Siddique 2007). According to Farrell and Simpson (2003), there are some companies that find it challenging to maintain commonality and economies of scale in products with strict customer design requirements that may vary greatly from project-to-project. These strict and varied requirements can result in high manufacturing cost, involve small production runs, and require long delivery times. Nevertheless, there are three organizational-design principles that together can form the basis of an effective mass-customization program (Feitzinger and Lee 1996, p. 117).

- The design of a product should consist of independent modules that can be assembled into different forms of the product easily and inexpensively.
- Manufacturing processes should be designed in such a way that they also consist of independent modules that can be moved or rearranged easily to support different distribution-network designs.
- The supply network should be designed to provide two capabilities. First, it must be able to supply the basic product to the facilities performing the customization in a cost-effective manner. Second, it must also have the flexibility and the responsiveness to take individual customers' orders and deliver the finished, customized goods quickly.

The modular product design avoids complexity, while allowing for customization and a rapid and efficient final assembly. Storing only generic modules avoids the inventory risks arising from volume and variety risks (Van Hoek 2001, p. 163). Furthermore, this approach avoids complexity in operations, and as a final outcome, the customer can have a customized car with just a three-week lead time. Companies can also avoid building up inventories of finished goods in anticipation of future orders. The transportation aspect will also perform better since transportation between warehouses and factories can be avoided by shipping products directly to the customer instead of keeping them in stock. Kisperska-Moron and Swierczek (2011) address the issues of manufacturing postponement as

opposed to the logistics postponement. The manufacturing postponement could be interpreted as form postponement, whereas the logistics postponement basically denotes time and place postponement, cited from (Bowersox et al. 1996).
There can be found specific combination of all these types of postponement, and as a result of this, a manufacturing company can apply full or partial postponement strategies understood as; cited by (van Hoek 1997) from (Kisperska-Moron and Swierczek 2011)

- ETO including also pre-production stages, which could be considered as the full postponement,
- MTO related to the manufacturing process itself, which may be called the productions postponement,
- ATO (Assemble to order) narrowed only to certain final stages of production process addressed as an assembly postponement.

The concept of postponement has a long history in the academic literature and also of practical application. Researcher had previously understood postponement mainly as a strategy that changes the differentiation of goods according to their firm, and identity and an inventory location to as late a time as possible (Kisperska-Moron and Swierczek 2011, p. 193). However, according to Van Hoek (2001, p. 161), postponement is an organizational concept whereby some of the activities in the supply chain are not performed until customer orders are received. Companies can then finalize the output in accordance with customer preferences and even customize their products. MCC, a DaimlerChrysler car company, can illustrate this. MCC assembles cars to order and allows customers to specify the car specs in discussion with the sales person, also known as prosuming (Van Hoek 2001). Whereas car modules can still be produced in a flow shop environment, cars are assembled as batches of one.

3.7 Customer order decoupling point

“The CODP is traditionally defined as the point in the value chain for a product, where the product is linked to a specific customer order.” (Olhager 2012, p. 38)

Production strategies such as make-to-stock, assemble-to-order, make-to-order and engineer-to-order all relate to different positions of the CODP (Olhager 2012). Therefore the CODP divides the operations stages that are forecast-driven from those that are customer order-driven The author goes on to state that the bottleneck of a supply chain is often located in the CODP (Olhager 2012).

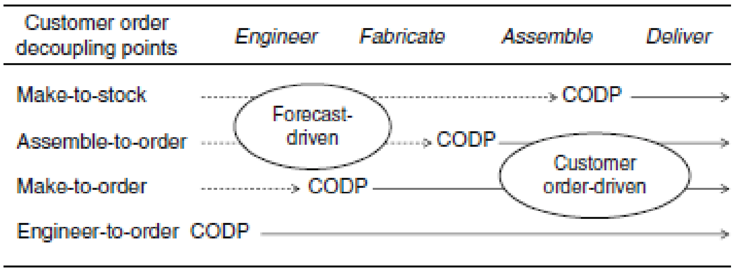


Figure 3-2 CODP (Olhager 2012, p. 38)

Due to the increase in competition, customer requirements for short lead-times in combination with customizations requires further integration of processes involving both engineering and production activities (Wikner and Rudberg 2005).

When formulating an operations strategy, it is important to have an understanding of what customer wants and their implications for manufacturing enterprises. If the customer value low cost products, the strategy should have an objective to obtain cost efficient production (Wikner and Rudberg 2005). However, in the 1970s and 1980s quality was introduced as a new differentiator, which had an important impact on how customers valued the products and consequently removed cost as the key differentiator.

Nevertheless, little by little producers figured out how to manage the quality aspects and emphasis is now shifting towards competition in terms of *time* and *customization* (Wikner and Rudberg 2005).

3.8 Bottleneck

The bottleneck is the *“part of a supply chain that limits throughput because it has the smallest individual capacity”* (Donaldson 2001).

A supply chain in its self does not have a constant capacity along its length, but each operation has a different capacity. If the supply chain is well designed the variation in capacity is small and the supply chain is said to be ‘balanced’ (Donaldson 2001). The author goes on to say that however much the capacity may vary there must be some point that limits the overall throughput of the chain, which forms the bottleneck. Furthermore, according to Donaldson (2001), the bottleneck creates an unbalanced chain, where the overall capacity of a supply chain is limited. The more unbalanced a chain is the more unused capacity it has away from the bottleneck.

3.9 SWOT-analysis

The SWOT-analysis is a structures approach to evaluate the current position the company holds in the market. SWOT is an acronym for strength, weaknesses, opportunities and threats. The strength and weaknesses are internal, while the opportunities and threats are external. Jobber (2004) argues that one should only include the strength and weaknesses which represent a value to the customer. The external factors, the opportunities and threats, should review the trends or anticipated developments in the market.

The next phase in the SWOT-analysis is to brainstorm and enlighten all factors for the four steps. After finishing this, the process of exploiting the strength and opportunities, as well as to find countermeasures to the weaknesses and threats can start. A direction can then be to see if it is possible to convert the weaknesses into strength, and the threats into opportunities. Jobber (2004) referrers to this strategy as the "conversion strategy" and recommend it as a measure when exploring new markets.

The figure below is an illustration of how a SWOT can be used in a company. The project manager at NOV Molde showed some of the strengths, weaknesses, opportunities and threats from the market analysis.

Figure 3-3 SWOT-analysis (Aitkenhead 2013)

3.10 BCG-Matrix

Boston consulting group (BCG) developed a tool to analyze growth and market share, often referred to as the BCG-matrix. The purpose is to be able to classify different business segments and decide whether it is "yesterday's products" or "tomorrow's livelihood" (Kotler et al. 2005, p. 66). The figure below illustrates the BCG matrix, and an explanation will be given for each square. The figure is inspired by Kotler et al. (2005), and is self-made by the students in a general form.

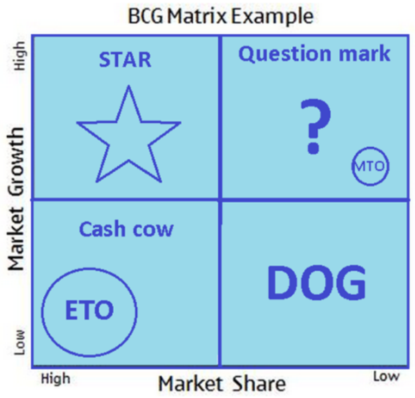


Figure 3-4 BCG Matrix (Kotler, Fredriksen, and Bielenberg 2005)

The matrix is divided into four squares which all represent the state of the strategic business unit (SBU). The x-axis represents the percentage market share which the specific SBU has in that particular segment. The y-axis illustrates the current market growth. The size of the "bubble" tells the reader how big the SBU's turnover is compared to the other SBU's within the company.

The upper right corner is the *question mark*. This square is in a market with rapid growth, but the SBU has got a low market share. The SBU in the question mark square needs a lot of economic resources due to the investments, research, facilitation and so forth. Also, it is common that the company tries to achieve market leadership and this makes it necessary to invest to keep up with the growth in the market. SBU's in this phase must be carefully evaluated in order to make a decision on whether or not to keep investing and grow this unit.

The upper left corner is denoted as the *stars*. In this square the company must keep investing in order to uphold their position as market leader. It is in this square that the competitors will try to gain ground and get the bigger market share. Investment must also be made if not to fall behind the development of the market.

The bottom left corner is where the *cash cow* SBU's are. Here the market growth is less intensive but the company still maintains a leading market share. Fewer investments are needed and it is very favorable to have SBU's here. Companies with only one SBU in the cash cow square are very vulnerable due to the threat of not being able to keep head above water if the cash cow disappears. This can happen when there are changes in the market or the product life cycle (PLC) ends. If this becomes the scenario for a business with only one cash cow, they might have to invest a lot to keep the position, and the profitability can cease.

The last corner, the bottom right, is referred to as the *dogs*. Here, the market growth is low and the SBU's market share as well. In this phase the company must evaluate and decide upon whether or not to keep the SBU "alive". Reasons to continue can be the prospects in the market or the possibility to become market leader.

After placing the different SBU's in their representative square, the company must decide if this portfolio of products is sustainable. This is because an unbalanced portfolio will have too many dogs or question marks and too few of stars and cash cows.

3.11 Matrix organization

In this section we will describe the matrix structure of an organization and provide the reader pros and cons for this structure. Furthermore we will briefly write about risk management to indicate that risks are inherent in projects.

Matrix management can be explained as a "hybrid organizational form in which a horizontal project management structure is overlaid on the normal functional hierarchy" (Larson and Clifford 2011, p. 72)

As international companies in the 1970s saw an increase in complexity, matrix structures were incorporated as the best way to organize multinational corporations (Wolf and Egelhoff 2013). Nevertheless, there have been difficulties to manage matrix structures, and according to Pitts and Daniels (1984), US multinational corporations left their matrix

structures because of this.
There is no single way of using the matrix structure. Companies apply it in a variety of different ways. While some organizations set up temporary matrix systems to deal with specific projects, others may use it as a permanent fixture (Larson and Clifford 2011, p. 73).

As companies change their matrix structure to what fits their situation, it also creates different matrix forms. Larson and Clifford (2011) illustrates three different kinds of matrix forms, which in practice, depends on the relative authority of the project and functional managers.

- Weak matrix
- Balanced matrix
- Strong matrix

The *weak matrix* is similar to a functional approach with the exception that there is a formally designated project manager responsible for coordinating project activities. In this form the functional manager is in charge of managing their part of the project, whereas the project manager acts as a staff assistant. The functional manager is making most of the decisions and decides who does what and when the work is finished.

The *balanced matrix* is the classic form where the project manager is responsible for defining what needs to be done while the functional manager is concerned with how it will be done. The unification between what should be done and how it should be done requires both parties to work closely together and jointly approve technical and operational decisions.

A *strong matrix* attempts to create the ‘feel’ of a project team within a matrix environment. The project manager controls most aspects of the project and have final say on major project decisions. The functional manager has title over his/her people and is consulted on a need basis. However, a functional manager’s department may serve as a “subcontractor” in some situations. If this occurs they have more control over specialized work.

When organizations use a matrix system, there are usually two chains of command, where one is along the functional lines and the other along project lines. This works in such a way that instead of assigning segments of a project to different units or creating an autonomous team, project partakers report simultaneously to both functional and project managers (Larson and Clifford 2011).

Larson and Clifford (2011) points out unique strengths and weaknesses that can occur with the matrix structure. This type of management can be efficient because resources can be shared across multiple projects as well as within functional divisions. Thus individuals can divide their work time through many projects on an as-needed basis. This will in turn reduce duplication required in a projectized structure. Matrix management can also yield a strong project focus by having a formally designated project manager who is responsible for coordinating and integrating contributions of different units (Larson and Clifford 2011, p. 75). This can contribute to an overall method to problem solving that is often missing in the functional organization.

Furthermore, it is easier for specialists to return to their homeport once the project is completed. This is because the project organization is overlaid on the functional divisions. In other words, the specialists maintain ties with their functional group. The last strength that is pointed out by Larson and Clifford (2011), is that a matrix management is flexible. The reason is that it provides flexible utilization of resources and expertise within the firm. While in some cases functional units may provide individuals who are managed by the project manager, other cases can be that the contributions are monitored by the functional manager.

Even though the strengths of the matrix structure are substantial, so are the potential weaknesses. The matrix is a complicated structure to create, and it is not ‘installed’ within a short time. According to Larson and Clifford (2011) experts argue that it takes 3-5 years for a matrix system to fully mature. One major weakness of the matrix approach is dysfunctional conflict. This conflict is motivated by egos of employees with competing ambitions, and it often leads to higher stress and a likelihood that employees will burn out. Even though the tension is viewed as a necessary mechanism for reaching a balance between complex technical issues and unique project requirements, the effects may be unfavorable. It may create conflicts on a personal level, and discussions can become heated arguments that produce hostility among the managers involved. Another downside of matrix structure is infighting. In a situation where resources and people are shared between different projects and functional activities, conflicts can occur. This can happen between project managers because they are interested in what is best for their project.

Moreover, it can be stressful for project participants due to the fact that they have likely more than one boss, i.e. functional manager and or more project managers. The last weakness that can happen is that the project will happen in a slow pace. Decision making can get slowed down as agreements have to be done across multiple functional groups.

Strengths

- Efficient
- Strong project focus
- Easier post-project transition
- Flexible

Weaknesses

- Dysfunctional conflict
- Infighting
- Stressful
- Slow

Even though the strengths in a matrix structure are considerable, so are the potential weaknesses.

3.11.1 Managing risk

The concept of risk has always been present in the industrial environment, and the risk management today is an integral part of project management (Olsson 2007). While risks can have positive consequences such as unexpected price reduction in materials, risk can be described as the negative outcome of an uncertainty, thus we will in this section focus on what can go wrong.

The sources of project risks are unlimited. There can be sources that are external to the organization such as inflation, market acceptance, exchange rates, and government regulations. In practice, these risk events are often referred to as "threats" to differentiate them from those that are not within the project manager's or team's responsibility area. Threats are one of the factors in the SWOT-analysis, found in the bottom right corner from Figure 3-5, which can be internal or external.

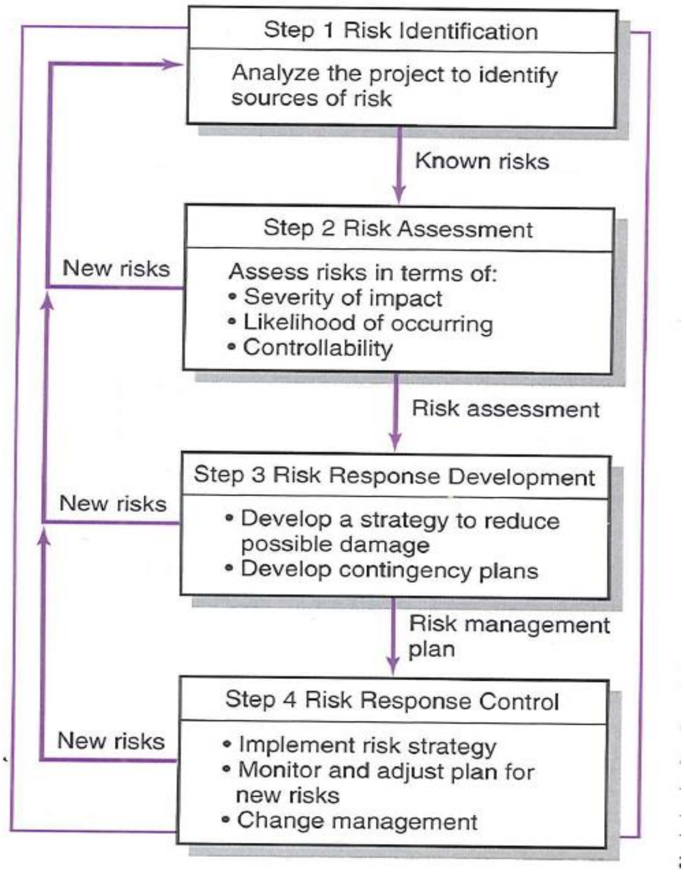


Figure 3-5 The risk management process (Larson and Clifford 2011, p. 213)

The figure above illustrates the four steps in the risk management process (Larson and Clifford 2011). The first step is to generate a list of all possible risks that could affect the project. The project manager usually pulls together a risk management team with core team members and other relevant stakeholders. They use brainstorming and other problem identifying techniques to identify potential problems.

Step two is to find out which risk can be excluded and which could pose serious threats to the welfare of the project. The risks need to be categorized on the level of occurrence and importance to the project. *Scenario analysis* is the most commonly used technique for analyzing risks. Larson and Clifford (2011, p. 216) state that risks need to be evaluated in terms of the likelihood the event is going to occur and the impact or consequences of its occurrence.

Step three deals with the decision that need to be made concerning which response is appropriate for the specific event. Responses to risk can be classified as mitigating, avoiding, transferring, sharing, or retaining. In some cases there will be made a conscious

decision to accept the risk of an event occurring. The reason is that some risks are so large that it is not possible to consider transferring or reducing the event. However, the risk can be retained by developing a contingency plan to implement if the risk materializes.
A *contingency plan* is an alternative plan that will be used if a possible foreseen risk event becomes a reality (Larson and Clifford 2011, p. 223). The contingency plan is a way of reducing or mitigating the negative impact of the risk event. Furthermore, the contingency plan is not part of the initial implementation plan. It only goes into effect after the risk is recognized.

Step four involves executing the risk response strategy, monitoring triggering events, initiating contingency plans, and watching for new risks. Step four is a summary of the results in previous steps. The summary is in a formal document which is often called the *risk register*. The register can be viewed as the backbone for the last step in the risk management process: risk control. It is important for project managers to monitor risks just like they track project progress.

4.0 Analysis and discussion

In this chapter data collected through interviews and raw data received from NOV will be analyzed and discussed. The background for our questions in the semi-structured interview will be explained and the answers given presented. Furthermore the Value Stream Map will be displayed and each step and variable will be looked into and analyzed. This will be the foundation for the discussion section of the thesis.

4.1 Analysis

In this section of the thesis the data collected through interviews and raw data received from NOV will be analyzed. The background for the questions asked in the interview will be explained and the answers given presented. Furthermore the VSM will be displayed and each step and variable will be looked into and analyzed. This will be the foundation for the discussion section of the thesis.

4.1.1 Interview

For an exploratory research, it is more valuable with a few, semi-structured interviews, rather than sending out standardized questions to as many as possible. Though we include our questionnaire as an appendix, it is just a template for our questions to the respondent. Due to the fact that this thesis uses semi-structured interviews, the questions are adjusted to each person that is interviewed. By conducting the interviews this way it is easier to adapt the questions so that only relevant and necessary information is gathered. Furthermore, additional data and views can be encountered which were not considered beforehand.

We will now address the reasons for each question and elaborate on why it was included.

1. **What position do you have in NOV?**

The first question is asked to get an introduction of the respondents work area. It is here we find which department the respondent works in and what their area of expertise is. By gathering such information it is easier to know what input to emphasize since the different respondents have different knowledge and responsibilities.

2. **What is your role in this project? Elaborate please.**
    a. Do you have final say in the decision making?
    b. Do you supervise all parts of the process?

The second question is to clarify the role the specific respondent has with regards to the project. By knowing where or what the respondent does, it is easier to determine what weight to place on the answers, either on the different operations, or altogether. We also provided two sub-questions which could tell us how much authority each respondent has. NOV is an organization that is matrix-based, which is one of the biggest management innovations to emerge in the past 30 years. We did not know what to expect from these sub-questions. However, the thought behind was to see if the respondents experienced any issues regarding this matrix structure. This structure is designed to optimally utilize resources where individuals work on several projects and also performing normal functional duties. The respondents we will interview are such individuals, either from a project manager point-of-view or employees that need to respond to a functional- and a project manager.

3. **What are your thoughts about the project?**
    a. In regards to NOV Molde itself
    b. Sustainability with modularized cranes
    c. The market and competition
    d. ETO-crane
    e. Customers.

The third question is asked to get each respondent's personal point of view on some specific aspect of the project and its surroundings. By asking this we are able to see if everyone has the same perception of the purpose and goal of the project. The reason for highlighting some areas is to get sufficient insight and knowledge of the situation from a holistic perspective. Dependent on the answers we receive, we might change the sub-questions.

4. **What pros can the project have for NOV Molde?**
    a. In regards to the demand
    b. The market
    c. Customers
    d. Operations
5. **What pros can the project have for NOV Molde?**
    a. In regards to the demand
    b. The market
    c. Customers
    d. Operations

For question 4 and 5, the respondents were asked about the pros and cons of the MTO project. To get more specific information, some cues were mentioned. Examples of the cues asked were pros and cons with consideration to the market, the customer and operations. Depending on the answer the cues will differ, but usually it is expected that their perceptions of the pros and cons will be unified.

6. **What types of risks do you consider this project to have? Your thoughts.**

7. **Are there any pitfalls that NOV Molde should pay attention to in the project?**

Question 6 and 7 were asked to illuminate the potential risk and pitfalls considered to be tied to the project. It is vital to get an overview of these factors when establishing hypotheses and it makes it easier to make more correct assumptions.

8. **Will the new project have any influence with consideration to the ETO crane?**
    a. Is the new crane competing in the same market as the existing crane, or are the customers divided into two different segments of the market?

Question eight refers to the market and the daily operation at NOV. This is an important question which will give an insight on how the respondents think the market, customers and operations will be affected when initiating this MTO project. After a discussion on the question, some follow up question will be asked to get more specific answers.

9. **Will there still be more or less the same demand for the ETO-crane?**

Question 9 was asked to determine the impression on how great of an impact the new crane will have on the existing crane. By having the respondents elaborate on how the demand for an ETO crane will be affected, it was easier to see the scope of this project.

10. **Can your existing business model derive advantage from the implementation of this project?**
    a. What about adopting cost efficient modules in to the ETO-crane?

Question 10 was asked to hopefully provide some discussion and ideas with regards to the research problem. We are interested in whether or not the existing business model will cause a reduction in lead time and cost, which again provides a growth in sales volume. This question was essential to get some educated input on the subject, and the feedback will be vital to the thesis.

11. **NOVs cranes are associated with high quality, have you considered that this opinion might be changed when NOV supplies a less expensive standardized crane?**

Question 11 was asked with consideration to NOVs reputation as a “high-end” product. A unanimous response will in this case not be surprising, but it is important to consider this aspect to get the bigger picture of the company.

12. **Your thoughts on whether or not NOV will continue to focus on standardization to cut down cost and time even more?**

The second to last question was asked to get confirmation that NOV will work towards more standardized cranes as a response to lost market shares. When the thesis decides upon the hypotheses and conclusions on future work and devolvement of the modularized crane, the answers from this question will be weighted.

13. **Do you believe that this will be the beginning of a 100 % standardized crane from NOV Molde?**

Finally, in order to include or exclude a scenario of a hundred percent standardized crane, a question on this subject was asked. The expectations are that it will be rejected, but the question is also asked to see if everyone perceives the same goals. The situation for this thesis is to make hypotheses for further research on this subject. Thus we need to see different scenarios and discuss potential possibilities and limitations in each of them.

4.1.2 Participant’s response

This section will provide the information we received from the respondents. The answers will be summarized in order to see what information these semi-structured interviews have given us. The summary will show similar and different opinions from our respondents. The respondents will be named with their capital initial letter, i.e. Kim Ramde would be respondent K. The position they have in NOV will also be included. Furthermore, theory will be used in the discussion to support the answers. First we will give a brief description about how the project started.

NOV’s processes have always been focused on engineering towards their cranes. The main market is the North Sea, where NOV Molde owns approximately 90 percent of the cranes.

However, an upswing in the marked occurred 5-6 years ago, and customers purchased many cranes. Some of the competitors seized this opportunity and developed their own standardized cranes. Due to the fact that NOV continued their engineer-to-order process after the financial crisis in 2009, they lost several customers. After a market analysis they asked themselves “why are we selling less if our products are better than our competitors?” NOV experienced that when customers no longer felt the need to specify what they want, they lost market shares. The result of this was the initiation of MTO strategy for NOV Molde.

There were two main factors for the decline in demand. The first factor is that NOV had longer lead time than their competitors. Engineer-to-order is a strategy where engineering needs to be done before one can start with production, which makes them already falling behind of the timeline compared to the standardized competitors.
The second factor is cost. The use of an ETO strategy can create many mistakes in the engineering. When a new crane is to be created, mistakes that have been made will not be discovered until the assembly and testing phase. The problems can for instance be wrong gear, misalignments of the components and so on. Consequently, a high amount of money will be spent on assembly and testing because of mistakes, which in turn creates a higher total cost. According to respondent L, who is the project manager with the modularized crane, this is only linked because NOV does not have a standardized product.

Respondent L mentioned that removing or minimizing the engineering will improve the lead time, since the engineering parties is a small part of the total cost. Increasing the efficiency of their supply chain will improve both time and cost. Respondent L goes on to state that modularized cranes are the future, but with some adjustments in the long run. This can be exemplified through the automobile industry. A car is an MTO product, and the more expensive a car is, the more flexible the car becomes. For the sake of only illustrating, an example we use is a comparison between a Citroën and a Mercedes. The general perception is that the Citroën is a middle class car whereas the Mercedes is a high class car. If you buy a Citroën you have options such as air condition, color of the car, electric windows and this does not make the car that expensive. If you buy a Mercedes you have more alternatives like censor the measures of your tires, engine size, buttons that enable you to regulate almost everything and so forth. The Mercedes is still an MTO product, but it is highly customized in specific ways through the variety of modules. This example suits all of the respondent's perceptions of the modularized crane. The core is standardized, while you still have a high degree of customization through modules.

All of the respondents had the same perspective when asked the thoughts about the MTO project; they want to take back the market share they have lost. They believe that the MTO strategy will meet the demand better. The reduction in cost and lead time will in turn create a higher competitive advantage.

The next two questions were about positive and negative sides of the MTO project.
Here we found that there is some variation in opinions; however this may be the cause of lack of involvement from some respondents with this project. With regards to the advantages the respondents replied the same. The product is less expensive and faster to produce. Since the modularized crane is flexible, and NOV has two different types of cranes, the company as a unit will become more flexible. Moreover, a cost reduction will be seen through standardization and modularization. Respondent H, who is a senior logistic coordinator, said that through the MTO concept, the company could produce more cranes in an assembly line, without using many hours on design and transportation. The respondents said that they will continue to sell approximately 8-10 ETO cranes a year with the customers in the North Sea. On the other hand, from our data collected through NOV, there is a goal of 50 modularized cranes to be sold per year. Therefore, the biggest advance for the modularized crane is the volume increases, and also that the company will grow as a unit.
With regards to the customers, respondent J, who is managing projects at NOV Hjelset, said that NOV can supply to a larger customer base with the MTO project. According to respondent J, the daily operation could be improved from the MTO project, and also provide input on how they operate on the ETO cranes today.

For the disadvantages we received different answers. We believe that this can be explained by which department the respondents work in, and also their degree of involvement with the MTO project. Respondent L emphasized that a change will happen in the organization, while respondent H talked about the customers' demand; i.e. customers want ETO specifications, but with the MTO price. However, respondent H mentioned that it is difficult to state what the actual disadvantages are before a crane is sold.

Respondent G, a senior consultant at the SCM department, said that there will be a reduction in the engineering department which corresponds to the response from respondent L. Respondent G also mentioned that the modularized crane will in the early stages have limitations with regards to the supply and demand. NOV will have new suppliers, which can be a risk. They do not know if the suppliers deliver the quality NOV is used to, and also deliver in the set time frame, which are important factors for their trademark. Moreover, the demand might not be as high as expected.

At the present time NOV have their production sites in Polen, Hjelset and NOV Korea. For the MTO project they are investigating if they want to stay in NOV Korea, or if they should move production site to China. Due to the price of steel and labor, the production is cheaper in China than Korea.

Another disadvantage, or rather a challenge, is the reduction in organizational flexibility, due to the lack of variation in the work. The respondents argue if the company can keep developing without focus on the engineering phase, or if this will make the operation even stronger.

An unavoidable outcome from this project, according to respondent L, the project manager, is that the organization will lose people. Engineers enjoy working in a challenging environment, and with the MTO engineers might get bored because they are not allowed to do changes. However, respondent J, an engineer at the electrical department, said that there will still be much to do with the modules, especially the electrical, hydraulic and mechanical components. NOV began with an MTO product and defined what the minimum requirements are, which is the core base. Nevertheless, they have developed the whole process around the modularized crane in their system so it can grow to be a configurable product. Therefore, the core of the crane is standardized, but the rest will be modularized and thus challenging tasks still exist.
In spite of this, respondent J, who is managing projects at NOV Hjelset, said that it is important for NOV to focus on standardization and not begin to sell the MTO product subsequent to their existing ETO product. This is to avoid the competition with the existing product. Respondent J also said that it is important to focus on quality, supply, and short stoppage time at maintenance.

Respondent L said that the biggest disadvantage is the change in the organization, and the company needs to adjust themselves and prepare for it. However, the respondent emphasizes that there are no problems, only challenges.

NOV's market is now divided into two different segments. As an example, the MTO project is targeting customers in Brazil, Gulf of Mexico, Russia and Japan, whereas the ETO crane will still focus on the North Sea. In spite of this, respondent L believes that the new project will have consequences for the ETO crane. However, this will not happen until later on. NOV will not replace ETO with only MTO products because there are customers that still want specialized products. Nevertheless, the trend suggests that customers are moving towards modularized cranes because an ETO crane demands that the customer spends a lot of time with the supplier. On a further note, respondent H thinks that some ETO customers may have interest for modularized cranes. However, the modularized crane will not be a substitute for the ETO-crane but rather an additional option. According to respondent J NOV will now compete with other companies that work with standardized cranes.

All of the respondents have the same perception on the quality of their products. They are not making a modularized crane with less quality than the ETO. They use the same standard rules and regulations and the performance of the crane is the same as before. Furthermore, they have increased efficiency of production and reduced the costs by eliminating "unnecessary" parts of a crane's operation and focus on its primary application. NOV is taking advantage by using components that departments for instance in Kristiansand, USA and Germany use, so they have bigger volume to buy. In other words, they are adjusting their design to use components other groups also use, and this will result in cost reduction.

4.1.3 Analysis of the value stream map

In this section we will elaborate on the different steps visualized in the VSM. First we will comment on what the changes are from the ETO to the MTO. Then follows the analysis of the measures NOV has conducted as well as a discussion on the topics related to the changes. The applied symbols in the VSM will be shown in Figure 4-1, and the symbols are taken from Microsoft Visio 2010.

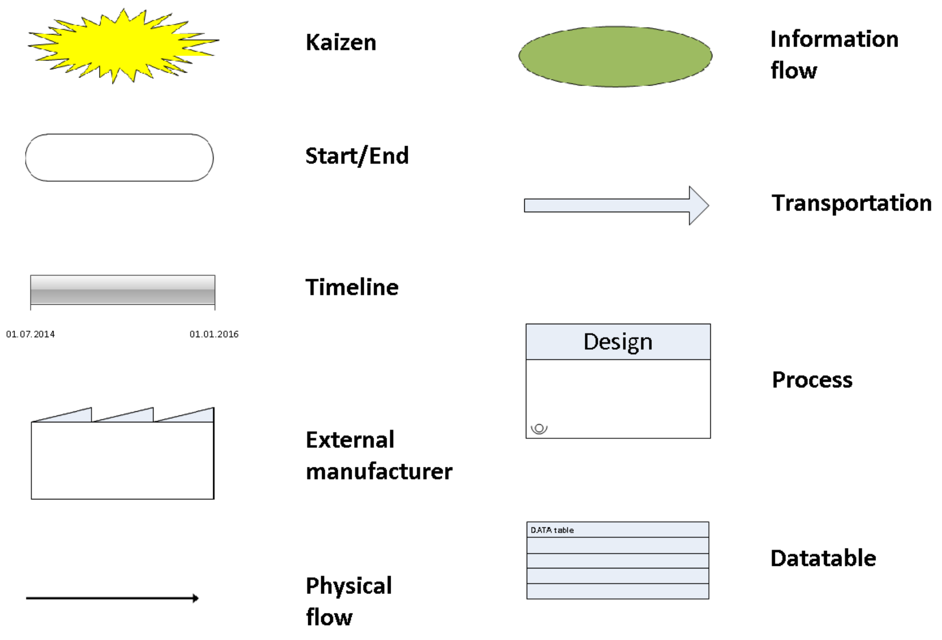
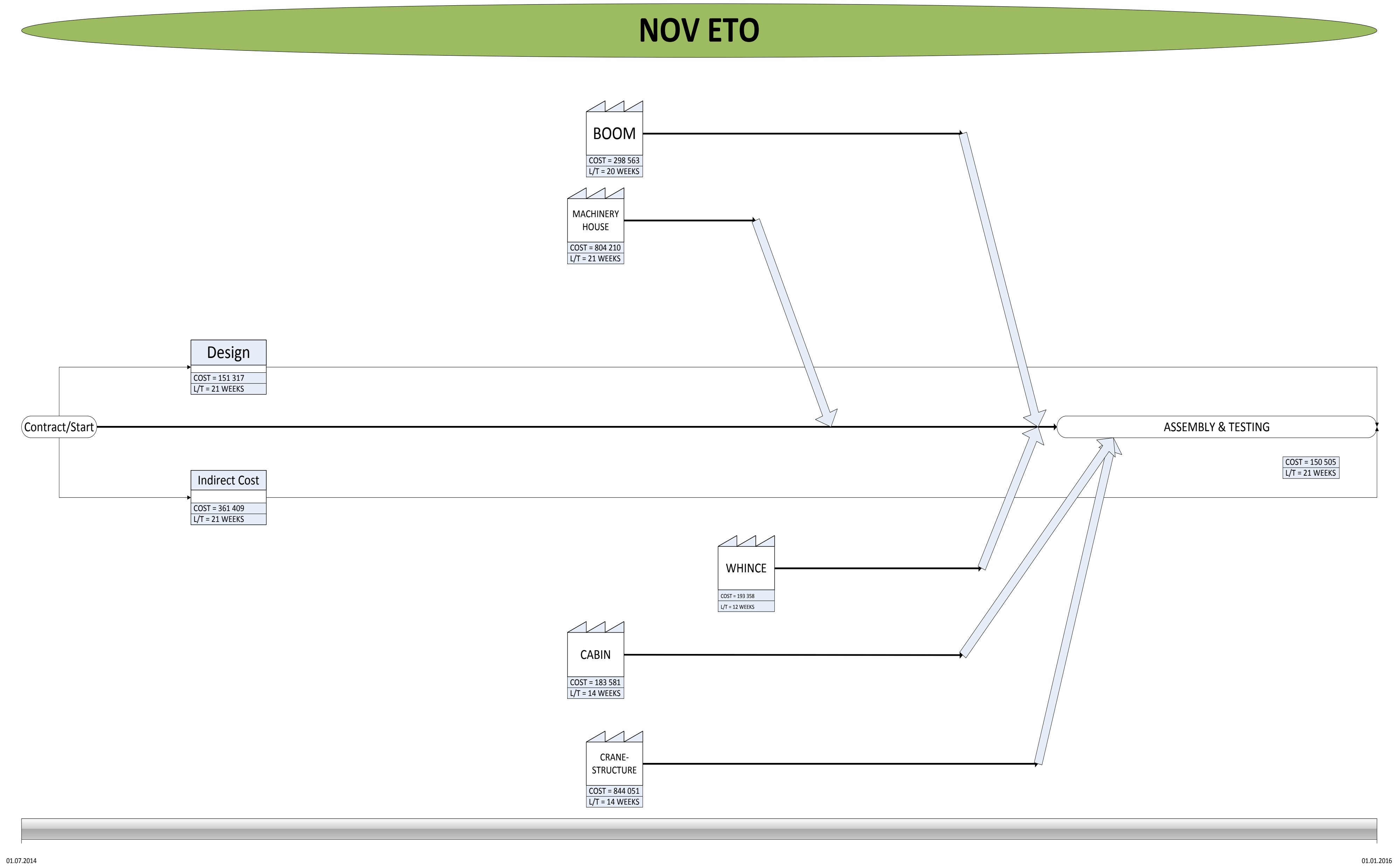


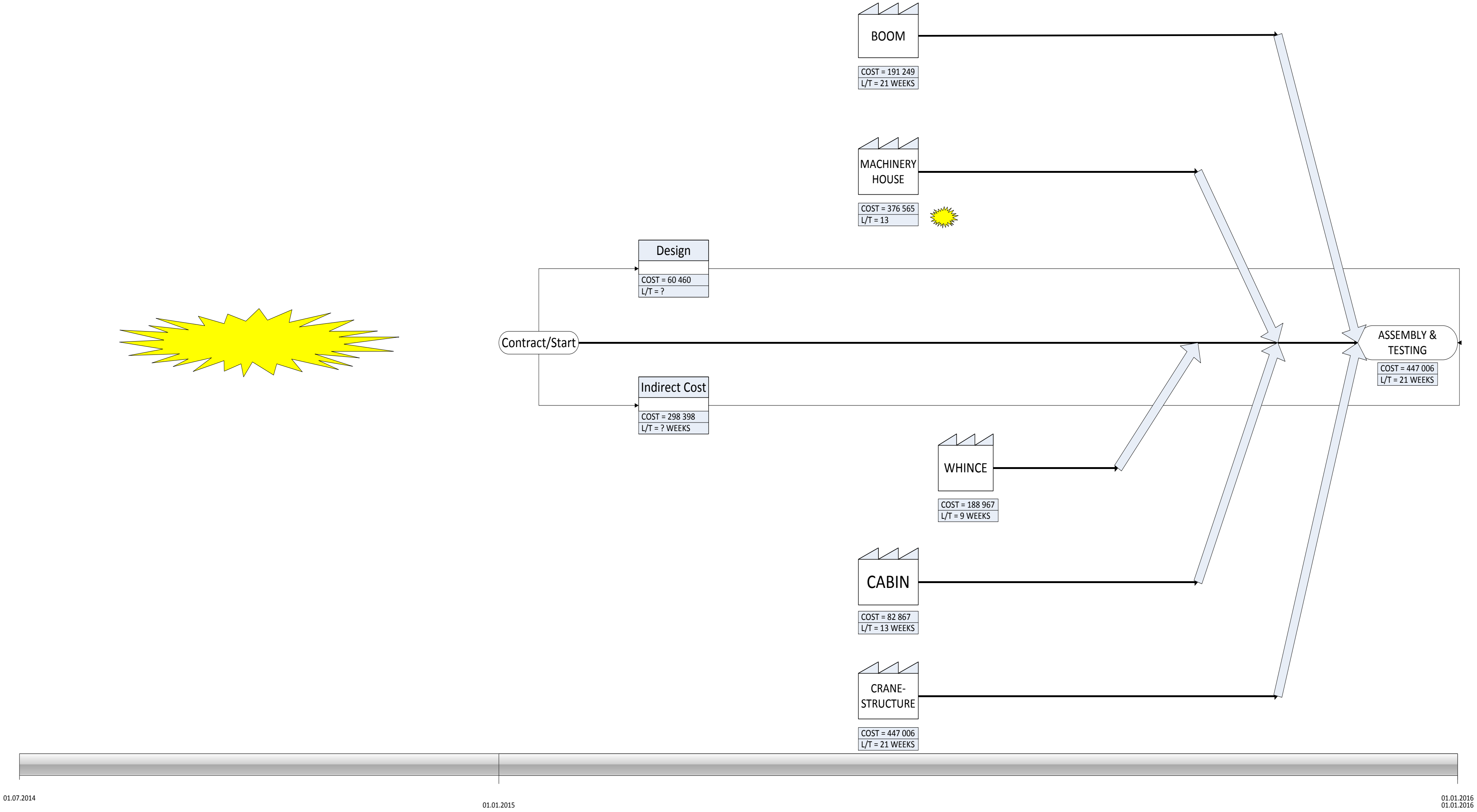
Figure 4-1 VSM Symbols. Microsoft Visio 2010

As the decline in demand for NOV's ETO cranes was a reality, a SWOT analysis was conducted in order to elicit what was wrong with the current process, as well as to detect opportunities and possibilities for the future. The two most obvious flaws, or weaknesses that were revealed was NOV's long lead-time and their high cost. As mentioned, this resulted in a modularization project, with a goal of 30 - 35 percent lead time reduction, from 18 to 12 months, and a cost reduction of 25-35 percent. The thesis will now look into the different measures on some of the components which were picked as the variables. In addition to the components, some other variables are addressed, such as design, indirect cost, transportation as well as assembly and testing. At the end of the analysis of each component follows a summary of the lead time and cost changes from an ETO crane, to a modularized crane.

In the illustrations below we have visualized the two processes. The first is the current state map which in our case is an ETO crane, while the second is the future state map which is a modularized crane. The metrics in the process boxes are the cost and lead time for the variable. The length of the physical flow arrow is relative to the timeline at the bottom of the illustration. In the FSM one can see that the start of the modularized crane is not until six months after the start for an ETO crane.


NOV ETO
BOOM
COST = 298 563
L/T = 20 WEEKS
MACHINERY HOUSE
COST = 804 210
L/T = 21 WEEKS
Design
COST = 151 317
L/T = 21 WEEKS
Contract/Start
ASSEMBLY & TESTING
COST = 150 505
L/T = 21 WEEKS
Indirect Cost
COST = 361 409
L/T = 21 WEEKS
WHINCE
COST = 193 358
L/T = 12 WEEKS
CABIN
COST = 183 581
L/T = 14 WEEKS
CRANE-STRUCTURE
COST = 844 051
L/T = 14 WEEKS
01.07.2014
01.01.2016

NOV MTO



BOOM
COST = 191 249
L/T = 21 WEEKS
MACHINERY HOUSE
COST = 376 565
L/T = 13
Design
COST = 60 460
L/T = ?
Contract/Start
ASSEMBLY & TESTING
COST = 447 006
L/T = 21 WEEKS
Indirect Cost
COST = 298 398
L/T = ? WEEKS
WHINCE
COST = 188 967
L/T = 9 WEEKS
CABIN
COST = 82 867
L/T = 13 WEEKS
CRANE-STRUCTURE
COST = 447 006
L/T = 21 WEEKS
01.07.2014
01.01.2015
01.01.2016
01.01.2016

Variable 1 Design

It was in the design phase of NOV's supply chain where the bottleneck was located. In this stage, all the other processes were dependent on the design to be completed before they could be initiated. After a contract is signed and NOV starts the production of an ETO crane, it takes 6-8 months before the design is ready and the manufacturing of other components can start. If NOV were to improve their lead time from 18 to 12 months, the design phase could be a critical phase to look into.

By introducing the modularized crane to their product family, NOV will be able to offer a crane with much shorter lead-time. The way they manage to reduce the lead-time is by applying predetermined modules which demand little to no man-hours of design. Then the customer can decide on the necessary specification within the boundaries set by the selection of modules. If the variation or options do not suit the needs, then an ETO crane might be a better alternative. At the stage NOV is at the moment, they have a certain selection of modules. In the future, when there have been enough sales, and the feedback from the market is sufficient, new modules can be developed to supplement the options and even better satisfy the needs of the customer. In the long run, NOV would like to be able to offer a “catalogue” with a large number of modules to their customers.

Some of the components are harder to predetermine than others. Here there are fewer modules to choose from for the customer. For instance, there are no alternatives to pick between when it comes to the a-frame, pedestal, pedestal adapter and base-frame. This is also the reason why the thesis views these components as one variable rather than four. For the boom, on the other hand, the customer can pick from a selection of three lengths; 45-, 50-, and 55 meters. With these three the customer can also choose to have a left or a right orientated crane. By operating with predetermined modules, NOV has cut the design phase by almost six month. The costs of engineers are not commanding in the total sum of the crane, but the costs are reduced significantly for this variable. The main impact on the supply chain for the design phase is the effect on the total lead-time.

As can be seen in the illustration of two supply chains in the VSM, there is placed a kaizen burst in this part of the operation. This is due to the significant changes that have been made. NOV has achieved a major improvement with consideration to the lead-time and this is symbolized in the FSM as the biggest change from the current state map by applying the kaizen-burst symbol.

The total reduction in lead time is approximately six months. It is only in the design phase that NOV has managed to reduce the lead time significantly. The cost reduction is 60 percent, which counts for USD 90.857. However, this amount does not affect the total cost very much since the design cost is not that big.

Variable 2 Boom

NOV has applied some adjustments to the boom which affect both the price as well as to simplify the transportation.

Firstly, the design of the boom is adjusted so that it better suits the space of a standard 20 feet container. This makes it easier and cheaper to transport internally on the manufacturing site. It also makes it more applicable for transportation at sea. Moreover, the bridge attached alongside the boom is moved inside in order to reduce the usage of unnecessary space.

The boom is designed straight so that every section does not have to be designed and calculated every time. Every piece fits together since it has the same size in both ends. In comparison to the ETO crane, the boom narrows in at the end, which makes the calculations for every piece important. Another advantage for the new boom is that it is scalable and can be produced to inventory since all the middle pieces are the same, no matter the order. This gives NOV the possibility of economies of scale which then again can provide a better price from the supplier.

Another important reason for the cost savings is the reduction of materials used to manufacture the boom.

The total reduction of the cost NOV has forecasted to achieve on the boom is about 35 percent. Also the design-team has made the boom scalable so that it can easily adapt to a potential expansion of the module range. By having a design they know the capacity of, and that they are certain fit together, NOV is also more flexible to where they can weld the boom. As long as the materials are the same, the quality of the boom is unaffected.

There is no kaizen burst in the FSM for this variable. However, it is a significant reduction in price and flexibility; the biggest reduction in cost lies in another variable. The total cost reduction on cost for the boom is 36 percent, which counts for USD 107.314.

Variable 3 Machinery house

Several of the components are critical and complex parts, which NOV wants to keep "in-house". In this case, "in-house" means that they are going to be produced in Europe with manufacturers that NOV are comfortable with and trust; the machinery house (MH) is one of these components. One of the reasons can be that if all the production is outsourced to the cheapest alternative, all the core knowledge NOV possess can be copied and the competitive advantage may decrease.

The MH is the kaizen burst of the costs reductions. NOV has managed to more than half their cost of an average MH. Some of the steps which can reduce the costs are that the customers pick the modules with the closest level of performance to their need, and build their "own" MH. The parts are predetermined and provide a level of service. The entire set of pieces is fit for a place in the house. This way, the customers feel that they get a customized product, while they still stay within the economical boundaries. If the customers at one point want to increase the performance of their crane, the items they did not want to pay for initially are easily integrated in the system. A difference between the MTO and ETO product is the availability of installments and maintenance. For instance, the MTO MH has one portable wall whereas the ETO MH does not. This simplifies the whole process within the MH for the modularized crane. Furthermore, every little piece in the MH has a specific number. This simplifies the process of replacing the components in case something goes wrong, misalignments or breaks.

There are some smaller adjustments to make transportation more convenient such as to move all the electrical wires and components inside the house, rather than to have it on the outside. But the significant difference is achieved through standardization of the parts within the MH.

The total cost reduction of the MH is 55 percent, which counts for USD 467.486.

Variable 4 Cabin

The cabin, along with the MH and the winches, is the critical components. This means that NOV wants to keep the production in Europe. The principle of the cabin is much alike the MH. The frame of the cabin is predetermined and all parts are specified with its particular number and fits in to a specific place. On this component the customers have a much more narrow set of choices, compared to before. The cabin may acquire the most additional alternatives from an increased amount of sales. The feedback and requests from several customers will create a foundation for the majority coveted accessories.

The result of cutting down the specifications and customized parts on the cabin is that NOV has managed to reduce the costs of a completed cabin to more than half the cost of an ETO crane cabin. The differences between the cabin from the current state map and the future state map are not all that much. However, NOV have successfully identified the specifications and reduced the alternatives, which has made the price go down significantly. Furthermore the frame of the cabin is more suited for transportation. The main factor for cost reductions for the cabin is the simplification of items. The result is a total cost reduction of 55 percent, which counts for USD 100.714.

Variable 5 Winches

This variable is one of the few variables with no significant improvements, neither with consideration to lead-time nor the cost. One of the reasons is that NOV uses the same supplier as they do with the ETO-cranes. The supplier is a major actor of winches within their segment. Therefore, there is not much to save on this except for quantity prices. Through interviews with employees at NOV, the impression is that NOV wants to develop their own winches. A strategic maneuver like this is referred to as vertical integration (Harrigan 1985), and perhaps a big company such as NOV should consider continuing this on several levels of the operation.

One driving force which motivates NOV to consider vertical integration is explained by Mahoney (1992), as «strategic consideration». This is one of the four categories of driving forces stated by the author. By vertically integrating the winch, NOV would reduce some of the bargaining power of the supplier. Furthermore, if NOV makes the winch model, the supply chain can be much more effective and flexible. Though there are little to be done on the winches in round one, the costs are reduced by thinning down the requirements and alternatives of winches. At the moment there are only four alternatives, but feedback from

NOV states that this is a flexible number. The specifications for the winch are few, usually just the lifting capacity, hence the small number of modules. In the “catalogue” of modules NOV have, there are as mentioned four winches. For the main winch there are a module with a lifting capacity of 20 tons which cost USD 77 000. The alternative to this is a winch with lifting capacity of 25 tons which then again is more expensive and cost approximately USD 82 000. Furthermore, they have the whip winch and the boom winch. However, in the long run when NOV receives feedback from customers, they might find that changes are in need for the winches. As an example there can be a great need for larger lifting capacity. Then a module will be made that meets these specifications and gets added to the “catalogue”.

The total cost reduction for the winch is 2 percent, which counts for USD 4.391

Variable 6 Crane structure

This variable is a combination of the a-frame, base-frame, pedestal and the pedestal adapter. The reason for this is that all of the above are defined by the size of the crane (OC3500), and do not have different modules. In order to reduce the multitude of variables which do not provide any additional value, these components where combined.

Some of the major savings on the structure comes from choosing cheaper work label for the welding. The material is still the same as for the customized crane, but the rest is outsourced to more convenient locations. Furthermore, NOV plan to mould some of the different modules for the modularized crane. This way, there are no costs tied to make the parts fit together, as opposed to the ETO-crane. By having “standardized” parts, there is less chance of mistakes; since mistakes detected towards the end of the contract are unfavorable and costly.

In the start-up phase of the modularization project, there will only be offered one size of the crane, the OC3550. This size is considered to be the golden mean, and meet most of the customer needs. NOV aims to get several sizes in order to cover more of the customer range. However, in the present time there is the pilot project with the OC3550. The cost reduction also lies in the design phase, but by narrowing down the alternatives, the expenses are more predictable and quantum orders give lower costs.

The total cost reduction of the crane structure is 44 percent, which counts for USD 357.204.

Variable 7 Transportation

By combining all the improvements made to the components, with consideration to transportation, the expenses are cut by approximately 25 percent of the average cost of an ETO crane.

Due to the fact that the welding is something which can be done with the same quality practically all over the world, some of the transportation costs are saved by only moving the material rather than a finished product. The plan for NOV is to weld products such as the boom, a-frame, base-frame and pedestal, at the assembly and testing site. As respondent H, a senior logistic coordinator, stated during the interviews, it is difficult to cut costs on transportation since the components are so big. Due to the size of components the carrier cannot transport more than one, no matter what adjustments are made. Thus, on-site welding process may be the best economical solution.

A step made, which are considered to have negative consequences from a transportation point of view, is the additional cost which follows the search for the cheapest manufacturer of certain items. Respondent H said that NOV uses a production concept which decreases the cost of production. Briefly told, large and complicated items were separated from small and easy items. This causes a larger transportation cost, which exceeds the savings from the manufacturing. The placement of where NOV should have their manufacturing and assembly and testing is an important issue as well. With the modularized crane, they are entertaining the idea of doing the most of these activities as close as possible to where the customers are. NOV have possibilities in the Gulf of Mexico, Brazil, Norway and Korea, and possibly China. Since the process is not commissioned, NOV is hesitant of making a statement.

The last point for the transportation costs are the unforeseen expenses. These expenses can come out in the assembly and testing phase, since mistakes in earlier stages will first be found at this phase. That in turn can increase the lead time and in order to avoid fees for late deliveries, NOV then have to hurry the transportation of the necessary parts, which can be expensive.

As mentioned, the total cost reduction is 26 percent, which counts for USD 34.036.

Variable 8 Indirect cost

This variable is created to collect all the indirect cost that did not fit the variables the thesis addresses such as travel expenses, documentation, taxes and so forth. It was important to include all the costs for both types of cranes when drawing the CSM and the FSM so that the visualization would be correct. In spite of that, the thesis will not go any further into the posts in this variable. The total cost reduction is 17 percent, which counts for USD 63.011.

Variable 9 Assembly and testing

For the assembly and testing, the data received suggested an increase in cost of nearly hundred percent. From the information that has been received through NOV and theory that has been read, we were prepared for an unfavorable number on this variable. One of the reasons is the change with the bottleneck. From an ETO perspective, the bottleneck lays in the engineering period because the production cannot start until the design of the product is completed. However, if the engineering is excluded, the bottleneck will in NOVs case be the assembly and testing. Therefore we predicted higher cost and the time it would take for completion in this phase. Due to the fact that NOV does not have a prototype to test on before offering to the customers, many errors need to be fixed on the way. This may cause longer lead time and higher cost than expected.
Nevertheless, we were not prepared for 96 percent cost increase. This can be explained by misalignments with consideration to our variables, and cost that includes unforeseen expenditures that can be a result of the learning process. However, they were included in our total budget. Furthermore, we came to an agreement with respondent L, the project manager, respondent G, a senior consultant at the SCM department, and Roar, our contact person at NOV to place some of the posts on assembly & testing and this may have caused the high percentage increase in cost. Roar and respondent G also mentioned in the last meetings that the two first cranes would provide some extra costs due to test-work. After a given number of sales, the testing would be reduced significantly, and the assembly costs will also decrease. Therefore, we assume that some costs will be shaved off after a few cranes are completed and sold.
Nevertheless the thesis keeps the costs as given, due to the fact that any thought on what the real cost will be with the modularized crane is solely based on speculations.

The result is a total cost increase of 96 percent, which counts for USD 144.546.

4.1.4 Summary of changes in cost

Table 4-1 gives an overview of some changes from an ETO crane to a modularized crane. The columns represent, from the left, the average cost of an ETO crane, the forecasted cost of a modularized crane, the difference in USD between the two crane types, the percentage difference between the two crane types, how big percentage the variable is of the total cost of an ETO crane, and last how big percentage the variable is of a modularized crane.

Table 4-1 Cost matrix

Variable/ crane	ETO	MTO	DIFF	% reduction from ETO	% of total amount ETO	% of total amount MTO
Boom	298 563	191 249	107 314	36 %	10 %	9 %
Cabin	183 581	82 867	100 714	55 %	6 %	4 %
Machinery house	844 051	376 565	467 486	55 %	27 %	18 %
Winch	193 358	188 967	4 391	2 %	6 %	9 %
Crane structure	804 210	447 006	357 204	44 %	26 %	22 %
Transportation	133 438	99 402	34 036	26 %	4 %	5 %
Design	151 317	60 460	90 857	60 %	5 %	3 %
Ind. Cost	361 409	298 398	63 011	17 %	12 %	15 %
Assembly testing	150 505	295 051	-144 546	-96 %	5 %	14 %
Tot. Cost	3 120 432	2 039 965	1 080 467	35 %	100 %	100 %

4.2 Discussion

In this section we will discuss our thoughts based on the analysis above. We will begin by discussing our three research questions to help us answer our research problem. The discussion will be supported by existing theories, collected data and feedback from the semi-structured interviews.

- Research question 1: Is it possible to apply modules from MTO in order to improve lead time and cost in the ETO?

As shown in the research question, we have a focus on what effect modules can have on lead time and cost, which are the two important variables for the thesis and also for NOV. From the theory provided in this thesis we include mass customization, postponement, and modular production to support our discussion around this research question. Literature from mass customization focuses mostly on the move from mass production to mass customization. Even though the shift from pure customization to customized standardization has been less publicized, this shift may be equally significant and, in fact, driven by the same technologies (Lampel and Mintzberg 2012). According to Haug et al. (2009) there are also other companies that have claimed to become mass customizers. However, it can be questioned if these companies conform to popular definitions of mass customizers, such as being able to offer products at price close to mass produced products.

From our interviews the respondents told us that the base core of the crane is standardized. However, NOV has not a 100 percent standardized crane, and our perception is that it will never be the case in the future. But the other way around can be a possibility. Respondent L, the project manager, said that in the future when they have an ETO crane and the SPEC says they need an offline filter unit, they will be able to go to the existing database of the MTO and take it out. This is the concept of the modularization itself, and thus they can produce an ETO crane, and still have parts they can apply from the modularized crane. The purpose of modular production is to decrease product complexity, while raising product variety offered to the customer. Respondent J, who is an engineer at the electrical department, said that they can apply standardized components from the machinery house to both types of cranes. Respondent J has his top competence within the MH, and said that the MH on the modularized crane has three permanent walls and one portable wall. The MH has electrical, hydraulic and mechanical components inside placed on one side. It is difficult to assemble and install this wall on the ETO crane because it has four permanent walls and needs to be installed from above. By applying the method used on the modularized crane to the ETO crane can reduce the complexity of assembly and testing, the time it takes to repair errors and make the operational processes more efficient. This is the purpose of modular production, where they decrease product complexity and at the same time raising product variety to the customer.

It has been said during the interviews that NOV will not go over to mass customization. As we see it, they would like to be placed in the middle position of pure customization and customized standardization. However, RQ 1 proposes a possibility of taking some parts from one product and uses it in another. The same possibility should be done with theories. According to Feitzinger and Lee (1996, pp. 116-117) the key to mass customizing effectively is postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network. Moreover, companies must rethink and integrate the designs of their products, the processes used to make and deliver those products, and the configuration of the entire supply network. As written in the literature review chapter, companies can operate at maximum efficiency and quickly meet customers' orders with a minimum amount of inventory.

Another reason we asked research question 1 is *modular product design*. A product with such a design provides a supply network with the flexibility that it requires to customize a product quickly and inexpensively (Feitzinger and Lee 1996). The authors state that a modular product design has three benefits. First, a company can maximize the number of standard components it uses in all forms of the product and assemble them for all product options in the early stages of the assembly process. The components that differentiate the product can be postponed until the later stages of the process. Second, a company can shorten their total time required for production by making the modules of the product separately. When doing so, the company can manufacture different modules at the same time. Third, a company can more easily diagnose production problems and isolate potential quality problems.

- Research question 2: With consideration to RQ1, can a crane made with the use of modules as well as customization be offered to the customer?

Respondent L, the project manager, said during the interview that this was the ultimate goal. Based on the research and analysis we have conducted, we will discuss the background for this question before answering it in the next chapter.

According to respondent L, there will always be a demand for customized cranes. However, the market analysis displays a demand for cheaper cranes with shorter lead time and this trend will continue to grow in the future.

There have been changes in the trends in the market of offshore cranes. After 2009 the demand for the more expensive, customized cranes declined and NOV needed to start thinking of how to meet these changes. As mentioned in the analysis section, there was conducted a SWOT-analysis. Here it was discovered that it was the lead-time and cost that was NOV biggest disadvantages. Respondent L said it was the lead-time that was to be improved at first, but they later on they found that there was a huge cost reduction potential. The result was the modularization project, or as we referred to it, the MTO project. A lot of time and work was put into the project to find smart solutions and reduce the lead-time and cost.

Though NOV's ETO cranes have been their cash cow for many years, the market declined and the company's market share dwindled. The countermeasure was the modularized crane. Now NOV hope that this crane can become their new cash cow so they can keep the customer as well as to expand their customer base. As can be seen in the first picture in Figure 3-4, is how the market was for NOV until 2009. The next picture illustrates how the scenario will be if the modularized crane is a success and becomes the best source of income for NOV. But throughout the research, we have interpreted it as a challenge that the engineers will not get stimulated enough if they are to work on the same modules every day. We want to emphasize that this is a big change from what employees are used to. Thus the company needs to be aware of this change and prepare for it. The engineering group is used to work with highly customized products, and changing their work to standardization can cause internal problems within the company. To deliver a modularized crane will require more work and responsibility to the supply chain and less on the engineering side. Therefore engineers are not as involved in the projects and this may result in the risk of stagnation for the development of the company. Some of the competitive advantage for NOV is their ability to meet the customers demand, no matter what. We therefore think that it will be important to keep the core competence in the company. If NOV is able to merge the two strategies, keep the possibility of customization available and at the same time use MTO principle, they can have a more flexible strategy. When there is a new customer demand which does not fit the modularized profile, the engineers get to work out a suitable solution. Then the new module is integrated in NOVs "catalogue" and they can offer the same solution for the next customers. This gives us the scenario visualized in the third matrix in Figure 4-2. This gives NOV a scenario with the price and lead-time for a modularized crane, as well as to keep the core competence.

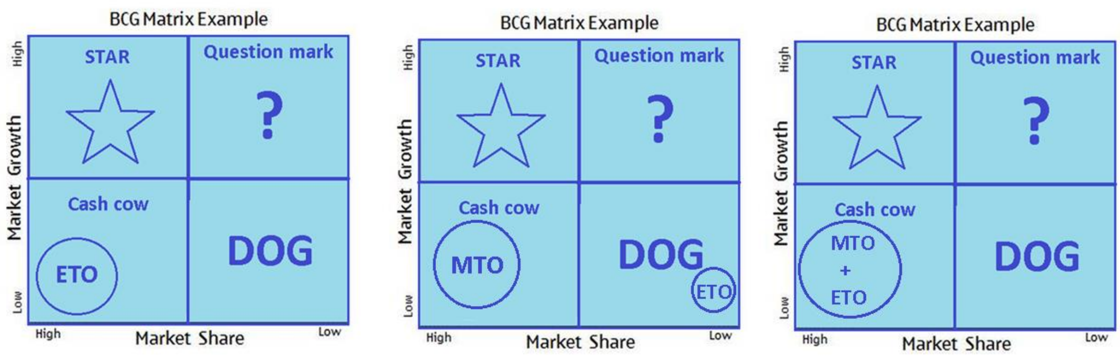


Figure 4-2 BCG Matrix (Kotler, Fredriksen, and Bielenberg 2005)

- Research question 3: Can acquirements about the bottleneck in the MTO supply chain be applied in the ETO supply chain, in order to improve efficiency?

To answer this research question we use the customer order decoupling point to discuss the positioning of the bottleneck. We also look to the analysis to see how NOV considers the bottleneck with regards to both the ETO crane and the modularized crane.

The bottleneck for NOV's ETO cranes was located in the design phase of the operation. There was also a weak spot in the assembly and testing phase due to the discovering of error this late in the process. With the MTO project NOV has managed to move the bottleneck away from the design phase. At first, the bottleneck will be in the assembly and testing for the MTO, but this is just until all the errors have been discovered and corrected. This gives them an assembly and testing phase which is most likely to work as planned. One way to secure to not make any mistakes with the first cranes is to make a prototype. During the interview this was brought up, but several of the respondents replied there was no founding for a prototype.

As we can see from Figure 3-2 below, the CODP for a MTO product is located in the fabrication stage. The theory suggests that the most normal location for the bottleneck is in the CODP. After the first batches of modularized cranes are made, and the assembly and testing is no longer an issue as the bottleneck, it will move to the CODP. The reason the bottleneck is in the assembly and testing at first is because NOV does not have a prototype to test for errors. In NOV's case the prototype will be the first couple of sales. This theory corresponds to the answers given by respondent L in the interview. The respondent states that the bottleneck for the modularized crane will be located in the supply of components.

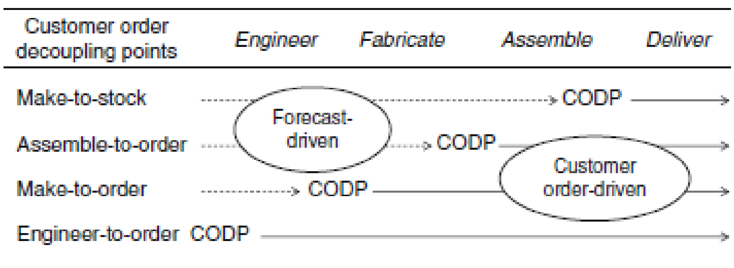


Figure 3-2 CODP

In the visualization of the value stream, one can see that the production of components to a modularized crane is a much larger part of the total lead-time, than compared to the value stream of the ETO crane.

With regards to research question 3, there seems to be little to apply from the MTO supply chain to the ETO supply chain. With the two supply chains operating separately, the main difference is that the design phase is reduced significantly for the MTO, but this is a crucial phase for the ETO. So the only process which NOV should consider is the acquirements of the assembly and testing. Respondent J talked a lot of how especially the MH have been improved towards the assembly. Dependent on the specifications from the customer, NOV might have alternatives to use other modules from the modularized crane which reduce the risk of failing. The reason for this is that the components are proven to work as expected.

From our primary data collection, we got the apprehension that NOV would like to have a "catalogue" with their modularized cranes. In other words, customers' perception will be that customers can customize NOV's standardized crane at a lower cost and shorter lead time. Through our thesis we started to think that NOV might end up with a merged strategy between the MTO and ETO strategy. The advantages of this strategy compared to the original MTO strategy, is that a customer can request something which is not in the "catalogue" and the company can still engineer this part. By postponing the differentiated components as late as possible in the process, NOV can finalize the output in accordance with customer preferences and even customize their products. Furthermore, extra cost will be additional to the price of the product and the item will be added to the "catalogue". After engineering a customized request, the "catalogue" will include another part which can be applied for future customers. In other words, the company will have new modules they know how to construct and know work without any extra cost. This theory or concept derives from Olhager (2012), however the strategy we describe is to our knowledge not documented. Therefore we want to extend the theory and add what we have defined as engineer-to-modules, which place itself between the ETO strategy and the MTO strategy. For the MTO concept in general, the practice is for the company to design the modules based on market research and forecast. The engineer-to-module concept differs from the MTO since it bases the design of modules on actual demand. It will also be the customers who pay the development cost of the modules.

5.0 Conclusion and hypothesis

In this chapter of the thesis we will conclude upon the analysis and discussion chapter. Based on these conclusions we will formulate some hypotheses which can be used for further research.

5.1 Conclusion

This thesis aims to get a better understanding of the correlation of two different supply chains within the same company. More than that, the goal is to explore and conclude on whether or not the two supply chains can benefit each other. With the visualization through the VSM and information and feedback from the interviews, this thesis focused on exploring and observing the process of implementing a new business model. The result will be the hypotheses based on the conclusions.

RQ1: Yes, during the process of writing this thesis there has been confirmed by respondent J that this is already a reality. Smart solutions developed in the process of the MTO project will be applied to make the ETO crane more efficient. This will help to reduce the costs as well as to reduce lead time in the assembly phase of certain components.

RQ2: Yes, like respondent L we believe so. And we also believe it to be the best solution and NOV should strive for it to be so. This way the company keeps its core competence as well as to reduce their original lead time and cost. They are more flexible and better equipped for further changes in the market.

RQ3: NO, from the data and feedback we have got we do not believe it to be so. Though respondent L suggested that there could be some slight improvements, we think this will be in the step of merging the two strategies. Then NOV can apply the advantages from the modularized crane and keep the perception of customization through the module "catalogue"

We think that NOV should use their expertise to improve number of modules so that they better can differentiate themselves from the rest of the actors on the market. These competitors operate with standardized cranes and by applying the engineer-to-module concept, and expanding the options for the customer NOV can secure a competitive advantage in this segment of the market as well.

5.2 Hypothesis

When Hernon and Schwartz (2013, p. 85) searches for a definition of a hypothesis, he states that

"Regardless of any specific definition, hypotheses provide a tentative or working explanation of some phenomenon, extend knowledge, offer an unambiguous and relational statement of the extent of a relationship between variables, present a statement that is testable, and guide the conduct of research".

Ary et al. (2010, p. 96) state that hypothesis "*relate theory to observation, and observation to theory…. They are tools in the research process, not end to themselves*".

Another definition which suits the nature of this thesis is one by (Babbie (2013, p. 44)):

"(…) a*n expectation about the nature of things derived from a theory*"

By these definitions the thesis will formulate several hypotheses for further research. The hypotheses will be based on the analysis, discussion and foremost the conclusion section of the thesis. Since all the data from the modularized crane is forecasted data, further research is necessary in order to conclude on the value of the data. When the project is initiated, the hypotheses can be tested and proved or disproved.

Hypothesis I
The two supply chains will merge together and leave NOV with one crane type which has optimized the capabilities of both production strategies.

Hypothesis II
The experience and knowledge acquired from operating in two segments of the market helps NOV improve the operation for both their business models in their separate markets.

Hypothesis III
After a period, the ETO crane moves to the "dog" in the BCG-matrix due to the evolving trend in the market and NOV should consider discarding the business model.

Hypothesis IV
The modularized crane calculations are not achievable and the project must be improved to satisfy the wanted lead-time and cost reductions, or it will be discarded.

6.0 Limitations and further research

In this chapter we will present the limitations of the paper and then move on to further research that can be conducted.

6.1 Limitations

The limitation for the research conducted in this thesis is firstly the lack of theory to compare NOVs situation with. We found no previous research which can help us indicate what will happen to the two supply chains, which in some ways are so alike, but still so different. Since this thesis want to look into whether or not the supply chains can use experience and knowledge acquired from each other to improve themselves, similar cases would have helped us to decide upon conclusions and formulate hypotheses. The result of this is that the hypotheses will be more speculative than if the data could be tied to research on subjects of the same sort.

The second limitation to our research is that we only used NOV in our study. If we were able to do research about other organizations that are doing similar transformations, this could have provided a better foundation to conclude this type of strategy. The validity of our data would have been stronger if we had looked into scenarios of the same situation NOV is going through.

Another limitation for the research is the forecasted data for the modularization project, though thoroughly calculated, they are unrealized and therefore less reliable than if tested. The conclusion and hypotheses of this thesis are all made with the proviso that the calculations are accumulated to reality.

6.2 Further research

Some of the further research which can be conducted on the subjects of this thesis is to test the hypotheses. When the modularization project has started they can get enough sales to calculate a more reliable average on lead-time and cost. This will prove or disprove on whether the research can be used or not. If existing data is approximately correct one can extend the research to see if more improvement can be made to the supply chain.

Research on how the organizational structure is affected by changing the focus from the engineering to the supply chain would also be something to look further into. Can a company, which has had one business philosophy for so many years, be able to adapt to the changes.

Finally, further research can be conducted on the trends in the market. Are they sustainable, or will the customers want customized or standardized cranes in the future. By researching this topic, NOV can prepare themselves on whether or not to continue the focus on cost and lead-time reductions. This will give them a better understanding whether or not to put all their focus into new modules and designs, or just keep that as an alternative to the ETO cranes. Further research on the area might prepare NOV better for possible changes in market.

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8.0 Appendencies

8.1 Interview

1. How did this project begin?
   Where, why and who decided upon this?

2. What is your role in this project? Elaborate please.
   a. Do you have final say in the decision making?
   b. Do you supervise all parts of the process?

3. What are your thoughts about the project?
   a. In regards to NOV Molde itself, sustainability with modularized cranes, the market, competition, customers.

4. What pros can the project have for NOV Molde?
   a. In regards to the demand, market, customers, and operations.

5. What cons can the project have for NOV Molde?
   a. In regards to the demand, market, customers and operations.

6. What types of risks do you consider this project to have? Your thoughts.

7. Are there any pitfalls that NOV Molde should pay attention to in the project?

8. Of these pitfalls, is there one or more that should be paid extra attention to in the project?

9. Will the new project have any influence with consideration to the ETO crane?
   a. Is the new crane competing in the same market as the existing crane, or are the customers divided in two different segments of the market?

10. Will there still be more or less the same demand for the ETO-crane?

11. Can your existing business model derive or take advantage from the implementation of this project?

12. NOVs cranes are associated with high quality, have you considered that this opinion might be changed when NOV supplies a less expensive standardized crane?

13. Your thoughts on whether or not NOV will continue to focus on standardization to cut down cost and time even more?

14. Do you believe that this will be the beginning of a 100 % standardized crane from NOV Molde?

8.2 ETO crane Cost table for crane T6179

				4 808	5 000	314 374	2 641 913	2 956 287	5 562	369 146	565 882	2 022 343	2 957 371
				INFO	INFO	1	2	3=1+2	INFO	4	5	6	7=4+5+6
				Budg.	%	Budget	Budget	Budget	Current	Current	Current	Current	Current
Proj	Sec	Act		MH	Done	HrsC	Cost/Ite	SumC	MH	HourC	OtherC	Ite	SumC
T6179	2	1000	Project Management	1 016	100	66 634	10 147	76 781	1 017	66 735	10 147	0	76 882
T6179	2	1001	Cushion	0	0	0	0	0	0	0	0	0	0
T6179	2	1035	Document Control	244	100	13 344	0	13 344	244	13 345	0	0	13 345
T6179	2	1100	Travel Expenses	0	100	0	36 453	36 453	0	0	36 453	0	36 453
T6179	2	2100	Design Mechanical	235	100	16 709	0	16 709	235	16 709	0	0	16 709
T6179	2	2110	Design Mechanical Follow Up	235	100	18 922	2 040	20 962	235	18 922	2 040	0	20 962
T6179	2	2200	Design Hydraulic	16	100	914	0	914	16	914	0	0	914
T6179	2	2210	Design Hydraulic Follow Up	31	100	2 243	0	2 243	31	2 242	0	0	2 242
T6179	2	2300	Design Electrical	56	100	3 244	0	3 244	56	3 244	0	0	3 244
T6179	2	2310	Design Electrical Follow Up	173	100	11 667	0	11 667	173	11 667	0	0	11 667
T6179	2	2350	Programming	53	100	3 968	0	3 968	53	3 968	0	0	3 968
T6179	2	2400	Design Review	0	0	0	0	0	0	0	0	0	0
T6179	2	2500	Structural Calculation	89	100	6 421	0	6 421	89	6 422	0	0	6 422
T6179	2	3100	Techn. Spec,Procedures,Doc	0	0	0	0	0	0	0	0	0	0
T6179	2	3200	Data Books (MRB)	70	100	4 105	0	4 105	72	4 278	0	0	4 278
T6179	2	3300	User`s Manual	8	100	435	0	435	8	435	0	0	435
T6179	2	3400	Approval Third Party	0	100	0	23 411	23 411	0	0	5 242	18 169	23 411
T6179	2	4100	Procurement Components	233	100	16 268	0	16 268	233	16 269	0	0	16 269
T6179	2	4200	Procurement Fabrication	409	100	34 785	0	34 785	409	34 784	0	0	34 784
T6179	2	5100	Preservation/Packing Crane	63	100	4 218	713	4 931	63	4 218	713	0	4 931
T6179	2	5200	Shipm. Crane Parts	0	0	0	7 283	7 283	0	0	7 283	0	7 283
T6179	2	5201	FII Molde - Polen	15	100	1 084	4 422	5 506	15	1 084	4 422	0	5 506
T6179	2	5202	Internal transport Polen	0	100	0	1 506	1 506	0	0	101	1 405	1 506
T6179	2	5203	FII Molde til Hochang	18	100	1 311	11 803	13 114	18	1 311	2 236	9 567	13 114
T6179	2	5205	Airfreight	3	100	199	9 682	9 881	3	199	5 449	4 984	10 632
T6179	2	5206	Main Comp. Polen-Hochang	0	100	0	59 800	59 800	0	0	59 800	0	59 800
T6179	2	6200	Ext. fabr. Hochang	0	100	0	568 727	568 727	0	0	1 439	567 288	568 727
T6179	2	6201	Ext. fabr. Boom	0	100	0	0	0	0	0	0	0	0
T6179	2	6202	Ext. fabr. Crane frame	0	100	0	0	0	0	0	0	0	0
T6179	2	6203	Ext. fabr. A-Frame	0	100	0	0	0	0	0	0	0	0
T6179	2	6204	Ext.fabr. Machinery house	0	100	0	74 439	74 439	0	0	3 198	71 242	74 439
T6179	2	6205	Ext. fabr. Winch	0	100	0	62 382	62 382	0	0	641	61 741	62 382
T6179	2	6206	Ext. fabr. Cabin	0	100	0	22 351	22 351	0	0	-2 098	24 449	22 351
T6179	2	6207	Ext. fabr. Bolt Package	0	100	0	52 825	52 825	0	0	0	52 825	52 825
T6179	2	6208	Ext. fabr. Pedestal Adapter	0	100	0	0	0	0	0	0	0	0
T6179	2	6209	Ext. fabr. misc.	0	0	0	0	0	0	0	0	0	0
T6179	2	6211	Ext. fabr. hydr. tank	0	100	0	25 458	25 458	0	0	0	25 458	25 458
T6179	2	6300	Assy Mech. HUB	0	100	0	138 785	138 785	0	0	8 343	130 441	138 784
T6179	2	6400	Assy Hyd.,Molde	0	100	0	16 560	16 560	0	0	-1 597	18 157	16 560
T6179	2	6500	Assembly Electrical	0	0	0	0	0	0	0	0	0	0
T6179	2	6501	Assy Eid Elektro	0	100	0	23 762	23 762	0	0	0	23 762	23 762
T6179	2	6502	Assy Mach. House- HUB	0	100	0	0	0	0	0	0	0	0
T6179	2	6503	Assembly Cabin - HUB	2	100	138	0	138	2	138	0	0	138
T6179	2	6600	Prod./Site Survey / QC	367	100	14 416	10 123	24 538	367	14 418	10 121	0	24 538
T6179	2	6601	QC Polen fabr.	198	100	12 579	11 759	24 338	198	12 580	11 759	0	24 340
T6179	2	6602	QC Polen Ass. EL.	42	100	2 653	3 610	6 263	42	2 653	3 610	0	6 263
T6179	2	6603	QC Polen Ass. MEK.	67	100	4 151	2 735	6 886	67	4 151	2 735	0	6 886
T6179	2	6604	QC Polen Ass. HYDR.	41	100	2 553	3 577	6 130	41	2 553	3 577	0	6 130
T6179	2	6605	QC Korea	781	100	47 443	41 754	89 197	781	47 444	41 754	0	89 198
T6179	2	6606	QC Testing	0	100	0	177	177	0	0	177	0	177
T6179	2	7000	Planning for installation	0	100	-1	0	-1	0	0	0	0	0
T6179	2	7100	Testing	268	100	18 323	23 296	41 619	268	18 324	23 295	0	41 619
T6179	2	7200	Factory Acceptance Test (FAT)	75	100	5 648	-1 226	4 422	75	5 648	-1 226	0	4 422
T6179	2	7300	Installation/Commissioning	0	0	0	350 923	350 923	757	54 458	296 465	0	350 923
T6179	2	8000	Mechanical Components	0	100	0	583 523	583 523	0	0	4 294	579 229	583 522
T6179	2	8100	Hydraulic Components	0	100	0	202 776	202 776	0	0	21 629	181 147	202 776
T6179	2	8200	Electrical Components	0	100	0	256 338	256 338	0	0	3 860	252 478	256 338
T6179	2	9988	FCA-Full Cost Absorption Allo	0	0	0	0	0	0	0	20	0	20
T6179	2	9994	Currency adjustment	0	0	0	0	0	0	0	0	0	0
T6179	2	9998	Waranty	0	0	0	0	0	1	35	1	0	35
T6179	2	9999	Contingency	0	0	0	0	0	0	0	0	0	0

8.3 Modularized crane cost

Sect.	Actv. No.	Activity Name	Cost Center / Dep. No.	Qt. Hours	Cost/Hour [USD]	Weight	Cost [NOK]	Cost [EUR]	Cost [USD]	Total Cost [USD]
2	900	Package Start Date								0,00
2	1000	Project Management	721	450	106,97					48 136,50
2	1001	Project Management - Equipment Responsible	743	250	99,15					24 787,50
2	1035	Document Control	722		80,42					0,00
2	1100	Travel Expenses					250 000,00			42 500,00
2	2100	Design Mechanical	743	150	99,15					14 872,50
2	2101	Design Pedestal	743		99,15					0,00
2	2102	Design Base Frame	743		99,15					0,00
2	2103	Design Boom	743		99,15					0,00
2	2105	Design A-Frame	743		99,15					0,00
2	2106	Design Machinery House	743		99,15					0,00
2	2107	Design Winch	743		99,15					0,00
2	2108	Design Cabin	743		99,15					0,00
2	2110	Design Mechanical Follow-up	743		99,15					0,00
2	2200	Design Hydraulic	770	80	92,30					7 384,00
2	2210	Design Hydraulic Follow-up	770		92,30					0,00
2	2290	Design Hydraulic 3D Model	770		92,30					0,00
2	2300	Design Electrical	761	100	94,11					9 411,00
2	2310	Design Electrical Follow-up	761		94,11					0,00
2	2350	Programming	762	100	95,03					9 503,00
2	2390	Design Electrical 3D Model	761		94,11					0,00
2	2500	Structural Calculations	741	70	103,23					7 226,10
2	3100	Tech. Specifications & Procedures	722	50	80,42					4 021,00
2	3200	MRB	722	50	80,42					4 021,00
2	3300	User Manual	722	50	80,42					4 021,00
2	3400	Approval Third Party					300 000,00			51 000,00
2	4100	Procurement Components	732	60	98,38					5 902,80
2	4200	Procurement Fabrication	731	150	103,81					15 571,50
2	5100	Preservation & Packing	732	60	98,38		50 000,00			14 402,80
2	5199	Ready for Shipment								0,00
2	5300	Delivery EXW								0,00
2	6201	Fabrication Pedestal				14 459,00	0,00	18 036,60	48 666,10	72 113,68
2	6202	Fabrication Base Frame				18 356,80	0,00	44 375,39	59 203,14	116 891,15
2	6203	Fabrication Boom				32 669,70	0,00	0,00	136 237,21	136 237,21
2	6205	Fabrication A-Frame				25 662,50	0,00	58 721,64	29 213,31	105 551,44
2	6206	Fabrication Machinery House				3 931,00	0,00	25 883,23	0,00	33 648,20
2	6207	Fabrication Winches				5 831,20	0,00	46 196,54	0,00	60 055,50
2	6208	Fabrication Cabin				1 530,00	0,00	39 800,00	0,00	51 740,00
2	6210	Fabrication Machined Parts				884,10	0,00	0,00	15 029,70	15 029,70
2	6211	Fabrication Hydraulic				0,00	0,00	0,00	0,00	0,00
2	6300	Assembly Crane				0,00	0,00	9 177,00	115 435,50	127 365,60
2	6306	Assembly Machinery House				0,00	0,00	30 912,00	0,00	40 185,60
2	6308	Assembly Cabin								0,00
2	6501	Assembly E. Cabinets				398,00	440 322,79	0,00	0,00	74 854,87
2	6602	Production site Survey / QC Poland	733				250 000,00			42 500,00
2	6603	Production site Survey / QC Korea	733				400 000,00			68 000,00
2	6990	Internal Transportation	732		98,38		500 000,00			85 000,00
2	7000	Installation Management								0,00
2	7100	Testing	762		95,03		600 000,00			102 000,00
2	7200	FAT	762		95,03		150 000,00			25 500,00
2	7300	Installation & Commisioning								0,00
2	8000	Mechanical Components				20 929,25	309 792,00	108 843,60	69 800,00	263 961,32
2	8100	Hydraulic Components				2 503,09	12 500,00	139 054,88	5 618,00	188 514,35
2	8200	Electrical Components				3 400,74	562 511,89	54 288,00	1 854,85	168 056,28
2	8995	Transportation Components	732		98,38					0,00

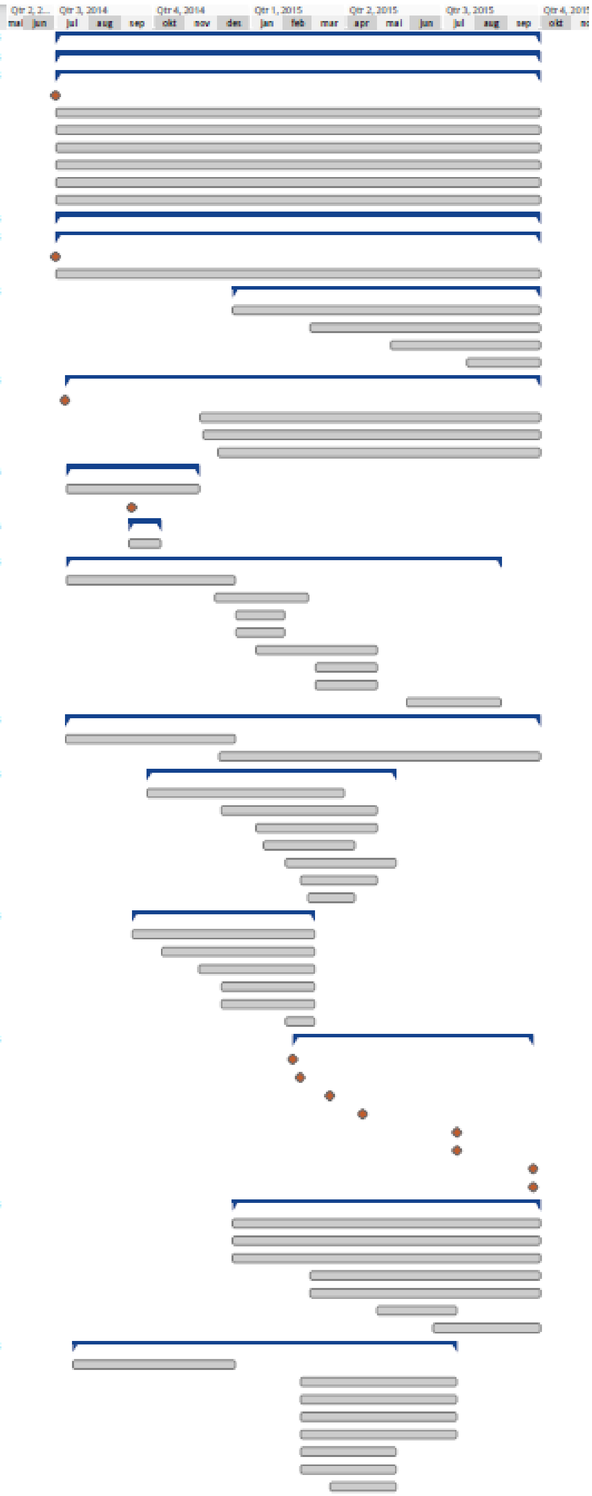
8.4 *Example of lead time for a NOV crane*

NATIONAL OILWELL VARCO

Project: Z1318

Printed: 30.04.2014

Name	Description	Start	Finish
Z1318	**Standard Crane**	**01.07.2014**	**01.10.2015**
Z1318	**Main Project**	**01.07.2014**	**01.10.2015**
01 PROJECT MANAGEMENT		**01.07.2014**	**01.10.2015**
Z1318-2-0900	Project Start Date	01.07.2014	01.07.2014
Z1318-2-1000	Project Management	01.07.2014	01.10.2015
Z1318-2-1020	QA/HSE	01.07.2014	01.10.2015
Z1318-2-1025	Project Planning	01.07.2014	01.10.2015
Z1318-2-1030	Project Controlling	01.07.2014	01.10.2015
Z1318-2-1035	Document Control	01.07.2014	01.10.2015
Z1318-2-1040	Project Support	01.07.2014	01.10.2015
Z1319	**Crane 1**	**01.07.2014**	**01.10.2015**
01 PROJECT MANAGEMENT		**01.07.2014**	**01.10.2015**
Z1318-2-0900	Project Start Date	01.07.2014	01.07.2014
Z1318-2-1000	Project Management	01.07.2014	01.10.2015
02 DOCUMENTATION		**15.12.2014**	**01.10.2015**
Z1318-2-3400	Approval Third Party	15.12.2014	01.10.2015
Z1318-2-3100	Techn. Spec, Procedures, Doc	26.02.2015	01.10.2015
Z1318-2-3300	Users Manual	13.05.2015	01.10.2015
Z1318-2-3200	Data Books (MRB)	24.07.2015	01.10.2015
03 GENERAL ENGINEERING		**10.07.2014**	**01.10.2015**
Z1318-2-1250	Design Basis Meeting / DR1	10.07.2014	10.07.2014
Z1318-2-2710	Design Mechanical Follow Up	14.11.2014	01.10.2015
Z1318-2-2720	Design Hydraulic Follow Up	17.11.2014	01.10.2015
Z1318-2-2730	Design Electrical Follow Up	01.12.2014	01.10.2015
04 MECHANICAL ENGINEERING		**11.07.2014**	**13.11.2014**
Z1318-2-2100	Design Engineering	11.07.2014	13.11.2014
Z1318-2-2101	Design basis ready for procurement	11.09.2014	11.09.2014
05 HYDRAULIC ENGINEERING		**08.09.2014**	**08.10.2014**
Z1318-2-2200	Design Hydraulic	08.09.2014	08.10.2014
06 ELECTRICAL ENGINEERING		**11.07.2014**	**25.08.2015**
Z1318-2-2300	Design Electrical	11.07.2014	17.12.2014
Z1318-2-2370	Main El. Motors	28.11.2014	24.02.2015
Z1318-2-2375	Electrical Cabinets for Machinery House (Power; P...	18.12.2014	02.02.2015
Z1318-2-2376	Electrical Cabinet for Cabin	18.12.2014	02.02.2015
Z1318-2-2373	SRU	06.01.2015	30.04.2015
Z1318-2-2372	Load Cells	03.03.2015	30.04.2015
Z1318-2-2374	Camera Systems	03.03.2015	30.04.2015
Z1318-2-2350	Programming	28.05.2015	25.08.2015
07 STRUCTURAL ENGINEERING		**10.07.2014**	**01.10.2015**
Z1318-2-2500	Design Structural	10.07.2014	17.12.2014
Z1318-2-2750	Design calc. Follow Up	02.12.2014	01.10.2015
08 MECHANICAL - Due Date - Ordering LLI		**25.09.2014**	**18.05.2015**
Z1318-2-2172	Gears & Brakes - Winch	25.09.2014	30.03.2015
Z1318-2-2176	Hook Block & Swivel	04.12.2014	30.04.2015
Z1318-2-2180	Wire (Verope)	06.01.2015	30.04.2015
Z1318-2-2175	Kick Out Sylinder	13.01.2015	09.04.2015
Z1318-2-2174	Slew Bearing	03.02.2015	18.05.2015
Z1318-2-2173	Nuts & Bolts	17.02.2015	30.04.2015
Z1318-2-2177	Wiresheaves	24.02.2015	09.04.2015
09 HYDRAULIC - Due Date - Ordering LLI		**11.09.2014**	**02.03.2015**
Z1318-2-2276	Hydraulic Motors	11.09.2014	02.03.2015
Z1318-2-2277	Hydraulic Pumps	09.10.2014	02.03.2015
Z1318-2-2275	Hydraulic Valveblocks	13.11.2014	02.03.2015
Z1318-2-2272	Oil Cooler	04.12.2014	02.03.2015
Z1318-2-2274	Accumulator	04.12.2014	02.03.2015
Z1318-2-2278	Hydraulic Tank	03.02.2015	02.03.2015
14 COMP AT WORKS		**10.02.2015**	**24.09.2015**
Z1318-2-4524	Comp At Works - Pedestal Adapter Assembly	09.02.2015	09.02.2015
Z1318-2-4526	Comp at Works - Assembly Cabin	17.02.2015	17.02.2015
Z1318-2-4512	Comp at Works - Assembly Machinery House/ HPU	16.03.2015	16.03.2015
Z1318-2-4528	Comp At Works - Winch Assembly	16.04.2015	16.04.2015
Z1318-2-4520	Comp At Works - Final Assembly	15.07.2015	15.07.2015
Z1318-2-4529	Comp At Works - Main Structure Assembly	15.07.2015	15.07.2015
Z1318-2-4531	Comp At Works - Spareparts	24.09.2015	24.09.2015
Z1318-2-4532	Comp at Works - Offshore Installation	24.09.2015	24.09.2015
15 PROCUREMENT		**15.12.2014**	**01.10.2015**
Z1318-2-8000	Mechanical Components	15.12.2014	01.10.2015
Z1318-2-8100	Hydraulic Components	15.12.2014	01.10.2015
Z1318-2-8200	Electrical Components	15.12.2014	01.10.2015
Z1318-2-4100	Procurement Components	26.02.2015	01.10.2015
Z1318-2-4200	Procurement Fabrication	26.02.2015	01.10.2015
Z1318-2-6602	Prod/Site Survey/QC. - Europe	30.04.2015	14.07.2015
Z1318-2-6603	Prod/Site Survey/QC. Korea	22.06.2015	01.10.2015
16 MANUFACTURING		**17.07.2014**	**14.07.2015**
Z1318-2-6211	Fabrication of casted parts	17.07.2014	17.12.2014
Z1318-2-6201	Ext. Fabr. Pedestal	17.02.2015	14.07.2015
Z1318-2-6202	Ext. Fabr. Crane Frame	17.02.2015	14.07.2015
Z1318-2-6203	Ext. Fabr. Boom	17.02.2015	14.07.2015
Z1318-2-6204	Ext. Fabr. A-Frame	17.02.2015	14.07.2015
Z1318-2-6206	Fabrication, Assembly & Test - Machinery House...	17.02.2015	18.05.2015
Z1318-2-6208	Fabrication, Assembly & Test - Cabin -POL	17.02.2015	18.05.2015
Z1318-2-6207	Fabrication, Assembly & Test - Winch - POL	17.03.2015	18.05.2015



Status Date: 22.09.2013

Filter: None

NATIONAL OILWELL VARCO

Project: Z1318

Printed: 30.04.2014

Name	Description	Start	Finish
17 ASSEMBLY		**15.07.2015**	**25.08.2015**
Z1318-2-6301	Assembly Main Structure	15.07.2015	11.08.2015
Z1318-2-6300	Final Assembly Crane	12.08.2015	25.08.2015
18 TRANSPORTATION		**18.12.2014**	**14.07.2015**
Z1318-2-6995	Internal transport – Casted parts	18.12.2014	16.02.2015
Z1318-2-6994	Internal Transport – Winch drums	03.03.2015	16.03.2015
Z1318-2-6993	Internal transport – Pedestal Flange	31.03.2015	02.06.2015
Z1318-2-6990	Internal Transport - Machinery House	19.05.2015	14.07.2015
Z1318-2-6991	Internal Transport - Cabin	19.05.2015	14.07.2015
Z1318-2-6992	Internal Transport - Winch	19.05.2015	14.07.2015
Z1318-2-8995	Transp. Comp. to WorkSHop	19.05.2015	14.07.2015
19 TESTING		**26.08.2015**	**16.09.2015**
Z1318-2-7100	Testing	26.08.2015	14.09.2015
Z1318-2-7200	Factory Acceptance Test (FAT)	15.09.2015	16.09.2015
20 SHIPMENT / DELIVERY		**17.09.2015**	**01.10.2015**
Z1318-2-5100	Preservation/Packing Crane	17.09.2015	30.09.2015
Z1318-2-5199	Ready for Shipment	01.10.2015	01.10.2015
Z1318-2-5300	Delivery Crane	01.10.2015	01.10.2015