UNIVERSITY OF AGDER

Procurement and inventory control in Engineer-to-order businesses

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This Master's thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education.

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Preface

This Master's thesis is the final requisite in the Master of Science degree in Industrial and Technology Management at the University of Agder. It has been carried out in association with Spenncon Hønefoss, Lean Communications, and the Faculty of Engineering and Science, Department of Engineering Sciences, at the University of Agder. The work has been carried out in the period from January to May 2012 and is the equivalent of one semester, or 30 credits.

The subject of the thesis is based on the course OMS 3059 Quality Management and Lean Six Sigma held at Carlson School of Management, University of Minnesota, where both authors attended as exchange students the fall semester of 2011. During the exchange program we acquired a great deal of knowledge in terms of process improvement and lean principles, which has proved to be of great value during this research process.

We would like to thank our advisor Anita Romsdal, researcher at SINTEF Trondheim, for providing guidance and productive feedback towards a pleasing final result. In addition we would like to thank our contact person Gaute Hørlyk, Lean Communications consultant located at Spenncon Hønefoss, for providing us with insightful and constructive assistance vital to our result.

From Spenncon Sandnes we thank Magne Aarsland for taking the time to visit us personally at our location at UiA, Grimstad. His assistance provided us with valuable insight to Spenncon's ERP system iNetto. Last, but not least, we would like to thank the purchasing department at Spenncon Hønefoss by Magnar Dammen and Terje Eriksen for impeccable collaboration and great spirits.

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Abstract

The challenges facing Engineer-to-order (ETO) businesses are increasing product complexity and competition. ETO companies are involved in the design, manufacture and construction of capital equipment and each product is customized to meet customer requirements, and is most often produced in low volume. The inventory of capital goods contains a range of components, from low volume to high volume.

ETO businesses are characterized by a high degree of uncertainty. This is because demand often fluctuates and markets are not easy to forecast due to the uncertainty of future orders from customers. It is therefore better to have access to the raw materials than to have a large inventory of completed goods. There exists a challenge in keeping low levels of raw material inventory, and at the same time successfully supply production with the right materials to maintain promised lead-time to the customer. A high level of inventory is one of the greater costs to any production company.

The subject of the thesis is how to manage procurement, and control inventory in an Engineer to Order (ETO) business. The title is:

"Procurement and inventory control in Engineer-to-order businesses"

This thesis is a case study with Spenncon Hønefoss as research objective, and was done on the basis of the following two research questions:

RQ1. How can ETO companies manage procurement and control inventory?
RQ2. How can Spenncon Hønefoss improve procurement and inventory control?

In order to answer the research questions a literature study has been carried out. Important areas of study have been ETO and supply chain management in such businesses, concepts on lean and just-in-time, more traditional concepts on suppliers and inventory, and process improvement.

Some common challenges identified with ETO companies are such as the high degree of uncertainty due to uneven customer demand, the decoupling point located at the design stage, which again makes forecasting for procurement difficult, the fact that in some cases design will

make decisions without coordinating with procurement, lack of information sharing, both internally and with suppliers, and lack of trust in the supply chain.

The problems identified in the case study are:

- Poor information sharing between departments
- High cost of goods in inventory
- Low inventory turnover
- Drafters do not always use standard components in design
- Little utilization of the ERP system's potential in procurement
- Quantity and reason for purchasing unclear
- Poor information sharing with suppliers
- Supplier contracts are lacking and outdated

The following are suggestions for improvements in Spenncon Hønefoss:

- Make use of company-wide information-sharing through ERP
- Implement just-in-time purchasing, controlled with the help of the ERP system
- Allow longer time for procurement to acquire special components
- Proper implementation, and training of employees in use the ERP system
- Improve information flow between departments and with suppliers
- Develop new supplier contracts stating price, delivery time, and delivery cost
- Help suppliers in developing quality measurements systems

This thesis' main focus has been procurement and inventory control. Focusing on only one part of the supply chain can lead to sub-optimization. Steps have been taken in order to try to include production and production planning in the assessments done regarding the supply chain. It is necessary to note that production planning was not within the main scope.

The work is presented in such a way that it should be relevant for any engineer-to-order and build-to-order businesses. It is believed that especially the precast concrete industry in general can benefit from this work. As for Spenncon, this case study focused on the factory at Hønefoss, but some of the knowledge gained from this thesis should be applicable over the entire range of Spenncon factories in Norway, and even factories across the Consolis group.

For future research a study can be made on the importance of coordination between departments in general in ETO companies. More specifically for the precast industry, and in order to further argue for the use of ERP systems in ETO businesses, a best-practice analysis of similar companies could be done, perhaps Strängbetong in Sweden or E-Betoonelement in Estonia, who both have implemented an ERP system with success.

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1 Introduction

The challenges facing Engineer-to-order (ETO) businesses are increasing product complexity and competition. ETO companies are involved in the design, manufacture and construction of capital equipment and each product is customized to meet customer requirements, and is most often produced in low volume. The inventory of capital goods contains a range of components, from low volume to high volume.

ETO businesses tend to be characterized by a high degree of uncertainty. This is because demand often fluctuates and markets are not easy to forecast, due to the uncertainty of future orders from customers and a large range of products. It is therefore better to have access to the raw materials than to have a large inventory of completed goods. There exists a challenge in keeping low levels of raw material inventory, and at the same time successfully supply production with the right materials to maintain promised lead-time to the customer. A high level of inventory is one of the greater costs to any production company.

A single case study has been chosen as research method and Spenncon Norway has been chosen as research object. There have recently been demands from upper management to reduce the high levels of inventory at Spenncon's six different plants. Our case study takes on a single plant at Hønefoss Norway, where there has, according to management, been poor focus on the process of procurement and little attention given to the level of inventory. Up until this point focus has been to keep inventory levels sufficient to ensure production meets their deadlines.

"The increase of stock, which raises wages, tends to lower profit"
Adam Smith, the Wealth of Nations, 1776

In order to identify problems and suggest improvements to Spenncon, this thesis has taken the form of an analysis with the current situation presented in an "AS IS"-chapter, resulting in a problem discussion, and suggested improvement to the respected processes.

The title of this thesis is:

"Procurement and inventory control in Engineer-to-order businesses"

This title encapsulates the following research questions:

RQ1. How can ETO companies manage procurement and control inventory?

To contribute with new knowledge an illustrative case study involving the ETO company Spenncon Hønefoss is used. As a result this thesis also looks to find out:

RQ2. How can Spenncon Hønefoss improve procurement and inventory control?

This thesis has a clear focus on procurement and their processes, together with inventory levels. It will only aim to analyze and suggest improvements to this part of the production facility. In addition reflections and discussions have been made with regards to the relationships and contracts with the suppliers.

Even though Spenncon has in total six production units in Norway, our work is focused on a single plant located at Hønefoss. Though the production involves a vast number of materials, our focus has been limited to reinforcing steel and embedded components. This decision was made in cooperation with the management at Spenncon Hønefoss. The reason for this choice is that of the four product categories, these two have shown the highest potential for improvement.

The structure of the thesis can be viewed in the following figure:

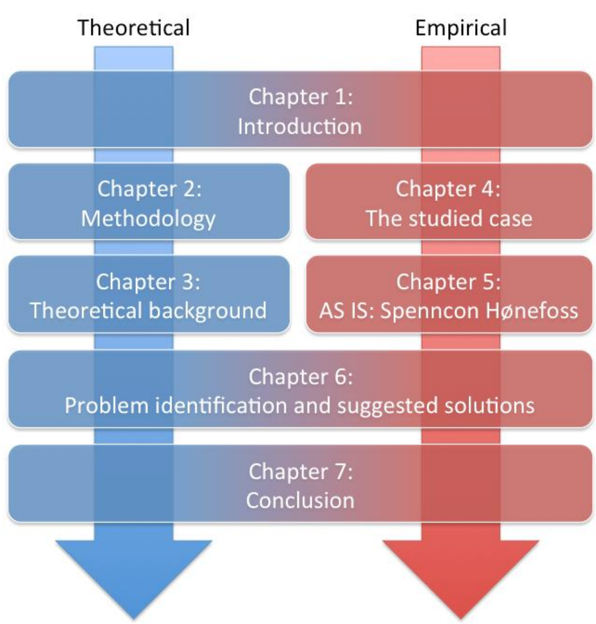

Figure 1: Thesis structure

2 Methodology

This chapter provides a review of the selected methodology in this thesis. The design of research, or the method, describes how to proceed in collecting information and how this information should be analyzed and processed. This thesis uses a single case study with a chosen Engineer-to-order business as research object. The method is inspired by Yin (2003). The argument for choosing case study as research method can be viewed in the following table:

Strategy	Form of Research Question	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case study	How, why?	No	Yes

Table 1: Relevant Situations for Different Research Strategies (COSMOS Corp. in Yin 2003)

According to Yin (2003), the specific strategy of case study has its advantage when a "how" or "why" question is being asked about a contemporary set of events over which the investigator has little or no control. The argument is that the research question "How can ETO companies best manage procurement and inventory?" requires no control of behavioral events, and focuses on contemporary events.

In brief, the case study method allows researchers to retain the meaningful characteristics of real-life events, such as organizational and managerial processes. It is also preferred in examination of contemporary events, but only when the researches cannot manipulate the relevant behaviors. In order to carry out such a case study, a research design can prove useful.

This thesis makes use of Yin's Four Design Tests (Yin, 2003) as criteria for judging the quality of the research design. Because a research design is supposed to be a logical set of statements, one can also judge the quality of any given design according to certain logical tests. The four tests are:

- *Construct validity:* Establishing correct operational measures for the concepts being studied.
- *Internal validity:* Establishing a causal relationship, whereby certain conditions are shown to lead to other conditions.
- *External validity:* Establishing the domain to which a study's findings can be generalized.
- *Reliability:* Demonstrating that the operations of a study, such as the data collection procedures, can be repeated with the same results.

According to Yin (2003), these four tests have been commonly used to ensure the quality of empirical social research. Yin identifies several tactics for dealing with the tactics in working with case studies. Table 2 on the following page lists the four tests with the given case study tactics, whether they have been performed or not, and the justification of each test.

The Four Design Test suggests the performed research is valid and reliable. However, there is reason to address certain validity tests not performed in the research. The fact that key informants have not reviewed drafts of the case study report may give rise to questions as to why this was not done. The limited time span for this research resulted in a decision to not wait for various key informants to review drafts of the entire report and produce feedback. Instead, the informant has reviewed statements and assumptions with direct connection to the informant. This has been a continuous process throughout the entire research period. The people involved in making the process flowchart also reviewed the chart.

With regards to internal validity, pattern matching, and the use of logical models, this has not been carried out due to limited time. Pattern matching requires the researcher to be present at the company for greater lengths of time comparing an empirically based pattern with a predicted one. The use of logical models is another type of pattern matching and consists of matching empirically observed events to theoretically predicted events. No predictions were made.

Test	Case Study Tactic	Performed	Justification
Construct Validity	• Use multiple sources of evidence • Establish chain of evidence • Have key informants review draft case study report	Yes Yes No	• More than one source of information has been used when possible. • There is a clear link between evidence and results. • Statements and assumptions have been consulted with the respective informant. Result of interviews, incl. flowchart, reviewed by informants.
Internal Validity	• Do pattern matching • Do explanation-building • Address rival explanations • Use logical models	No Yes Yes No	• No predicted patterns were made. • Empirically based behavior compared with theoretically expected behavior. • Has been addressed when applicable • No logical models were made.
External Validity	• Use theory in single-case studies • Use replication logic in multiple-case studies	Yes No	• Theory has been used to support empirical research. • Not a multiple-case study.
Reliability	• Use case study protocol • Develop case study database	Yes Yes	• Project plan, research design, and suggested thesis structure has been consulted throughout the research period. • Documented evidence, company data, and interviews are collected in a database.

Table 2: Case Study Tactics for Four Design Tests, COSMOS Corporation in Yin 2003

The information regarding processes in Spenncon Hønefoss has been collected from two involving parties, Spenncon Hønefoss' purchasing department and Lean Communications. The information has been collected from key informants within the parties and could, to some degree, be biased. Information about Spenncon's ERP system iNetto has been collected from a two sources, Spenncon Norway's ERP responsible and the iNetto User's Manual. The researchers have never used iNetto themselves. The information regarding purchasing orders made in 2011 has been collected from Spenncon Hønefoss and their suppliers, and comparisons have confirmed the match.

Even though this is a case specific study, the results can be used in other production facilities in Spenncon, regardless of location. The research regarding procurement processes should also apply to other Engineer-to-order companies. The suggested improvements are made in order for Spenncon Hønefoss to employ for all present and future relevant processes.

2.1 Research Design

Churchill and Iacobucci (2005) present their research design as illustrated in Figure 2. This was chosen as the path to follow through the project. With a proper research design the process of justification and validity can be made easier.

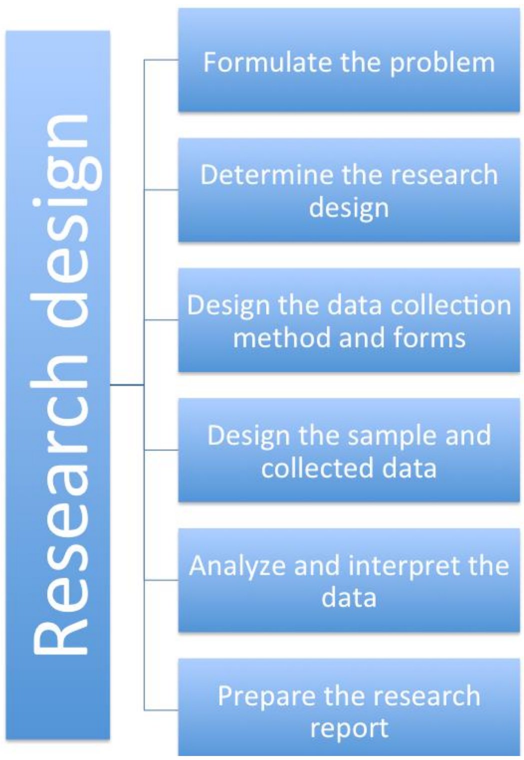

Figure 2: Research Design (Churchill & Iacobucci, 2005)

2.1.1 Formulate the problem

The first part of the research process is to formulate the problem by presenting a title for the thesis and specifying research questions. Our title and research questions are based on empirical data and theory, and were developed in collaboration with Spenncon Hønefoss and Lean Communications. During the research period different aspects regarding the situation at Spenncon Hønefoss were discovered.

2.1.2 Determine the research design

As defined earlier with the help of Yin, this is a single case study with data collected from Spenncon's production facility at Hønefoss. This provides great involvement in this company's processes, but makes it more challenging to generalize the results to fit other companies. As the "AS IS"-chapter will show, Spenncon is an Engineer-to-order company, and some of the conclusions and documentation can be transferred and applied to other companies.

Churchill and Iacobucci (2005) recognize three types of research design; Exploratory, Descriptive and Casual research. We have been using descriptive research. This is because exploratory is a type of research conducted for a problem that has not been clearly defined, while both descriptive and casual researches are aimed at more precisely formulated problems. Descriptive research describes data and characteristics about the population or phenomenon being studied, and this is where data collection is specified in the way that both data collection and sample design will produce precise results and conclusions.

2.1.3 Design the data collection methods and forms

The next step is to define the methods and the data to collect. Johannessen, Kristoffersen, and Tufte (2011) divide the methods into qualitative and quantitative. Both methods have been used in this thesis. The qualitative method is used when investigating the why and how of decision-making. With this, smaller but often more focused samples are needed, than with the quantitative method. The quantitative method is used when doing empirical investigation of social phenomena via statistical, mathematical or computational techniques.

Next, Churchill and Iacobucci (2005) divides data into primary and secondary data and both have been collected. Secondary data are data collected by someone other than the researcher. Such are company facts, financial data, supplier contracts and inventory data, all provided by Spenncon or Lean Communications. Primary data are gathered by the researches. Examples in this thesis are information regarding processes and supply chain structure.

Yin (2003) presents six sources of evidence that aimes to describe the most commonly used ways to collect data in a case study. The six are; documentation, archival records, interviews, direct observation, participant-observation, and physical artifacts. This thesis has based its data collection on three of the six, namely documentation, archival records and interviews. Documentation has provided information about Spenncon's supplier contracts, procedure guidelines, inventory lists, and its ERP system iNetto. Archival records are business records such as income statement, supplier invoice records, and inventory tracking documents. Interviews have mainly provided information about the process of procurement.

During open interviews of key personnel it was essential to let the interview subject talk freely in order to get a broad perspective and listen to their opinions, without guiding them in any direction. This was important to gain knowledge about the process of procurement at Spenncon Hønefoss and how people involved experience their part of the process. In addition some questions were written before the interviews in order to acquire knowledge about specific areas. Interviews were also essential to develop the process flowchart.

The reasons for not including the last three of the sources were mostly due to lack of time or that the source did not apply to the research done. Direct observation and participant-observation was considered time consuming and not necessary. Physical artifacts were considered not to be applicable.

2.1.4 Design the sample and collect data

In order to create a theoretical background, secondary resources such as scientific articles and books have been selected, much in cooperation with advisor Anita Romsdal from SINTEF.

The empirical collection has been based on sources from Spenncon Hønefoss' procurement, financial, and ERP departments, and interviews of personnel from the respective departments. Information gathered are inventory levels from January 2011 to February 2012, the entire business statement for Spenncon Norway for 2011, and invoice records for 2011 from the following suppliers; FN Steel, Celsa Nordic, Halfen DEHA, Pretec and SB Produksjon. In addition information regarding the purchasing department, their processes, and iNetto has been gathered through interviews. The interviews have been located at Spenncon Hønefoss and UiA, and have been followed up by e-mail and telephone. Questions have been asked to multiple people in order to get a broader perspective and to uncover different aspects on the topic.

2.1.5 Analyze and interpret the data

In order to find an answer to the previously stated research questions the data were summarized and edited. The documentation and the information gathered from interviews have been compared and collected in an "AS IS"-description. As a result of the "AS IS"-description a chapter covering the problem discussion was written. The chapter ends in a summary of all observed problems regarding company, inventory, production planning, procurement processes and supplier relationships.

2.1.6 Prepare the research report

The research report summarizes the results, conclusions and recommendations. This includes the "AS IS"-description, problem discussion, and the suggested improvements. The report should be of such standard that it could be used by Spenncon Norway as documentation, review of internal processes and a guide to implementation of the suggested improvements.

2.2 Summary

This chapter has argued for the choice of research design and method. In order to carry out a research project a proper research design must be applied. This thesis is a single case study with a chosen Engineer-to-order business as research object. The argument given complies with Table 1 presented by Yin (2003). The research design follows that of Churchill and Iacobucci (2005), with smaller moderations, and the validity is argued for using Yin's Four Design Tests.

3 Theoretical Background

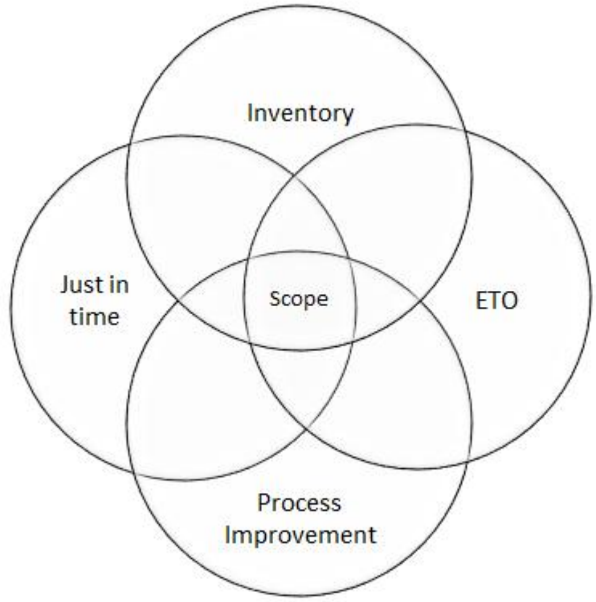

Figure 3: Scope

This chapter presents the current theoretical principles related to the research questions, and the discussion around these. In order to cover the scope of this case study (Figure 3), this chapter starts off with an introduction to engineer-to-order businesses and theory regarding supply chain in this type of businesses, followed by concepts of lean and just-in-time. It continues with traditional concepts linked to suppliers, followed by functions of inventory and cost of inventory. As this thesis will be suggesting improvements to procurement and inventory management at Spenncon Hønefoss, the theory chapter is rounded off with an introduction to theory and concepts related to process improvement. In each of this areas the most important and relevant principles have been chosen. After each section in this chapter a summary of the key aspects of that specific theoretical principle can be found.

3.1 Engineer-to-order

ETO companies, also called Build-to-order (BTO)[1], are involved in the design, manufacture and construction of capital equipment. ETO includes mostly assembly operations where the components and parts are outsourced (Gunasekaran & Ngai, 2009). Each product is customized to meet customer requirements and is most often produced in low volume. The inventory of capital goods contains a range of components, from low volume to high volume.

3.1.1 Introduction to ETO

The industry tends to be characterized by a high degree of uncertainty. This is because demand tends to be uneven. Each unit of demand can require a large proportion of capacity. Markets are

[1] This thesis does not distinguish between the terms ETO and BTO.

not easy to forecast due to the order being entirely customer driven. Product specifications and sales volumes can differ greatly from customer to customer. Forecasting the demand is therefore difficult due to the customized nature of the products.

In an ETO business the production order is driven by actual customer orders, with the customer order decoupling point (CODP) at the design stage (Gosling & Naim, 2009). The customer is therefore exposed to the total production time. This includes conceptual and detailed design, procurement, manufacturing, assembly, testing and commissioning. To improve the reliability of lead-time estimates, it is required to have accurate forecasting of activity durations at the contract negotiations and planning stages.

It is possible to distinguish two different types of processes:

- The non-physical, which includes engineering design and planning activities.
- The physical, which includes component manufacturing, assembly and installation.

Between an ETO company and its customers and suppliers, there are two different stages of interaction.

The first stage is a response to a tender invitation for a particular contract and involves the preliminary development of the conceptual design and the definition of major components. Selected suppliers are contacted in order to obtain information on costs and lead times. This can often include a number of phases of negotiation, which aims to match overall project costs and lead-time with requirements from the customer and the market (McGovern, Hicks, & Earl, 1999). More information is provided on supplier relationships in section 3.3. Only non-physical activities are associated with the tendering response. This includes design, estimation, and planning. Crucial to success at this stage is to have absolute technical understanding of customer requirements, as well as being able to meet price, delivery, and quality requirements.

The second stage takes place after a contract has been signed. The initial non-physical activities are development of an overall plan and detailed design. Procurement, component manufacturing, assembly, construction, and commissioning follow this. The level of physical activity associated with manufacturing, assembly and construction depends on the level of vertical integration.

3.1.2 Supply chain management in ETO

Companies in the ETO sector, as other sectors, seek to reduce costs, shorten lead times, and manage risks. The transactions carried out between companies in the supply chain are characterized by adding value to the product as it moves down the chain (McGovern et al., 1999). In order to compete in the market it is important that the supply chain is flexible to adjust to shifting demands. This is especially important in the case of volatile and uncertain markets, where companies and supply chains need to adapt quickly in order to compete with other companies (Gosling, Naim, & Towill, 2012).

The common model of a large-scale economically powerful focal manufacturer supported by smaller and economically weaker suppliers is quite inappropriate in context with ETO companies. It is actually common to find power biased toward the supplier in an ETO supply chain relationship. This is due to the fact that many items are only required in low volumes and on an infrequent basis. The value of the purchase order might not be of very high significance to the supplier.

Supply chain management literature has mainly been focused on buyer-supplier relationships in the automotive sector and is not necessarily translatable to describe the ETO supply chain. It is also found that the general supply environment for ETO companies is characterized by far more dynamic change than in other sectors, such as the automotive industry. The uncertainty of demand limits the scope for developing long-term supply chain relationships. The research of McGovern et al. (1999) reveals that many ETO companies are engaged in multi-sourced adversarial trading. This means the trading assumes a game-like appearance, which is characterized by win-lose transactions and mutual mistrust. They found little evidence of strategic linkage between company and suppliers.

ETO companies' competitive advantage derives through understanding customer requirements, translating them into specifications at product level, and integrating components into the product. Detailed technical specifications may constrain design choices for the supplier. Some important product features that affect customer satisfaction must be specified to the supplier. The challenge of ETO companies is to control design to meet stated and unstated customer requirements.

3.1.3 Procurement in ETO companies

Procurement is the acquisition of goods or services. Procurement decisions may take place in three ways:

- Customers specify their preferred suppliers;
- The sourcing of components is specified at the tendering stage; and
- Design Engineering may specify items during the product development process.

The manufacturing and procurement decisions made early in the stages of product design might impose constraints. These arise as a result of decisions made at the tendering stage. The decisions sometimes take place by default as designers select items from a supplier catalogue based on functionality, without coordinating with procurement. It is not uncommon for it to be little reuse of engineering designs. According to McGovern et al. (1999), there is anecdotal evidence that many designers enjoy the creative challenge of developing new configurations. These give rise to unnecessary variety that increase cost, lead time, uncertainty and risk, which in terms make procurement and supply activities more complex.

According to Burt and Doyle (1993), about 80 percent of avoidable costs are controllable at the design stage. This means that early involvement of procurement in tendering and product design decisions is essential in order to reduce costs.

3.1.4 Summary

To summarize, the following characteristics and challenges are found within ETO companies:

- High degree of uncertainty due to uneven customer demand and therefore;
- Forecasting is difficult, the customer order decoupling point located at the design stage.
- Projects are often a respond to a tender
- Products customized to meet customer requirements
- Common to have power biased toward the supplier
- Little strategic linkage observed between company and suppliers

- Competitive advantage derives through understanding customer requirements
- Design makes decisions without coordinating with procurement

3.2 Lean thinking and Just-in-time

Two important concepts that are impossible to get around when working with supply chain and process improvement in production facilities are lean and just-in-time (JIT). Both are greatly influenced by Japanese automotive industry and overlap one another, even though they have their own characteristics.

3.2.1 Lean thinking

The term Lean production refers to approaches in production that originated in Ford Motor Company in the early 1900s. Womack, Jones, and Roos (1990) introduced the term "Lean Production" in 1990 in the book *The Machine That Changed the World*. It is a summary of a five year long American research program, "International Motor Vehicle Program", which functioned as a benchmarking of the global automotive industry. The reason for this research was American Automotive industry's continuing loss of market shares to Japanese competitors. The term "lean" reflected Toyota's production system. Experience show that Toyota's way of organizing production and value chain is both flexible and cost efficient, compared to more conservative methods according to Evans and Lindsay (2010). Toyota managed to show that high level of quality does not equal high cost.

According to Womack and Jones (1996), lean thinking can be summarized as:

1. Correctly specify and enhance value;
2. Identify the value stream for each product and remove wasted actions (*muda*);
3. Make the product flow without interruptions;
4. Let the customer pull value from the producer; and
5. Pursue perfection

"Lean thinking can be applied to any industry from agriculture to aerospace and any process from repetitive manufacturing to customized assembly."

(Motwani, 2003)

Management must focus on each product and its value stream. Their goal must be to enhance the value and eliminate all waste. These principles are the foundation for mapping and analyzing value streams (Kalsaas & Askildsen, 2009). Companies that strive towards implementing lean production must expect the process to take at least five years to completely change the culture within the organization (Womack & Jones, 1996).

After implementing changes in the company it is time to implement them at suppliers and customers. This is what Womack and Jones (1996) refer to as “lean enterprise”, which is very much the same as managing a value chain. Womack and Jones argue that the company that is leading the lean enterprise is the company that is responsible for production and assembly. This is the last step in the value chain where the value stream converges and transform into an end product, ready to be shipped to the customer.

Waste

The basic principle of lean is responsiveness to change and minimization of waste (Motwani, 2003, pp. 339 – 346). Waste is anything that does not add value to the process, that does not add value to the product and/or that the customer would be unwilling to pay for. Toyota’s Chief Engineer, Taiichi Ohno, as a part of the Toyota Production System, identified seven wastes. In recent time an eight waste have been added. The following eight are commonly sources of waste in production:

- Transportation
- **Inventory**
- Motion
- Waiting or Work in Process
- Over-processing
- Over-production
- Defects
- Under-utilization of people

The scope of this research emphasizes inventory, which is either raw materials, work-in-progress (WIP), or finished goods. It represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value, is referred to as a waste.

3.2.2 Just-in-time

Just-in-time is a concept first introduced by the Toyota Motor Corporation. This total manufacturing system encompasses product design, equipment selection, materials management, quality assurance, line layout, job design, and productivity improvement. With the use of JIT a company will try to reduce the size of inventory as much as possible to increase its productivity, improve quality, and to reduce production lead times. The Toyota Production System was developed over a period of twenty years. In comparison to their competitors Toyota ended up with higher quality, lower cost, and less labor time per vehicle. By the mid-1980s a large number of international manufacturing firms had taken a strong interest in understanding and trying to replicate Toyota's system.

Just-in-time mainly consists of two core elements; use as little resources as possible and eliminate all waste. Waste is all that generate costs, but add no value for the customer (see section 3.2.1). As with Toyota, anyone else that is successful in practicing JIT will find that they have to move towards greater flexibility, a simpler way of production, and more integration.

JIT starts with locating and studying the problems, finding the causes, and making improvements through elimination of those causes. A production facility can use buffer inventory to cover up problems in the production unit. By removing such cover-ups one can expose the problems and take correct action. When a problem is properly taken care of, the company will be left with both an improvement and a reduction of inventory – with equal reduction in capital previously needed to conceal the problem.

However, it is important to notice that for ETO SCM, production scheduling and delivery time optimization for suppliers should have different criteria for optimization than in traditional SCM. The timing of JIT supplies should be based on the supplier's promised delivery time and the production schedule (Gunasekaran & Ngai, 2009). This way the company can obtain order quantities that reflect the actual upcoming need in production.

With this strategy it is important that the goods delivered from suppliers are correct type and quantity, and that the quality is guaranteed for. The essence of JIT purchase is that it is based on mutual trust and partnership. Suppliers must function as a part of the team, which in term means fewer suppliers, more sole suppliers, and less time looking for suppliers. JIT argues that the indirect cost of working with a long-term supplier relationship is lower than that of a tender based purchase system, even if the price level can look favorably on a short-term basis.

3.2.3 Summary

The essential aspects of this chapter are:

- Lean is responsiveness to change and minimization of waste
- Inventory represents a capital outlay that has not yet produced an income
- Buffer inventory can be used to cover up problems
- JIT supplies must be based on promised delivery time and production schedule
- It is important that supplier deliveries are accurate and quality-assured
- JIT purchase is based on mutual trust and partnership
- Long term supplier relationships are favorable

3.3 Supplier relationships

McGovern et al. (1999) found evidence of companies recognizing the importance of developing better and more collaborative relations with their suppliers because purchased items and services can account for up to 80 percent of contract value. This section introduces some theoretical principles related to suppliers and supplier relationship. The supplier can be an external outsourced company delivering to the vendor, or it can be integrated in to the business hierarchy through vertical integration.

There are disagreements about what way is the best for managing a supplier relationship. Cox (2004) states that the diversity in the argumentation from the adoption of transparent, win-win partnering; on the other hand is the diametrically opposed zero-sum approach associated with win-lose outcomes. Win-win partnering is based in a trusting, long-term arrangement and it is a part of the philosophy of “lean thinking”.

In section 3.1.2 it is stated that ETO supplier relationships are multi-sourced win-lose transactions. Win-lose partnering is a more difficult concept, and relates to zero sum game, but there is some semantic confusion as in reality no trade made is truly zero sum. Win-lose is relating to exchanges made under coercion, when one part has power over another to force trough a trade that is less optimal (Yeung, Selen, Zhang, & Huo, 2009). The win-lose trades can also occur because of information asymmetry, that is because one part of the trade is missing information that can alter the gain form the trade. This asymmetry can be caused by opportunistic behavior.

3.3.1 Opportunistic behavior

This opportunistic behavior creates, in theory, a fear that leads to strict contracts that increases the transaction cost. According to Granovetter (2008) the construction industry stated "their contracts are designed with the possibility of liability lawsuits and court subpoenas in mind." This is not the best means to build trust. By close cooperation with suppliers the company is able to secure deals, which guaranties a stable price and supply of merchandise, and creates a stable customer relationship for both parts.

The theory presented in section 3.2.2 about just-in-time argues that the indirect cost of working with a long-term supplier relationship is lower than that of a tender based purchase system, even if the price level can look favorably on a short-term basis. According to the 4th key principle of Dr. W. Edwards Deming's fourteen key principles for transforming business effectiveness (Evans & Lindsay, 2010): *"Purchasing departments have long been driven by cost minimization and competition among suppliers without regards to quality".* This is supported by the transaction theory, which states that a business can seek to reduce uncertainty in transactions with suppliers through minimizing the information asymmetry and opportunistic behavior (Kalsaas & Askildsen, 2009).

Information asymmetry, in the economic sense, deals with the study of decisions in transactions where a party possesses better or more information than the other part. Asymmetric information can lead to adverse selection, a market process in which bad results occur when buyers or sellers have access to different information. Most commonly, information asymmetries are studied in the context of principal–agent problems.

3.3.2 The principal-agent problem

The principal-agent problem treats the difficulties that occur under the conditions of incomplete and asymmetrical information when a principal hires an agent to pursue the principal's interests. The problem lays in potential moral hazard and conflict of interest. Moral hazard is undue risk taken because the party that takes the risk does not carry the related costs. When the agent is chosen the principal carries all the risk related to uncertainty of the agent acting in the principal's best interest.

The principal-agent theory has its source in contract law, where it is known as *The Law of agency.* "Mechanisms" are used to try to align the interests of the agent in solidarity with those of the principal. Kalsaas and Askildsen (2009, p. 62) list two types of mechanisms the principal could use:

- Behavior oriented contracts (compensation per hour, km, etc.)
- Result oriented contracts (compensation per unit, distance driven, etc.)

Behavior oriented contracts are theoretically related to leadership as hierarchical control. While result oriented contracts uses incentives like commission, bonus for early delivery and liquidated damages for late deliveries. Kalsaas and Askildsen (2009) state that a good contract will include the proper mix of both types. This contradicts what Dr. William Edwards Deming (1986) says in his seven deadly diseases of management about evaluating the agents by performance or merit rating (The 3rd disease), and what was presented in section 3.3.1 about opportunistic behavior and building mutual trust. Either way contracts are still needed.

As stated in section 3.1.1, ETO companies can have an unpredictable demand pattern. By taking this into account when negotiating with suppliers, an agreement where the supplier are willing to buy back the surplus inventory at the end of an set time period could lead to decreased overall costs related to the goods. Formulating contracts in the form (w_1,w_2,b), where w_1 is the wholesale price offered for production mode, and i and b is a return price offered for items left over at the end of a time period (Gunasekaran & Ngai, 2009). Such a contract can coordinate the manufacturer and distributor to act in the best interest of their relationship.

3.3.3 Suppliers and Quality

With inventories reduced to its barest minimum, the quality of materials must be higher. There is no buffer inventory to handle the losses due to quality. Because of this it is important to collaborate tightly with the supplier to ensure optimal quality control in all their processes. The investment, monetary or otherwise, done with regards to supporting suppliers in their design, production and quality control will pay off through savings in reduced inspection of received goods, material handling, and inventory. The amount of paper work in the purchasing department can also be greatly reduced due to a higher level of control. To provide an example, Motorola provides extensive assistance and training to their suppliers to improve capabilities and quality, and expects results in return (Evans & Lindsay, 2010). A reduction in the number of suppliers can lead to a closer relationship and reduce delivery cost, provide stabile quality and increase delivery service (Dale, Ragnheiður, & Strandhagen, 2004).

3.3.4 Summary

The key takeaways from this chapter are:

- A business can seek to reduce uncertainty in transactions with suppliers through minimizing the information asymmetry
- Good contracts are important
- The company should collaborate with suppliers to ensure optimal quality control before components are shipped

3.4 Information systems

Mutually sharing information among the supply chain members is, as stated in section 3.1.1, an essential part of handling the supply chain in ETO businesses, especially when it comes to planning and monitoring processes. In this section Material Requirements Planning and Enterprise Resource Planning will be introduced. Decisions about material flow in ETO and BTO supply chains are separated from traditional supply chains. IT/IS (Information Technology/Information Systems) is the backbone and refer to electronic data interchange (EDI), Internet, WWW, and Radio Frequency Identification (RFID). These can all be part of providing an open platform and shared-information system for customer-supplier links along the supply chain. Tight integration among partnering firms can only be achieved by these IT/IS. (Gunasekaran & Ngai, 2009)

Most of the activities in ETO supply chains are carried out using IT/IS and in a virtual enterprise mode. The control of material flow is therefore driven by customer orders. These trigger the production orders for the assembly line, and the schedule of the assembly line becomes the order to suppliers of different components and parts. Some material flow decisions include scheduling, inventory control, MPS, MRP/ERP, and Process Control.

3.4.1 Material Requirements planning

Material Requirements Planning (MRP) is a production planning and inventory control system used to manage manufacturing processes. MRP is mostly software based, but it is also possible to conduct MRP by hand. This type of production planning saw the light of day in the 1960's and quickly grew as modern computers became more and more available.

MRP is used to ensure that materials are available for production and products are available for delivery, while maintaining the lowest inventory possible. Planning manufacturing activities, delivering schedules, and purchasing activities are required in order to achieve this.

The system is based on a breakdown of part-lists to calculate a material need. The material need is then time shifted according to lead times and added to a gross need. By subtracting available material, you will end up with a net need that has to be purchased or produced.

The breakdown is done with a Bill of Material Processor (BOMP). Demand estimates are done through MRP/I-logic (Material Requirements Planning) or MRP/II (Manufacturing Resource Planning). This depends if it is material or production planning. The size of the cycles can be the purchase order or the customer need.

Information required for MRP

To successfully carry out material requirement planning the following input information is needed:

1. The master production schedule projected out to the planning horizon
2. The inventory status of all items, including backorders
3. The timing and quantities involved
4. All the relevant bills of materials and associated level codes
5. All routings, only needed in capacity requirements planning
6. Production or procurement lead-time offset for each operation
7. Possible scrap/yield allowance

Additional information may be needed in order to determine the replenishment quantities for any specific item (Silver, Pyke, & Peterson, 1998).

Uncertainties in MRP

The normal approach to uncertainty is to introduce safety stock. The idea is that safety stock is not really appropriate in a dependent demand situation. Shortages and excess inventories can be effectively avoided through the adjustment of lead times by shifting priorities of shop and vendor orders.

In general frequent expediting should be avoided. It is necessary to consider safety stock, or safety time, which is scheduling a purchase order for completion ahead of required time. The sources for uncertainty in MRP are:

- Supply timing
- Supply quality (yield)
- Demand timing
- Demand quantity

Research on dealing with the uncertainties in MRP concludes that safety time is only preferable to safety stock when it is possible to make accurate forecasts of future required shipments. Otherwise safety stock is a more robust way of coping with changes in customer requirements or with deviations from the forecasts (Silver et al., 1998, p. 613).

3.4.2 Enterprise Resource Planning

Enterprise Resource Planning (ERP) is an extension of the MRP. The main difference between the two is that MRP is mainly a tool for the production department while ERP lets the entire firm operate from the same data. The most used ERP systems run on a single database (Silver et al., 1998).

Because all functions of the production operate with the same data, coordination is made a lot easier. When the customer alerts the sales department of an upcoming purchase, the sales person queries the ERP system for delivery time and price. Because the same system is used in production, inventory, and production planning, the data available should be very accurate for providing a delivery time. When the purchase order is accepted, the sales department enters what, and how much, the customer has ordered. This is then instantly available to the inventory and purchasing department. They are able to determine what and when materials are needed for production of that specific customer order.

This continues all the way through the value chain down to the billing department where the original customer order was entered by the sales department, and any modifications can be looked up. The customer can then be billed accordingly.

3.4.3 Summary

The key aspects presented in this section are:

- Tight integration among partnering firms can be achieved through IT/IS
- MRP is a production planning and inventory control system used to manage manufacturing processes
- MRP is used to ensure that materials are available for production and products available for delivery
- Uncertainties in MRP are supply timing and quality, and demand timing and quality
- ERP is an extension of MRP
- ERP lets the entire firm operate from the same data

3.5 Inventory

Presented in this section are the inventory functions and different concepts linked to inventory-stocked goods. While not necessarily groundbreaking theory it is of importance for the upcoming chapters that a joint understanding of inventory terminology has been established.

Inventories are considered to be the most important portion of a business' assets (Silver et al., 1998). The size of an inventory can greatly impact the business financial results because the cost of keeping inventory is a major factor, and can take a big chunk out of the profit margin. High inventory sizes do not only cost a lot to keep, they are bad for the business financial performance measures. This can result in that the company appears less profitable than it really is.

3.5.1 Inventory functions

There exist four different categories of goods stored in inventory (1) Raw materials, basic materials that are essential to the production. (2) Work-in-progress, transitional storage of goods and parts. (3) Finished goods, storing of the finished goods in pending transportation to the customer. And (4) MRO items, Maintenance Repair Operation item storage (Johnson, Leenders, & Flynn, 2011). A short lead-time on spare parts is important to the business for it to be able to sustain a high level of customer service.

This thesis is mainly concerned with the raw materials stored in inventory. There are five types of inventory where raw materials can be stored; Pipeline, Cycle, Buffer, Anticipation, and to some extent decoupling inventory.

Transit or pipeline inventories are used to stock the supply and distribution pipelines linking an organization to its suppliers and customers as well as internal transportation. Transit inventories are dependent on location and mode of transportation.

Cycle inventories arise do to the fact that that items are purchased, transported, and produced in lots rather than continuously. The size of cycle inventories is a trade-off between the cost of holding inventory and the cost of making more frequent purchase orders and/or setups.

Buffer, uncertainty, or safety stock gives protection against variability in supplier performance due to shutdown, strike, lead-time variations, late deliveries, poor quality items, and so on.

Anticipation or certainty inventories are accumulated for well-defined future needs. Seasonal inventories are a great example of an anticipation inventory. Other reasons for anticipation inventories include; strikes, weather, shortages, or announced price increase. These are all reasons that can be assumed beyond a reasonable doubt.

Decoupling inventory function can be performed by all inventories. They make it possible to continue activities on each side of a process linkage. Raw materials exist only on one side of the first process, as once the raw material has been processed it is no longer raw; it's a work-in-progress. It is recognized as a unique category as it is an excellent area for negotiations (Johnson et al., 2011).

3.5.2 Inventory's impact on business finances

Inventories have an important impact on the balance sheet and the income statement. Both of these are widely used aggregate scorecards[2] of management performance. According to Silver et al. (1998) the inventory impacts the following post on the balance sheet. Note: While all are not relevant to the case study, it is important to know which factors inventory affects.

From an accountant's point of view, inventory is a current asset. That is an asset that can be converted to cash or used to pay current liabilities within twelve months. Current liabilities are defined as all liabilities, or outstanding depth, that the company is to settle in cash within twelve months. There are five major items included in current assets: Cash, short-term investments, accounts receivables, inventory, and repaid expenses.

[2] Scorecard is a strategic performance management tool.

Operating profit

The income statement represents the flow of revenue and expenses for a given period.

Operating profit = Revenue – Operating expenses

Equation 1: Operating Profit

The cost of carrying inventory represents a significant component of operating expenses. Reducing the combined inventory level will decrease the inventory carrying charge, and thus decrease operating expenses. Changes in inventory level also affect the sales revenue on a short-term basis. Decreasing inventory level will inevitably result in that more of the inventory is used than is purchased, which leads to an apparent[3] increase in sales profit.

Costs of carrying inventory

Silver et al. (1998) argue that for every item carried in the inventory, the cost of having it must be less than the cost of not having it. This is the only reason why inventories exist. The costs of carrying inventory are not easy to accurately quantify, due to the many variables.

Direct inventory cost factors

Carrying, or holding cost, is the cost of carrying items in inventory. Carrying cost is difficult to calculate accurately, due to the many factors that influence it, and the variability of many of the factors. The carrying cost can be extrapolated from the following formula:

$$Carrying\ cost\ per\ year = \bar{I}\,vr$$

Equation 2: Carrying cost

Where $\bar{I}$ is the average inventory in units. *V* the *unit value* is the price, including freight paid to the supplier, plus any cost incurred during the value adding process, expressed in NOK per item. *r* the c*arrying charge* is the cost in NOK of carrying one NOK of inventory for one year.

The carrying charge is only related the keeping inventory, which include, but is not limited to, the following factors:

[3] The inventory has at some point in time been paid for.

Warehousing costs	Rent Utilities Salaries Insurance Property Tax
Financial costs	Opportunity cost[4] Obsolescence Pillage Damage Insurance Price fluctuation
Cost of special storage requirements	Temperature Humidity

Table 3: Inventory cost factors

The largest portion of the carrying charge is by far the opportunity cost related to having capital tied up in inventory that could otherwise been used elsewhere, and the opportunity cost related to warehouse storage space claimed by inventory.

Costs related to the decision of reducing inventory

As stated in the section above, the cost of having inventory is dependent on its value and size. By reducing the size of the inventory the company is able to reduce its inventory carrying costs. However, reducing the inventory increases the rate of replenishment, or *inventory turnover.* There are costs that depend on the ordering of goods and refilling the inventory, which needs to be addressed before a decision to reduce inventory size is taken.

Ordering cost denotes the fixed cost associated with replenishment. It includes, but is not limited to: Telephone calls, authorization, typing of purchase orders, receiving, and inspection. They do not include the actual cost of the product and delivery.

Stock out cost is the cost of having insufficient capacity in the short run. They include emergency shipment or substitution of a less profitable item.

Variations in delivered cost are costs associated with purchasing in quantities, or at times when prices or delivery costs are higher than at of other quantities or times. Suppliers often offer certain quantities or times of the year at discount. Purchasing in in different quantities or times

[4] Opportunity cost is the cost related to picking the second best choice among several mutually exclusive choices. This is the difference in return, monetary or otherwise, between the alternative chosen and the one that is foregone.

may result in higher purchase or transportation costs, but buying in larger quantities may result in significantly higher carrying cost

Setup cost is the cost of setting up a production run. A reduction in setup costs would allow smaller production runs and consequently smaller purchasing orders, more frequent deliveries, and smaller inventory.

Replenishment lead-time is defined as the time that elapses from the moment the purchase order is placed until it is in the warehouse, ready to use. This is not a direct cost but it is important in the consideration inventory size.

3.5.3 Inventory turnover

The primary performance measurement for inventory management is inventory turnover. This is a measure of the number of times the inventory is used in a set time period.

$$Inventory\ Turnover = \frac{Cost\ of\ goods\ used}{Average\ inventory}$$

Equation 3: Inventory turnover

Turnover is a useful measure. A low turnover rate may point to overstocking, which lead to higher carrying costs. A high turnover rate may indicate inadequate inventory levels, which may lead to a loss in business. The balance point is highly subjective.

3.5.4 Risk connected to having and not having inventory

Risk is present no matter what supply strategy is used. Risk is the state of uncertainty where some of the possibilities involve loss. It is important that it is carefully assessed so that the risks are known. Being aware that there exists a risk factor will help to prevent any unforeseen incidents (Johnson et al., 2011).

Risks related to inventory are:

- Stock-out – is insufficient capacity. This leads to emergency shipment or substitution of a less profitable item.
- Obsolescence – a product or materials falls into disuse or become out of date
- Theft – one of the greatest risks especially with high value inventory
- Loss of inventory

- Price fluctuation – risk of having capital tied up in highly volatile assets
- Damage

The largest risk with zero inventories lies in the uncertainty that the material will be delivered in time for production start. Childerhouse, Hermiz, Mason-Jones, Popp, and Towill (2003), argue that there is the presence of this uncertainty that stimulates the creation of buffers in inventory. Gosling et al. (2012) further state that this uncertainty can be mitigated through flexibility in the supply chain. Flexibility is a reflection of the ability of a system to change, or react with little penalty in time, effort cost or performance.

3.5.5 Focusing inventory control

Peter Kraljic postulated Kraljic's model in his article; "Purchasing must become supply management" published in 1983 in the September issue of Harvard Business Review. The model shows the importance of focusing purchasing departments to spend their time on those products that matters most. The matrix developed for this model utilizes two dimensions to classify a company's materials or components.

Value: "Defined in terms of volume purchased, percentage of total purchase cost, or impact on product quality or business growth." (Kraljic, 1983)

Market Risk: "Is assessed in terms of availability, number of suppliers, competitive demand, make-or-buy opportunities, and storage risk and substitution possibilities." (Kraljic, 1983)

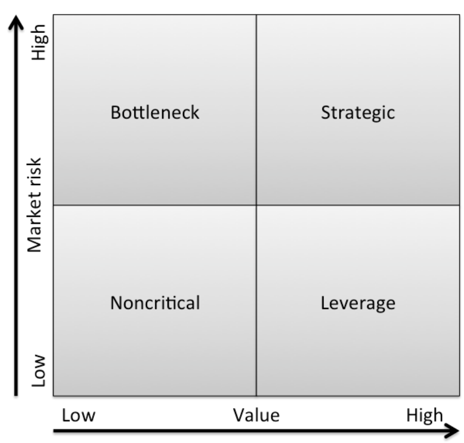

Figure 4: Kraljic's matrix

As seen in section 3.5.2 there are costs related to the size of the inventory kept. Due to this there are developed many methods for optimizing the size of the inventory. The following two sections will briefly describe a method for classifying inventory items, and the pros and cons of forecasting.

ABC Analysis

This is a technique used in inventory categorization and material management. It is also known as selective inventory control. It is used to design individual decision models for different categories of goods. The ABC analysis provides a mechanism for identifying items that will have a significant impact on overall inventory cost while also providing a mechanism for identifying different categories of stock that will require different management and controls (Silver et al., 1998).

This theory suggests that inventories are not of equal value. The inventory is grouped into three categories A, B, and C (hence the name) in order of their estimated significance.

‘A’ items – very important
‘B’ items – important
‘C’ items – marginally important

The ‘A’ items require, because of their higher value, a more frequent analysis, and an organization needs to be able to choose appropriate purchase order pattern to avoid excess capacity. ‘B’ items are less important than ‘A’ items and require less frequent analysis and strict order patterns, but still more than ‘C’ items.

For ETO businesses it is important to have the required goods in time for production while still controlling costs related having them available. By organizing according to value it is possible to split the procurement strategy into several different categories according to value.

Forecasting, and the cost there of

Forecasting is the use of statistical tools to create demand pattern of a specific product. Due to this difficulty forecasting should be used carefully, as the forecasts will be in error. Planning and control procedures should thus reflect the presence of such errors. It is, for example, it is necessary to have safety stock in case of stock outs. Depending on the scope of the forecast the costs of forecasting errors can be very high; The American company Fruit of the Loom lost more the 40 million USD in the first half of 1994 due to "lost sales and excess hiring and firing" (Silver et al., 1998, p. 74) caused by poor forecasting.

$$E(\text{Total cost of using the procedure}) = E(\text{cost of operating}) + E(\text{Cost of errors})$$

Equation 4: Cost of operation

The main concern is keeping the expected relevant cost as low as possible. These costs should include both the cost of obtaining the forecast and the cost of using the forecast, i.e. the cost of forecasting errors.

3.5.6 Summary

When it comes to inventory, it is important to keep in mind that:

- Both holding and not holding inventory costs money
- Holding inventory ties up monetary resources
- The biggest uncertainty with inventory is stock-out
- The biggest uncertainty without inventory is delivery time and quality
- Strict control over the inventory and procurement is required to reduce that size of said inventory
- Costs of forecasting errors can be very high

3.6 Process Improvement

This section is about improving the process of procurement and inventory management. To sensibly do this, there is the need for some theory about process improvement. Successful quality and business performance improvement depends on the ability to identify and solve problems (Evans & Lindsay, 2010). The concept of systematic, fact based, and, often statistical, problem-solving approach is difficult for many to grasp. According to Evans and Lindsay (2010) can as many as 75 – 80 percent of the population have a problem with this. Still the uses of such an approach are vital for identifying the source of the problem, understanding the causes, and developing improvements.

Various methodologies for process improvement have been developed over the years. They all share some common concepts (Evans & Lindsay, 2010):

1. *Redefining and analyzing the problem:* Collect and organize information, analyze the data and underlying assumptions, and reexamine the problem for new perspectives, with the goal of achieving a workable problem definition.
2. *Generating ideas:* "Brainstorm" to develop potential solutions.
3. *Evaluating and selecting ideas:* Determine whether the ideas have merit and will achieve the problems solver's goal.
4. *Implementing ideas:* Sell the solution and gain acceptance by those who must use them.

In an organization there should be process owners who are responsible for process performance and have the authority to manage and improve their own processes. Assigning process owners ensures that someone is responsible to manage the process and optimize its effects.

"Improvement should be a proactive task of management and be viewed as an opportunity, not simply as a reaction to problems and competitive threats."
J.R. Evans and W.M. Lindsay, Manage for quality and performance excellence, 2010

3.6.1 Critical to quality

Much of the process improvement literature is about quality and Six Sigma. High quality is paramount in every process. Material that does not arrive on time can be a quality defect in the transportation process or with the suppliers. Work-in-progress inventory piling up between two steps in production is a quality defect in the production planning. Developed by Motorola in 1986, Six Sigma is an example of a business management strategy that seeks to improve the quality of process outputs by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes.

3.6.2 Employee involvement

It is important to include the affected employees in the improvement process. No one knows a process better than the people that work with it every day. These people can possess knowledge that would might otherwise never been discovered. Another reason for including employees in the process is that this leads to a more open flow of information. This follow of information is vital for encouraging the will to change.

The will to change requires that the need for change is clear and that employees have faith in the fact that they can change. The will to change represents the cognitive assessment that is done before a change, resulting in either resistance to or support for a change. Resistance is a natural part of a process of change. The resistance arises when one move from something known to something unknown and people fear and avoid situations they believe they cannot master. This is why it is difficult to change established thinking- and behavior patterns (Burnes & James, 1995).

Information is a key aspect in preventing this resistance. Informing the employees will be important in order to motivate staff towards the change. Most unwillingness to change comes from lack of knowledge. Proper training is also important the feeling of not mastering or understanding the skills needed can greatly reduce motivation. Proper ways pull this off can be found in theory on organizational change, like Lawrence & Lorche, Buckley & Perkins, Lewins, and John P. Kotter.

3.6.3 Lean tools

Among tools for improvement in Six Sigma methodology we find seven simple tools: Flowcharts, check sheets, histograms, Pareto diagrams, cause-and-effect diagrams, scatter diagrams, and control charts. For this thesis we will focus mainly on the basic flowchart as a process improvement tool of choice in order to understand the process of purchasing materials and what initiates a purchase order. Control charts are used to understand order frequency.

Flowchart

A flowchart identifies the sequence of activities or the flow of materials and information in a process. Flowcharts help the people involved in the process understand it much better and more objectively by providing a picture of the steps needed to accomplish a task (Evans & Lindsay, 2010). According to Evans and Lindsay (2010), the best way to develop flowcharts is by having people involved in the process help construct the flowchart. Relevant questions in the process are such as; “What happens next?” “Who makes the decision at this point?” and “What operation is performed at this point?”

Through the activity of making a flowchart all employees can come to understand how they fit into a process and who are their suppliers and customers. By participating there can be felt a sense of responsibility and ownership over the process which can lead to more willing work to improve it. In addition, the new perspective can result in better communication with other employees also involved in the process. Once a flowchart is constructed, it can be used to identify quality problems as well as areas for process improvement.

3.6.4 Summary

The essentials from this chapter are:

- The underlying premise is that improvement derives from knowledge
- This knowledge comes from engineering management, or how a process is made easier, more accurate, faster, less costly, safer, or to better meet customer needs
- Most of process improvements are about acquiring the needed level of knowledge to possess insight into the process to be able to identify the underlying problem
- The improvement process can begin once the root causes of the problems are identified
- Successful quality and business performance improvement depends on the ability to identify and solve problems

4 The studied case

As was outlined in the introduction, the research questions will be demonstrated by a case study involving Spenncon Hønefoss. This chapter is a brief introduction to Spenncon Norway and its suppliers.

4.1 Spenncon Norway

Spenncon AS is one of Norway's leading suppliers of prefabricated concrete elements. The company has over 700 employees and a turnover of more than 1.2 billion NOK. They are a part the international business group Consolis. The group has revenue of 1.8 billion euro, with more than 10,000 employees in over 25 countries.

4.1.1 History

On June the 13th 1961 Tor B. Aslaksrud, Helge E. Tronrud and Oscar Semb, founded "Forspent Betong AS" on Hensmoen, not far from Hønefoss, Norway. Their goal was to produce prefabricated concrete elements. Shortly after the production started at Hensmoen, business was going well and the company acquired several of its competitors in Norway through the 70's and 80's. In the beginning of the 1990's the company, by now called "SpennGruppen AS", was bought by the Finnish company "Partek", and restructured. In 1996 the sister companies created during the restructuration process merged and took the name "Spenncon AS". In 1997 the parent company "Partek" sold "Spenncon AS" to "Addtek", which a year later changed its name to "Consolis", and is today the current owner of "Spenncon AS". [5]

4.1.2 Manufacturing Style

Spenncon is an Engineer-to-order company. This statement is based on the observation of Spenncon sharing the following characteristics and challenges with other ETO companies:

- Projects are often a respond to a tender
- Companies may only have a short time to respond to a call for tender
- Products customized to meet customer requirements
- High degree of uncertainty due to uneven customer demand and therefore;
- Forecasting is difficult, the customer order decoupling point located at the design stage.
- Little strategic linkage observed between company and suppliers

[5] http://www.spenncon.no/i.asp?Omoss

4.1.3 The ERP system iNetto

Spenncon Norway has since 2004 used a company-wide ERP system called iNetto, specifically designed for the pre-cast industry. It was developed by Consolis' Finnish subsidiary Parma and was completed in 2003. Other companies are Strängbetong in Sweden and E-Betoonelement in Estonia. In addition iNetto is used in a number of other countries, namely Latvia, Lithuania, Poland, Czech Republic and Hungary. The ERP system includes material register, tendering, construction, products, material receipts, procurement, transportation, and an option for supplier involvement. Read more about the use of iNetto in section 5.3.3.

4.1.4 Production

Spenncon Hønefoss produces prefabricated concrete elements. These products are: Hollow core slabs (Figure 5, left), columns, beams, railway sleepers (Figure 5, right) and switches, insulated walls, facades, shafts, MOFIX foundations, tunnels, edge elements, and balconies. Around ten percent of the production is standard products. The standard production is mostly related to the production of railway sleepers. The remaining is produced to specific customer orders.

Figure 5: Hollow core slabs (left) and railway sleeper (right)

4.1.5 Components

This section will briefly describe the different components that are used in concrete element production.

Reinforced steel is a long piece of steel that is cast into the concrete element to absorb tension and shear loads. It also increases the tensile strength of the concrete. While reinforced steel is technically an embedded component, it will be seen as a separate component for the sake of clarity. Spenncon uses three different kinds of reinforcing steel; bar, mesh, and PC strand. Reinforcing bars are basically steel bars; mesh is bars in a grid pattern; and PC strands are reinforcements used in pre-stressed concrete to increase the maximum span width of the concrete, and are designed to handle large tension loads.

Embedded components are a generic term for components that are cast into the concrete to achieve desired features. This includes lifting anchors, welding plates, fastening anchors, insulation, and plastic supports to hold the reinforced steel in place, to name a few.

4.2 Spenncon's suppliers

Spenncon deals with a variety of suppliers, two suppliers of reinforced steel and several of embedded components. Some of these will be addressed in more detail in the "AS IS"-description.

4.2.1 Suppliers of reinforcing steel

Spenncon Norway currently has two suppliers of reinforced steel. These suppliers are decided on tender by the parent company Consolis. For the entire year of 2011 and the start of 2012, Spenncon Norway's reinforced steel suppliers were Celsa Nordic (reinforcing bar and mesh) and FN steel (PC Strand).

4.2.2 Suppliers of embedded components

Spenncon Norway has several suppliers of embedded components: Pretec, SB produksjon, Halfen-DEHA, Peikko, Hagex, Tools, and TESS, to name some. Each purchasing department is free to choose their own suppliers.

4.3 Lean Communications

Lean Communications is a consultant company that was assisting Spenncon Norway with business improvements in the field of lean production at the time this research was carried out. They are the promoters of this case study. Lean Communications is working as consultants at Spenncon on an 18-month contract. The company was founded in the autumn of 2009 and is located in Munkedamsveien 35, Oslo. They specialize in implementing the lean philosophy through communication[6].

[6] http://www.leancommunications.no/Om%20oss/cid/29925/

5 AS IS: Spenncon Hønefoss

To effectively identify cost-effective changes, or measure the results of those changes, it is necessary to fully understand the existing business processes. This "AS IS" is done with the intent to do exactly this. It will be the basis for the next chapter that will discuss the problems found in this chapter and the possible solutions. All the numbers presented in this thesis are for this production unit, unless stated otherwise. The calculations are done with the data available as of April 1st 2012.

Looking at the current condition of Spenncon's finances will give an idea of the size of Spenncon Hønefoss' economy and its size relative to the monetary resources tied up in inventory. The analysis can also make it possible to, if need be, measure the effectiveness of any solution. Spenncon Hønefoss has for some time had problems with their liquidity. This is why Lean Communications was first involved with them. They helped Spenncon Hønefoss reduce its finished goods inventory, among other things. Spenncon's liquidity is now gradually improving.

Earnings before interests and taxes	Spenncon Hønefoss
Revenue	362 295 365,00 NOK
Sum direct costs	319 692 085,00 NOK
Sum indirect costs	24 366 909,00 NOK
Administrative costs	13 066 021,00 NOK
Extraordinary costs	6 851 659,00 NOK
Operating income before JC	-1 681 309,00 NOK
Joint costs	18 555 000,00 NOK
EBITDA	-20 236 000,00 NOK
Depreciation and amortization	13 321 000,00 NOK
Operating income (EBIT)	-6 915 000,00 NOK

Table 4: Spenncon Hønefoss' finances

Spenncon Hønefoss sold goods and services for 362.3 million NOK in 2011. To achieve this they used materials for 115.4 million NOK according to their 2011 balance sheet. Earnings before interest and taxes (EBIT) or operating profit ended on 6.9 million NOK in the red.

5.1 Inventory

As stated in the theoretical background section 3.5.2, inventory can have a great impact on a business' financial state. A detailed look at the state of the inventory can narrow it down to a more specific factor. The analysis will give an indication of how much is in the inventory. It is also important it determine the flow of materials through the inventory.

5.1.1 Spenncon's inventory

Spenncon's raw materials inventory is comprised of four groups of materials

Concrete	Reinforced steel	Embedded components	Casting and production materials
Sand	PC strand	Ass. products	Ass. products
Silica	Reinforcing bar		
Gravel	Reinforcing mesh		
Concrete			

Table 5: Raw material inventories

The three first categories of material are directly used in the production and will result in the goods that are sold to the customer. The last category, casting- and production materials, are accessories that facilitate the production of goods. This includes wood for casts, saw blades, etc.

5.1.2 Inventory cost distribution

The cost of the goods in the raw material inventory was on average 11.3 million NOK in 2011. Distributed as follows:

	Average per month 2011	Percent of total cost of inv.
Concrete	379 176 NOK	3.4 %
Reinforced steel	3 875 170 NOK	34.3 %
Embedded components	6 555 681 NOK	58.0 %
Casting and prod. materials	484 365 NOK	4.3 %
Total inventory	11 294 392 NOK	100.0 %

Table 6: Average inventory

There are 16 items in the concrete category, 23 in reinforced steel, 205 in embedded components, and 30 in casting and production materials. Note that this is the number of individual products (e.g. Wire eye, 8 mm, etc.) in each category.

5.1.3 Cost of goods used

The numbers in Table 6 does not say much about the size of the inventory without any numbers on how much is used in the production.

	Average per month 2011	Total 2011
Concrete	3 472 167 NOK	41 666 008 NOK
Reinforced steel	2 777 967 NOK	33 335 614 NOK
Embedded components	2 606 151 NOK	31 273 813 NOK
Casting and prod. materials	397 480 NOK	4 769 764 NOK
Total used	9 253 767 NOK	111 045 198 NOK

Table 7: Average cost of goods used

This shows the average cost of goods used and the total cost of goods used in 2011. The production suffers somewhat from Easter, summer, and Christmas holidays. The production is fairly constant the rest of the year. As far as growth goes there is a steady increase in production each year.

5.1.4 Inventory Turnover

With an average inventory size 11.3 million, and an average consumption of 9.3 million, there is a little more than one month of production in the inventory on average. This is shown by inventory turnover. The turnover values in Table 8 and Table 9 are calculated for a twelve month time period, January – December 2011, using Equation 3.

	Inventory turnover
Concrete	109,89
Reinforced steel	7,84
Embedded components	4,77
Casting and prod. materials	9,85
Total used	9,83

Table 8: Inventory turnover 2011

The reinforced steel category contains three subcategories and 23 individual products. Since it is only three subcategories, data is available that makes it possible to split the reinforced steel into these tree subcategories and then calculate the turnover individually.

The result in Table 9 shows that the individual turnover rate barely exceeds ten, and it is down to almost four on one of the items.

	Average inventory	Cost of goods used	Inventory turnover	Used per month (avg.)
PC strand	2 012 728 NOK	21 016 154 NOK	10.44	264.32 tons[7]
Reinforcing bar	957 550 NOK	8 691 121 NOK	9.07	121.73 tons
Reinforcing mesh	904 893 NOK	3 628 339 NOK	4.01	46.56 tons
Total for reinforced steel	3 875 170 NOK	33 335 614 NOK	7.84	432.61 tons

Table 9: Inventory turnover 2011 – Reinforced steel

Table 10 contains the individual lay times for the different categories from Spenncon's own inventory tracking document.

	Lay time (Days) (average 2011)	Inventory turnover
Concrete	3,19	109,89
PC strand	32,62	10.44
Reinforcing bar	35,39	9.07
Reinforcing mesh	129,46	4.01
Embedded components	71,19	4,77
Casting and prod. materials	28,31	9,85
Total inventory	35,67	9,83

Table 10: Inventory lay time in days

Included in Table 10 are the inventory turnovers for the categories, for comparison.

5.2 Production Planning

Spenncon have a small portion of standard products (< 10 percent). There is close to no regularity in their production schedule and they need to know what their customers want before they can start production. All sold projects are put into a roughly sketched production plan. This is to ensure production capability can meet demand. There is an internal demand from Head Planner that drawings are completed and delivered at a certain amount of days in advance of this date; there is a ten working days deadline for wet casting and a five working days deadline for hollow-core slab.

[7] Metric ton (1000 kg) calculated from an average price per ton per year

5.3 Procurement

Purchasing is closely related to the state of inventory, but is an integral part of the process that it is necessary to treat separate. Because of this there will be some cross-referencing to data presented in chapter 5. The data available for this part of the analysis is mainly from conversations and interviews with involved personnel.

A purchasing manager runs the purchasing department at Spenncon Hønefoss. In addition there is a main purchaser who handles the act of purchasing materials and also keeps track of inventory. Some of the more general activities, like choosing suppliers and drafting supplier agreements, are done at a company-wide level.

5.3.1 The Manual

Keeping track of inventories is done by manually counting each item or number of packages at the end of each month, and the results are kept in a stock list. To be able to determine what needs to be ordered a manual is consulted. The manual is a list over every inventory item currently kept in Spenncon Norway. It is unclear when the manual was first written, but it has been revised an unknown amount of times since its origination. Last known revision was approximately in 2007 according to sources at Spenncon Hønefoss. At approximately the same time the manual was written into Spenncon's ERP system iNetto.

Every item is listed with a part number, which factory is utilizing the item, and price per unit. In addition every item is stated with a minimum inventory quantity and the quantity to order when the minimum is reached. An example would be that a certain item is listed with 200/1000; where 200 SKU[8] is minimum stock and 1000 SKU order quantity. When the quantity in inventory reaches 200 SKU or less, 1000 SKU is ordered. The uncertainty here is if 200 SKU is the correct minimum level and if 1000 SKU is the correct order quantity. In addition there exists an uncertainty whether the price is still correct and whether the item is still used in production.

5.3.2 Initiation of a purchase order

Even though the manual has a minimum stock level where one should order a set quantity, there is no system in place for alerting whenever a stock should reach minimum. The only system

[8] **S**tock **K**eeping **U**nit

known at this point, and it only applies for a limited number of embedded components, is what is called a “two box”-system. This works on the premise that there are two boxes or pallets of components, when one is empty a new one is ordered. For this to work the order needs to arrive before the last box is empty.

In order to get the best possible perspective on the process of procurement, and to map other ways a purchase order is initiated, a process flowchart was made in corporation with the purchasing department.

The “AS IS” process flowchart:

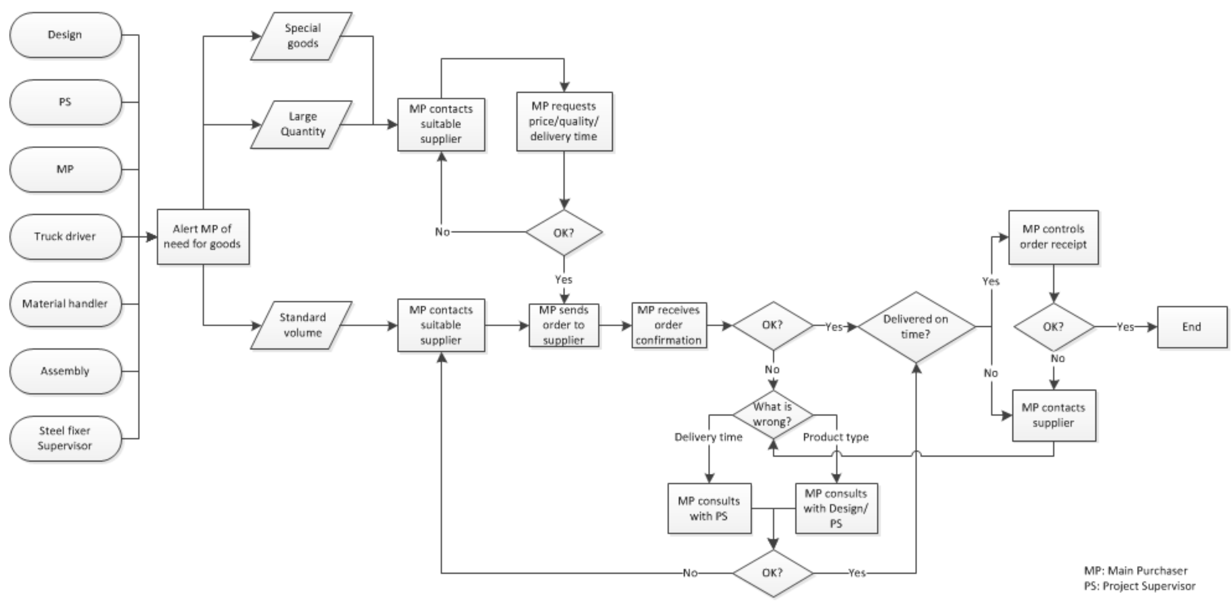

Figure 6: The procurement process (See appendix 9.6 for larger image)

For the main purchaser to take the step to make an order, at least one of the following actions must take place:

- Designer reports of special goods in an upcoming project
- Project supervisor reports of unusually large quantity in an upcoming project
- Main purchaser discovers an item that is below minimum stock during inventory counting at the end of a month
- The truck driver, material handler, assembly, or steel fixer supervisor discovers an item that is below minimum stock at any given time

5.3.3 Use of ERP in purchasing

As first mentioned in 4.1.3, Spenncon Norway uses an ERP system called iNetto. The ERP system is company-wide and includes a variety of functions like Material Register, Proposal, Design, Construction, Products, Material Receipts, Material Consumption, Inventory Value, Transportation, and an Outbox for supplier involvement. However, according to iNetto responsible in Spenncon Norway, not all the functions are yet adapted. This means that functions like the Outbox, Material Consumption and Inventory Value was not yet in use at the time this thesis was written.

Functions that are in use, and are relevant for procurement, are Material Register, Proposal and Design. All of these functions can be used to improve the process of procurement.

Material register was originally created by writing “the manual” into iNetto. It is important to point out that the same system for minimum stock and set order quantity (i.e. 200/1000) applies here, but iNetto needs proper input to utilize this.

Proposal is the action of responding to a tender. As stated in section 3.1.3, one of three ways procurement decisions may take place is that the sourcing of components is specified at the tendering stage. The decisions made at this stage take place by default as designers select items from a supplier catalogue based on functionality, without coordinating with procurement.

Spenncon utilizes iNetto for proposals by making use of the Material Register and produce Material Receipts for intended projects. These receipts are summaries of what materials are required and contribute to pricing the proposal.

Design is the process of designing the product (e.g. concrete elements) for a confirmed project. As stated in section 3.1.3, about 80 percent of avoidable costs are controllable at the design stage. This means that early involvement of procurement in tendering and product design decisions is essential in order to reduce costs.

In addition, a second way of procurement decision-making is when design engineers specify items during the product development process. This is shared through iNetto via CAD drawings. Each template contains a material’s list that is specified when drawing a component and this is automatically exported to iNetto's Material Register. It is known that Spenncon Hønefoss' purchasing department already has some contact with their design engineers regarding upcoming need for special components, but not through iNetto.

5.3.4 Purchasing, Cost of inventory and cost of goods used

The amount of stock in the inventory is directly related to the amount used and the amount purchased. The cost of goods purchased each month is inevitably enough to cover changes in the inventory cost from one month to the next and the cost of the goods used.

$$P = \Delta I + GU + GL$$

Equation 5: Cost of goods purchased

Where *P* is the cost of goods purchased, Δ*I* is the difference in cost of inventory from this month and the previous, *GU* is the cost of goods used, and *GL* is the cost of goods lost to quality, theft, obsolescence, cutting, or other reasons.

Using Equation 5 and numbers from Spenncon's inventory tracking document (goods purchased is not tracked) to calculate the cost of purchased goods each month, gives the data in Table 11. The term *GL* is difficult to measure and thus is assumed to be zero for the intent of this calculation.

Cost of purchased goods	
Jan. 11	12 500 231.97 NOK
Feb. 11	11 912 742.58 NOK
March. 11	11 640 264.16 NOK
Apr. 11	9 442 544.19 NOK
May. 11	10 065 933.07 NOK
Jun. 11	11 134 371.41 NOK
July. 11	1 700 967.86 NOK
Aug. 11	11 734 912.42 NOK
Sep. 11	9 357 602.24 NOK
Oct. 11	10 316 985.21 NOK
Nov. 11	7 510 338.07 NOK
Des. 11	2 897 479.68 NOK
Total 2011	110 214 372.80 NOK

Table 11: Calculated cost of goods purchased

110.2 million NOK were used for materials in 2011 according to this calculation. The 2011 balance sheet states that 115.4 million NOK was used to purchase materials. These facts would make it reasonable to assume that the term *GL* is 5.2 million NOK, i.e. close to five percent of goods purchased is lost due to theft or quality issues. Although this difference can be because the value stated in the balance sheet includes some costs that is not material related to productions. Or it can be a combination of both. A printout from the ERP system iNetto show that five percent of the reinforcing steel is lost due to cutting (a little over 1.6 million NOK), which can explain some of the difference in the values.

5.4 Suppliers

Spenncon Norway has two suppliers of reinforced steel and a number of suppliers of embedded components. This section is not an evaluation of the suppliers, but rather of how Spenncon uses its suppliers. (Print-outs from the distribution calculation, run chart, and key numbers are found in appendix 9.4, 9.5, and 9.6)

5.4.1 Suppliers of Reinforced Steel

The suppliers of reinforced steel are decided through a universal tender that the parent company Consolis handles. This tender is usually three months. In the start of 2012 Spenncon's reinforced steel suppliers were Celsa Nordic and FN Steel. They had also supplied Spenncon for the entire year of 2011.

Celsa Nordic

Celsa Nordic supplies reinforcing bars and mesh to all Spenncon factories in Norway. They are located in Mo i Rana, Norway 970 km from Spenncon's Hønefoss location. Celsa Nordic delivered goods for 13.5 million NOK to Spenncon Hønefoss. This was done through a total of 105 orders and 76 deliveries, which resulted in an average of four workdays between each delivery. Celsa Nordic delivers some embedded components as well as reinforcing steel.

FN Steel

FN Steel is the supplier of PC strand. They are located in Hjulsbro, Lindkjöping, Sweden 525 km from Spenncon Hønefoss. They made 97 orders for a total of 15.2 million NOK to Spenncon

Hønefoss, resulting in 76 deliveries or an average of 4 workdays between each delivery. In addition to PC strand they supply collets for fixing the PC strand to the die.

5.4.2 Suppliers of Embedded Components

As mentioned, Spenncon has many suppliers of embedded components and this thesis will take a closer look at three of them. These were chosen in collaboration with Spenncon Hønefoss' purchasing department. The embedded component suppliers are suppliers Spenncon have chosen themselves. Embedded components are a standard product. Spenncon orders the products they need from the supplier that can provide them at the given time. If none of their suppliers can provide the product, they will find a new supplier that can.

The three suppliers deliver for the most part directly from their own inventory. There are very few products they have to order from their suppliers. Halfen-DEHA, Pretec, and SB Produksjon all have contracts with Spenncon where the trade conditions are outlined. The suppliers, not Spenncon, wrote these contracts. The three suppliers in this thesis constitute only of 1/5th of the 31.4 million NOK Spenncon spent on embedded components in 2011. These three alone stacked up a total of 191 orders and 165 deliveries in the same year.

Halfen-DEHA

Of the three suppliers that were analyzed Halfen-DEHA AB is the smallest with 200 000 NOK and 36 deliveries. Halfen-DEHA is located in Mölnlycke southeast of Gothenburg, about 370km from Spenncon's factory at Hønefoss. An average of six workdays passed between each delivery. Halfen-DEHA is mainly used to supply lifting fixtures.

Pretec

Spenncon placed 111 purchase orders that totaled 2.5 million NOK in 2011. There is no evidence of significant order planning. Pretec made 96 deliveries during the year, averaging three workdays between each delivery. Pretec is located at Borgenhaugen, approximately 150 km from Spenncon Hønefoss. This location might explain the high frequency of deliveries. Pretec explained that the materials that Spenncon orders from them are mainly stock items that are shipped within very few days.

SB Produksjon

SB produksjon is located in Åndalsnes, Møre og Romsdal. Of the three suppliers, this is the one that is located furthest way from Spenncon with 400km. SB produksjon delivered embedded components for 3.8 million NOK in 2011. And is thus the largest of the three studied suppliers. Spenncon uses this supplier to preorder embedded components to large projects. Six deliveries for a total of 1.6 million NOK were made from June to October, and were all placed February 1st. A total of 48 orders were placed, resulting in 35 deliveries to Spenncon Hønefoss. This works out to seven workdays on average between each delivery.

6 Problem identification and suggested solutions

The goal for this chapter is to identify problems with the current situation of Spenncon Hønefoss that was presented in chapter 5. This chapter will also present suggested improvements to the problems found. The goal for this chapter is to identify the problem areas and account for the possible improvements that Spenncon Hønefoss can implement to develop their business further. The improvements will be presented in a somewhat generalized way to better answer how ETO companies can best utilize procurement strategies and inventory control.

The chapter will more or less have the same layout as chapter 5 and starts with the inventory. The management at Spenncon had a hypothesis that there were problems related to inventory. After this the production planning, procurement, and supplier relationship will be considered, the need for this is identified the inventory section. Lastly a discussion tying the finds to the research questions is found.

6.1 Inventory

Spenncon Hønefoss ended the year 2011, 6.9 million NOK in the red. Every item of income and expense that relates to a company's main operations will affect the amount of operating income. As said in the theoretical background section 3.5.2, the cost of keeping inventory is a part of the direct cost and also influences the operating income. The inventory balance at the end of each month will indirectly affect how much operating income a company reports since it is an essential component of calculating gross profit. To understand the details it is necessary to take a look at the problems regarding inventory.

The average monthly amount of material in the inventory has a value in excess of 11 million NOK in 2011. This is about two million NOK more than the average cost of the goods used in a month. This seems to be an unnecessary large buffer to have for the time period. To take the PC strand as an example: Monthly Spenncon Hønefoss consumes 264 metric tons of this material, while at the end of each month (when inventory levels are calculated) there are 304 tons of PC strand in stock, on average. There are several of the embedded components that have a disproportionately high number of units in inventory. There are for example over 15 000 units of one type of clips, and that clip has a list price of 23 NOK/clip. There are at least a dozen other instances of high cost/high quantity items.

6.1.1 Inventory turnover

The inventory turnover indicates how many times the inventory is used in a given time period. The time period used is one year from January 2011 to December 2011. The focus of this section will be reinforced steel and embedded components, because concrete is for all intents and purposes not a stock item and is delivered at a just-in-time policy. Casting and production materials are similarly a very small part of the inventory with little to gain from improvements.

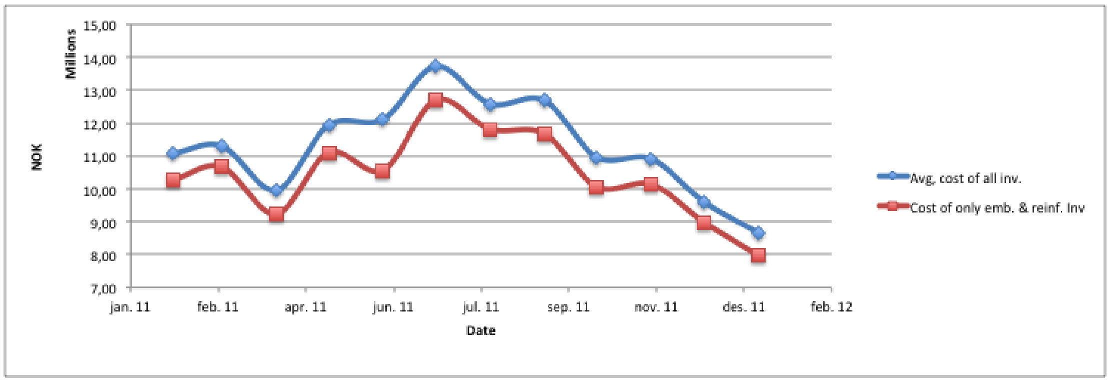

Figure 7: The cost of inventory vs. the cost of only embedded and reinforced steel

As seen in Figure 7, the casting and production materials, and concrete is a marginal part of the inventory and is fairly constant at slightly less than one million.

Reinforced steel is split into three subcategories to achieve greater precision: PC strand is the subcategory that has the lowest lay time of the three, with an inventory turnover of 10.44/year. PC strand is also the most used of the reinforcing steels, with 264 metric tons per month on average. It is important to note that there are also only three different dimension of PC strand used by Spenncon: 6.9 mm, 12.9 mm, and 15.7 mm. This product is stationary in inventory for 32 days on average before it is used (Table 10). With these facts taken into account, this is subcategory that should be able to achieve higher turnovers.

Reinforcing bar is a subcategory with only two product types in 8 different sizes from 6 to 32 mm and an average monthly usage of 122 tons. This product uses 35 days to get through the inventory. Reinforcing mesh is the least utilized reinforcing type. It is expended 47 tons of mesh on average each month. This results in a turnover of 4.01 and a travel time through the inventory of 129.46 days, or four months and one week.

The turnover rate for embedded components is 4.8 inventory turnovers in one year. This material category is by far the largest with nearly 60 percent of the total inventory value. Embedded components encompass just over 200 individual products. This is by far too large to draw any reasonable conclusion from; still, an average of 71 days to get through the inventory should be considered too long.

6.1.2 Inventory segmentation

It is clear that there are difficulties related to controlling the inventory. Embedded components encompass over 200 individual products, nearly 60 percent of the total inventory value. It had in 2011 a turnover of 4.8. By dividing components into groups, turnovers could be calculated for smaller segments. It would be reasonable to assume that inventory turnover rates would diverge for each individual segment. For purely inventory control reasons this category should be divided in to smaller segments with no more than 50 items in each segment. This should allow for stricter control over how long materials are kept in inventory. These groups can be made based on what kind of product (Insulation, lifting details, Pandrol clips, assembly parts, etc.) or the use of ABC Pareto distribution of the goods based on cost. See section 3.5.5.

6.1.3 Inventory reduction

The high frequency of deliveries, and the high level of control in the production planning process, makes it reasonable to believe that there exists no real reason for the high cost of goods in inventory that is today. It seems buffer inventory is just embedded deep within the organizational culture. By altering the mindset towards keeping lower levels of inventory, a company would already be well on their way to better inventory control. This can be tied up to common theory on organizational change, like Kotter’s 8 step model, where altering the mindset of the staff is often an early and important step towards a successful change.

6.1.4 Summary

Management in Spenncon suspected that there is a problem with the inventory. In this section has confirmed that there is too much material that spends too long time in the inventory.

Process	Problem	Reason	Solution
Inventory	High cost of goods in inventory	High lay times of goods in inventory	Implement JIT purchasing. Control with the help of ERP
	Low inventory turnover		

Table 12: Summary of inventory

Problem areas

The reason for large inventory quantity has to be in one or both of the following areas:

1. Production planning
2. Procurement methods

To be certain, an identification of problems in production planning and procurement is needed. A closer look at these two problem areas will be presented in section 6.2 and 6.3

6.2 Production Planning

Section 6.1.4 (point 1) identifies that the production planning as a potential problem. As stated in section 3.1.1, one of the things that characterize an ETO company is having challenges with production planning due to customized products. Spenncon is not the first company to recognize this.

6.2.1 Production planning problems

As previously stated their production plan consists of an overview of confirmed project in the future. Internal requirement towards design drawings gives the purchasing department 5-10 days to order and receive the components required in production. It is the responsibility of production planning to see to that the internal requirement is adhered to at all times. There are no observations in this research suggesting that there are significant problems with regards to production planning not following the set deadlines.

The main problem identified with regards to production planning is that the technical drafters use components that may not be among the standard products used in Spenncon. This is not only a problem for Spenncon, but according to section 3.1.1 it is also common for ETO businesses in general. Standard products are products already written in the manual, already registered in iNetto, and often already in stock.

6.2.2 Responsibility sharing

The responsibility of having the needed parts before production start must not only fall to the purchasing department alone. It is important that this is shared interdepartmentally. E.g. it is the production department's responsibility that the drawings and part lists are submitted in the ERP system before the deadline. If they are not, it is the purchasing department's responsibility to request these immediately. It should be the norm that it is acceptable that a drafter uses a component that is not registered in the manual, but this must result in the deadline for submission being altered in favor of the purchasing department, giving them more time to acquire the materials.

6.2.3 Summary

One problem identified in the procurement was that the drafters do not always use standard components; this makes it difficult to maintain control over delivery times. It was also identified a system wide weakness with information sharing.

Process	Problem	Reason	Solution
Company	Poor information-sharing between departments	No established way of sharing information between departments	Make use of company-wide information-sharing through ERP
Production Planning	Drafters do not always use standard components	Increased lead-time due to longer time to acquire special components	Purchasing department must be allowed longer time to acquire special components

Table 13: Summary of production planning

6.3 Procurement

Section 6.1.4 also identifies procurement procedures (point 2) as a possible reason for the high inventory level. From what has been observed there are no established methods used at Spenncon Hønefoss to ensure economically wise solutions to common challenges with regards to procurement processes in ETO companies. Such methods would be Kanban, just-in-time, forecasts, ERP system, etc. The theory has shown that ERP systems can play an important role in ETO businesses.

This is the longest section in chapter 6 and because of this a short paragraph with some information about the outline is needed. This section will start with an identification of the problems with procurement, followed by a look at just-in-time as an ordering strategy. Then a look at how purchasing is done and how iNetto should be utilized. Lastly a summary the most important findings are found.

6.3.1 Procurement problems

In Spenncon the ERP system iNetto has been in place for quite some time, but it has been observed that the purchasing team does not utilize iNetto's information sharing capabilities, especially when it comes to controlling inventory and demand. The system requires accurate updating of inventory levels. During interviews of personnel in the purchasing department there was expressed a concern towards the amount of time and energy this input requires.

Since iNetto is properly utilized in production planning, procurement can access the system and retrieve the information on required components themselves. However, it is still important to adhere to the deadline, as the departments must look to share responsibilities. The responsibility of having the items necessary for production when they are needed does not seem to be shared between production planning and procurement. Spenncon's purchasing department has expressed concern towards lack of time to acquire goods, which is quite common in ETO businesses. At Spenncon Hønefoss one factor lies in design drawings, the hired drafters are not familiar with which components are easy to acquire, which are usually in stock at Hønefoss and which are not. This can be considered a burden to the purchasing department, as they must continue to order nonstandard components. Another factor is poor communication, but this is on a company level and may involve more than the production- and procurement departments.

Even though Spenncon has not yet implemented iNetto throughout, the system still offers a valuable amount of information about production plans and material requirements. The production plan is locked two weeks ahead of casting and there are ways to obtain information about required materials even further ahead in time. As Spenncon utilizes iNetto for proposals and production planning, procurement has full access to all the information made at these stages. Because the purchasing department does not utilize iNetto, such information advantages are wasted.

It has also been observed that the purchasing department does not trust the delivery times of suppliers, which result in stockpiling of materials. The research done on invoice records shown in section 5.4.2, and questioning of the supplier has shown that most components ordered are stock items. The suppliers are usually able to deliver within a few days. Note that the purchasing department holds the uncertainty of trusting the suppliers alone.

Regarding the manual and the example given on minimum stock and order quantity (200/1000), a significant problem with the list is the lack of proper system for determining these numbers. There has not been observed any established methods as a source for the quantities. The researchers have not succeeded in determining how the numbers came to be. It has been stated that when the document was first written the numbers were based on experience. The result may be order quantities that are not optimal.

Materials seem to be ordered whenever an initiation to order has been presented. The initiation is often due to someone discovering an item below minimum stock, often by chance, which might result in information received being biased, incomplete, or even doubled up. As shown in section 5.4, the amount of orders sent to suppliers in 2011 was more frequent than what seemed to be necessary taking into account the large average size of inventory, the cost of materials used, and number of orders. The system currently in place can be viewed in the “AS IS”-description’s basic flowchart for the purchasing process (Figure 6).

By being involved in early decisions made in tender and design processes, procurement would have a greater knowledge about what components are needed in upcoming projects. If the drafters find it necessary to make use of special components, procurement will have the information early in the process.

In addition it has to be noted that just by reevaluating the manual and the amount of units kept of each item, the cost of inventory can be reduced significantly. Note that if iNetto is used and the inventory is eliminated updating the manual will not by necessary. Another problem that was identified is the lack of a system for when to order goods. In order for the system to alert the main purchaser when to order, the minimum stock needs to be updated and all the people involved with inventory must properly enter inventory values on a regular basis. If goods are ordered after the production schedule is set for the project, the correct amount of materials can be ordered. In order to enable this function the main purchaser must make use of the access to iNetto. If lack of proper training is an obstacle this has to be prioritized.

6.3.2 Just-in-time as an order strategy

Just-in-time is a prominent method for eliminating inventory and the associated carrying costs. This theory is described in more detail in section 3.2.2. Just-in-time production is reliant on suppliers that are accurate in delivery. This can be achieved through improving supplier contracts and supplier relationships. The delivery of goods needs to correspond with the production schedule and again, the delivery times need to be trusted. The timing of JIT deliveries should be based in the promised delivery time and, in turn, the schedule of Build-to-Order Supply Chain assembly operations (Gunasekaran & Ngai, 2009).

The "AS IS"-description shows that the suppliers of embedded components are able to handle this kind of order frequency, and to some extent do this already. A total of 167 deliveries in one year from the three embedded components suppliers analyzed for this thesis, and 150 deliveries for the two supplier of reinforcing steel, demonstrate that it would be possible to implement a more just-in-time delivery with nearly no increase in delivery costs. The problem with most embedded components is that it is difficult to describe a consistent demand pattern and JIT is best implemented to components that can be proved to have just that. Therefore it might be easier to have materials such as steel mesh, reinforced bar and PC strand delivered on a just-in-time basis.

This can be demonstrated with an example: In 2011 the average time between PC strand deliveries was four days. The maximum weight of a truck allowed on Norwegian roads is 50 tons (minus weight of a truck, which is about 15 tons, equals 35 tons deliver capacity per truck). PC strand is consumed at an average rate of 265 tons per month, or ten tons per workday. It would be reasonable to have a delivery of one truckload (35 tons) every 2-4 days. Deliveries more often would result in driving half-full trucks, which would lead to increased transport costs. Costs could further be reduced for both parts by invoicing every two weeks or once a month.

It should be considered when developing JIT relationships that suppliers are kept on longer contracts in order for the suppliers to establish trust. Well-functioning JIT relationships are not implemented over night. The value of long lasting relationships should not be underrated with regards to develop JIT. Price should not be the only factor deciding what supplier to use.

The use of just-in-time deliveries requires that the suppliers deliver goods of high quality, as mentioned in section 3.2.2, with the reduction in inventory size the impact a shipment of subpar quality materials will have on the production can be devastating. This is why it is important to collaborate with the suppliers to ensure an acceptable level of quality on the materials.

With the occurrence of high-risk and high-cost products a thorough consideration should be done to evaluate if stocking the products is necessary and how much should be kept in inventory. In the theoretical background section 3.5.4 it is stated that the risk depends on the type of resources and value. Kraljic's model shows the importance of focusing purchasing departments to spend their time on those products that matters most.

A total just-in-time production/ordering could be difficult to implement, but a gradual transition could be implemented, starting with just-in-time delivery of low-risk products and stocking up on high-risk items to mitigate risk. A transitional period with JIT deliveries and backup inventory could also be considered.

Another possibility, and possibly a more effective one as regards to decreasing cost of especially the embedded components in inventory, is to structure JIT-purchasing according to high cost items. An ABC analysis must then be done to achieve this, cf. section 3.5.5. Based on the Pareto principle, the ABC analysis is used for identifying items that will have a significant impact on overall inventory cost. It states that ten percent of the inventory is accountable for over 50 percent of the inventory cost. By having a stricter order and storage policy on those items the cost of goods in inventory will decrease.

6.3.3 Use of procurement forecasting on recurring materials

There are materials that are a recurring part in many products, like reinforcing steel. These products can either be stored in inventory since it is used in the majority of the product range, or it can be made a forecast for the material to achieve even more accurate deliveries. This is only feasible for product categories with enough throughputs. The product category of embedded components has too many different items to appropriately forecast. The products used depend on what product is being produced. It is important to note that improper use of forecasting can result in large hidden costs, see section 3.5.5.

6.3.4 Initiation of a purchase order

In order to create a systematic approach to the process of purchasing good, a new flowchart was made with suggested improvements. The idea of this flowchart (Figure 8) is that iNetto is now the most vital part of the process in an attempt to create a more systematic approach. The “AS IS”-description projected a state of confusion as initiations to order was created by random inputs from various people involved with inventory. The new system suggests that iNetto’s capacity of handling inventory lists is utilized properly. This requires procedures to accurately update inventory levels in iNetto at all times, something that cannot be overstated. An ERP system is only as good as the people using it; if the data is not entered, or entered incorrectly, data for the entire supply chain is corrupted. To achieve this high level of accuracy all staff must be educated in the use of the material requirement planning system. In addition the material database must be up to date with the newest material prices and current levels of inventory at all times. When this is fully functional the main purchaser can choose to consult the inventory lists and order the correct amount of materials for any upcoming project.

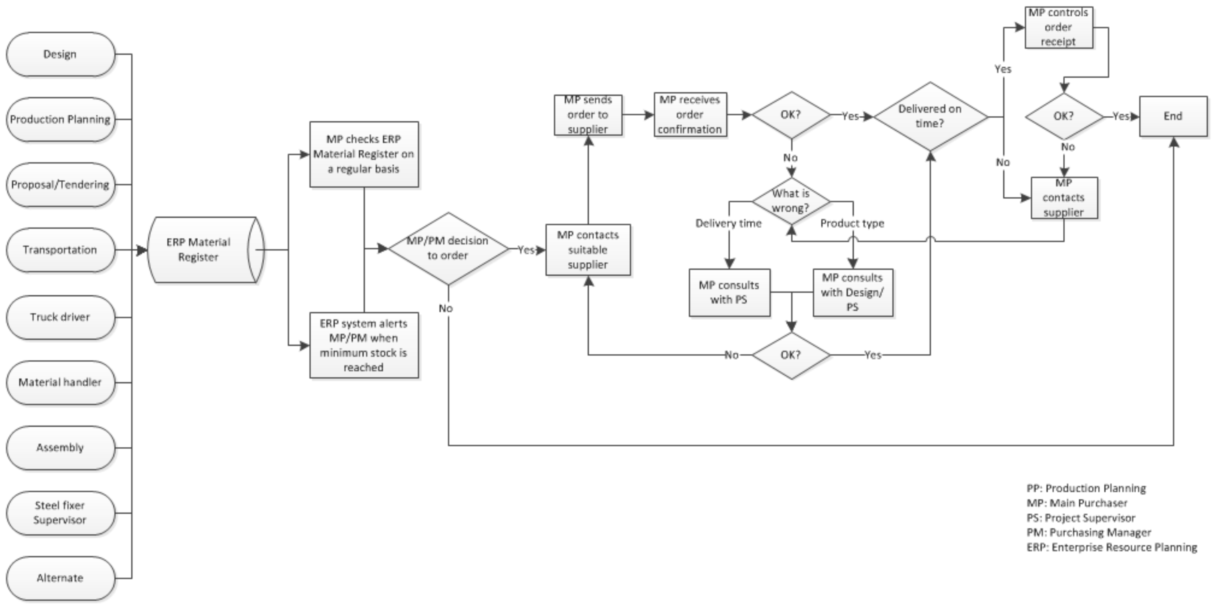

Figure 8 Suggested solution for procurement (For larger image, see Appendix 9.8)

6.3.5 Utilizing iNetto to its full potential

The use of their ERP system iNetto can facilitate the coordination between departments and suppliers that are needed to successfully handle the uncertainty of ETO demand. A presentation made by ERP-manager in Spenncon Norway suggests that the system is capable of managing all material handling in Spenncon. The system as it is presented in the “AS IS” is up and running for factory operation up until procurement and the entire production planning is done using iNetto. The actual bill of materials for the entire planned production should therefore be available in iNetto.

It would seem natural for a company with such a large variety of inventory to use ERP to gain control over inventory. As Spenncon utilizes iNetto for proposals, procurement has full access to all the information made at this stage. Already at this stage inventory levels must be extracted from iNetto and be compared to upcoming required inventory level needed at casting date. Materials and components must be ordered from suppliers within the shortest possible amount of days before production start. This is to ensure inventory levels are as low as possible at all times.

As stated above the use of an ERP system in material handling requires a high level of accuracy in the inventory accounting. This is something that has been expressed as a severe weakness by the purchasing department at Spenncon Hønefoss. The system requires a lot of input and the input must be correct. Another weakness that has been expressed is the lack of accurate values in the system. It is hard to decide whether to pin this is on wrong price levels, inaccurate material requirements or incorrect time study analyses. It is evident that the system needs calibration.

Staff has expressed lack of training in iNetto's interface. The system is complicated and requires more than a basic level of computer knowledge. A major resistance to utilizing the system comes from lack of training and experience.

For example if the required level of inventory should be known six months ahead, the purchase order should not be sent before it is absolutely necessary. The agreed upon delivery time from suppliers must be trusted. In addition, the purchasing department should not hold the uncertainty of trusting the supplier alone. As stated in section 3.3 better supplier contracts and supplier relationships must be developed, and this is the responsibility of Spenncon Hønefoss, Spenncon Norway, or even Consolis.

Even if procurement would obtain control over future materials required in production, this information would not be useful if the suppliers cannot deliver. It is known that iNetto possesses a function called an Outbox to keep suppliers updated on future orders, but this is not yet adapted or implemented. By having access to this, suppliers will be able to keep themselves updated on upcoming material needs in Spenncon and ensure sufficient stock.

For a successful implementation of a factory wide use of all the iNetto functionality is necessary to address the following:

- Education of all staff using iNetto – the high level of accuracy in inventory accounting is dependent on the people using the system
- An update of all material prices – as of now the material prices are not up to date in iNetto

- A reduction in number of suppliers – reducing the number of suppliers will ease the coordination

A well-functioning ERP system can facilitate the implementation of just-in-time methodology. The level of material and production control needed to have the ERP system working is exactly what JIT needs to work properly. If, on the other hand, the company has an ERP system that is subpar, the implementation of JIT will be chaotic.

6.3.6 Summary

This section identifies problems with procurement in the form of outdated purchasing methods/strategies and unsubstantiated inventory threshold levels. It presents the use of the ERP system iNetto, supplier integration, and just-in-time deliveries as possible solutions for the problems identified.

<table>
<tr><th>Process</th><th>Problem</th><th>Reason</th><th>Solution</th></tr>
<tr><td rowspan="4">Procurement</td><td>Little utilization of the ERP system's potential in procurement</td><td>Lack of training in use of the ERP system.</td><td>Proper training and thorough implementation of the ERP system can provide more accurate procurement</td></tr>
<tr><td>Quantity for material purchase unclear</td><td>Source for order quantity numbers uncertain</td><td rowspan="2">Use the ERP-system generated BOMs[9] for ordering</td></tr>
<tr><td rowspan="2">Reason for material purchase unclear</td><td>No system for initiation of order</td></tr>
<tr><td>Source for minimum stock numbers uncertain</td><td>Minimum stock values no longer required with the combination of JIT and ERP</td></tr>
</table>

Table 14: Summary of procurement

[9] Bill of Materials

6.4 Supplier Relationships

As presented in the theoretical background, to mitigate the risk that arises when inventory is decreased it is important to have flexibility in the supply chain. In the suppliers this flexibility is achieved through close collaboration.

Spenncon Norway has two suppliers of reinforced steel and a number of suppliers of embedded components. This is an evaluation of how Spenncon Hønefoss uses these suppliers. The universal tender for reinforced steel delivered to Consolis' companies is usually three months. This might be very short periods when trying to develop a good relationship with the supplier. However, it has been observed that both suppliers supplied Spenncon for more than a year.

When looking at the key numbers for orders to and deliveries from steel suppliers it shows that there were about 150 deliveries of reinforcing steel, and a mean delivery frequency of roughly every four working days from both suppliers. The three suppliers of embedded components alone stacked up a total of 191 orders and 165 deliveries in 2011. The mean amount of working days between deliveries ranges from three to seven. These are only three of eight, or 1/5th of the total monetary value of the embedded steel ordered in 2011. The problem is that these delivery frequencies are not utilized in any way by Spenncon's purchasing department. As shown in Table 10, this reinforcing steel is stationary in inventory for 32 days on average before it is used, something that does not comply with such a frequent delivery rate.

Contracts with suppliers of embedded steel are outdated. It is unclear whether the agreed on price and delivery times still apply. In addition it seems the suppliers wrote the contracts, as there are no consistency in the layout and elements of the contract. These contracts do not seem to be followed up by any means.

As mentioned in the theoretical background the cost of materials and services for an ETO company can account for up to 80 percent of contract value. JIT theory argues that the indirect cost of working with suppliers in a long-term relationship is lower than that of a tender based purchase system, even if the price level can look favorably on a short-term basis.

To maintain long-term supplier relationship it is important to achieve a two-way flow of information. To build trust it is necessary that information asymmetry does not occur. Information flow, either through ERP, phone, or email, replenishment requirements forwarded to suppliers should be based on actual orders. This requires close working with the suppliers and some ERP systems can include them as well. Structured ordering through an ERP database (see the flowchart in appendix 9.9) will allow components to be pulled from suppliers just as they are needed for production.

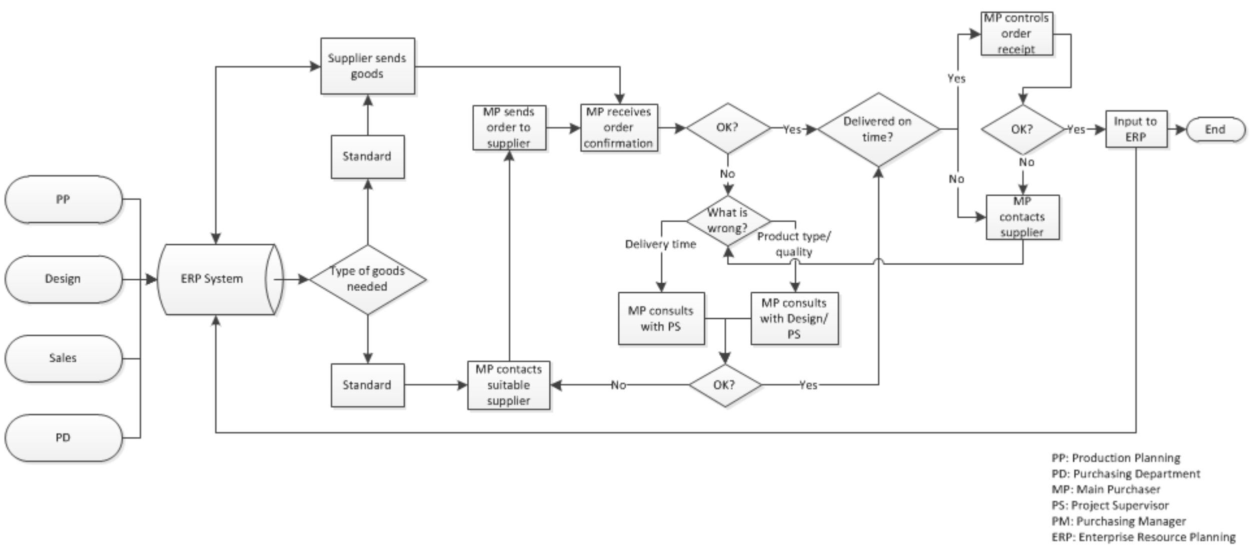

Figure 9: Suggested procurement solution with supplier integration (For larger image, see Appendix 9.9)

Long-term supplier relationship it is important to establish a mutual understanding of both what is required and what can be delivered in respect to quality and delivery times. With the implementation of JIT it is necessary to demand quality from the suppliers, as the buffer inventory is small or nonexistent. A collaborative effort to increase the quality through control and process improvement from both the company and its suppliers can be necessary and fruit full. If the ETO business is utilizing too many suppliers it can become necessary to reduce the number. The benefits are:

- Fewer suppliers to deal with – This makes it easier to follow up supplier relationships
- Closer relationship – To build trust and mutual understanding of the supply chain
- Increase the volume per supplier – More leverage in contract negotiation. A more valued customer
- Lower total cost – Deliveries from fewer suppliers leads to lower transportation cost
- More stable quality and deliveries – Fewer supplier leads to less variation

6.4.1 Spenncon's suppliers of reinforcing steel

In order to improve the relationship with suppliers of reinforced steel it should be considered to extend the length of the tender. In addition the control over the tendering should be transferred from Consolis to Spenncon Norway.

6.4.2 Spenncon's suppliers of embedded components

Spenncon Hønefoss uses eight suppliers of embedded components. It has previously been mentioned that it is important not to have too many supplier. Eight suppliers might, or might not, be too many, but it is questionable whether Spenncon has sufficient control in regards to the performance of their suppliers. It should be performed a detailed analysis of all the suppliers in order to determine an optimal way of using them. Spenncon should strive to compose better supplier agreements/contracts (Gunasekaran & Ngai, 2009) and not only use the contracts the suppliers provide. The contracts must also be kept up to date.

Spenncon can look to develop Quality Management Systems in collaboration with their suppliers. In this way the suppliers can control the quality of their products before shipping them to Hønefoss. This will ensure Spenncon receives quality goods and enhance the total control in the supply chain.

6.4.3 Summary

There is close to no supplier relationship present in Spenncon. There is limited information flow about upcoming orders or delays. The supplier contracts are neglected and scarce in their content.

Process	Problem	Reason	Solution
Supplier relationships	Poor information-sharing with suppliers	Lack of flexibility in the supply chain	Better information flow in the supply chain. Include all external and internal stakeholders
	Supplier contracts are lacking and outdated	Lacking control over product prices, delivery times, delivery cost, and quality	Develop new suppliers contracts stating price, delivery time, delivery cost
			Develop QMS[10] in collaboration with suppliers They perform quality control before shipping

Table 15: Summary of supplier relationship

[10] Quality Management System

6.5 Discussion

This section will tie the finds up against the research questions presented in the introduction. The thesis started out with two research questions:

RQ1. *How can ETO companies manage procurement and control inventory?*

RQ2. *How can Spenncon Hønefoss improve procurement and inventory control?*

Each research question has a dedicated section. Research question 2 is divided in two, first discussing procurement then control. This is done more clearly present and discuss the findings.

6.5.1 Research Question 1

The first research question is generally about ETO companies;

How can ETO companies manage procurement and control inventory?

One of the main characteristics of an ETO company is that it is difficult to predict demand. The customer order decoupling point is located at the design stage of production and the customer is subjected to the entire production time. This makes it close to impossible to forecast future material needs with the intent of keeping material in inventory. Thus it is easy to end up with either enormous quantities of material in inventory or too little, leading to long lead-times.

According to lean philosophy inventory is one of the seven none-value-adding wastes a company should avoid, and since the 1970s just-in-time production has been used to eliminate inventory in the automotive industry. The inherent uncertainty in ETO companies makes forecasting for JIT deliveries close to impossible. The position of the customer order decoupling point (CODP) at such an early stage in the supply chain can be used as an advantage. The CODP is at the design stage, and after this point the demand is certain. By procuring raw materials after the design is done and when the bill of materials is available, it is possible to achieve one hundred percent accuracy in procurement, and eliminating the inventory completely. But the elimination of inventory increases the effect of late deliveries and quality defects on the lead-time. This makes it more important to have flexible suppliers in regards to delivery time, and that they can be trusted to deliver the right high quality product on time.

Just-in-time theory states that the indirect cost of working with a supplier in a long-term relationship is lower than that of a tender based purchasing system. The indirect costs that can increase in a tender based system are related to uncertainty in delivery and quality level. A long-term supplier relationship is important to establish mutual understanding of what is required, and what can be required in respect to quality and delivery times.

The problem that occurs most frequently with supplier relationship is information asymmetry. To prevent this, a functional two-way flow of information is important. This can be achieved through allowing the suppliers access to the company's material requirement planning (or ERP) system. If the company utilizes many suppliers this is increasing risk. In order to create good relationships based on trust it may become convenient to reduce the number of suppliers. Spending resources on developing supplier flexibility by offering training in required areas and capabilities will improve the overall supply chain flexibility and reduce lead-times.

Short lead-times are a competitive advantage, but reliability and consistency in the lead-times is equally important. To maintain consistent lead-times it is crucial to uphold the deadlines in deliver, production, and production planning. This is especially important for the deadlines that external activities are dependent on, like the design stage. There should be maintained an open dialog between stages of the supply chain to early warn about possible delays, and control them as tightly as possible to prevent further delay.

To sum up, the best way found to control inventory in ETO is to get rid of it. As for procurement; if JIT is to be implemented it is necessary to keep in mind that to use ERP for JIT procurement requires an extraordinary high degree of control, both in production planning, and of suppliers. Implementing JIT deliveries alongside a mediocre ERP or MRP system can result in disaster.

6.5.2 Research Question 2

The second research question was specifically about Spenncon:

How can Spenncon Hønefoss improve procurement and inventory control?

This research question will have much of the same answers as RQ1 but will be focused towards Spenncon Hønefoss, addressing the problems identified. The procurement and inventory control processes at Spenncon has been analyzed in the process of answering research question 1. Identified problems at Spenncon Hønefoss are presented in Figure 10.

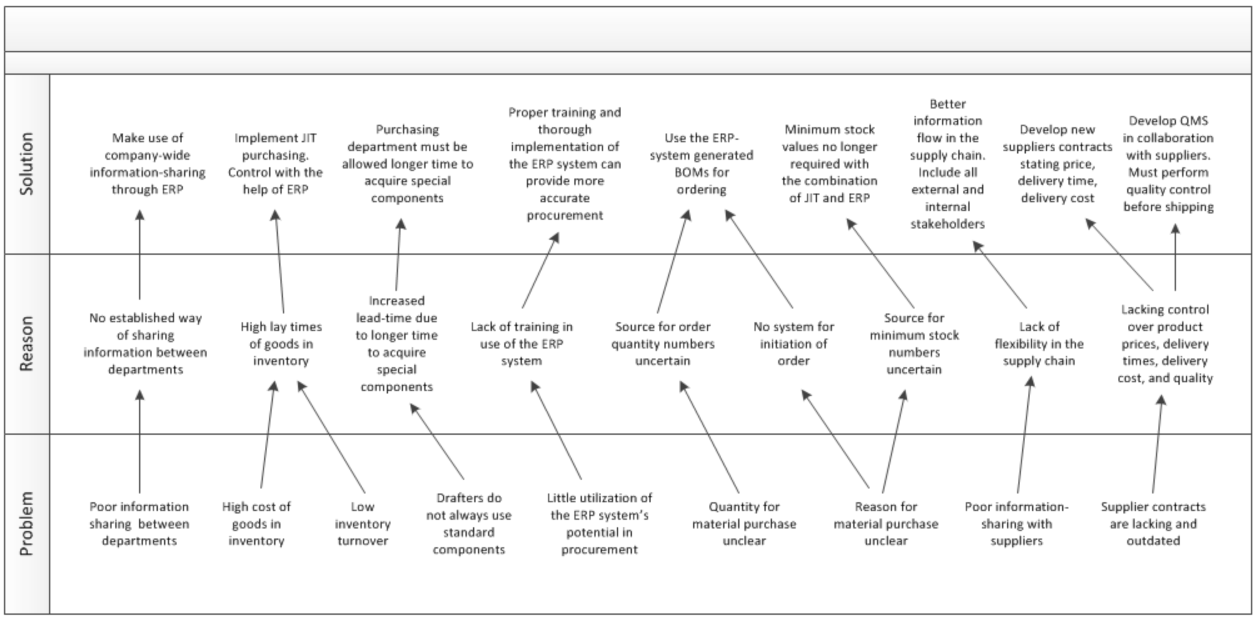

Figure 10: Graphical representation of the Problem Solutions (a larger version can be viewed in appendix 9.9)

The figure shows all the problems that were found in the procurement and inventory control processes at Spenncon Hønefoss. It also presents the causes of, and the solution to these. A more in-depth description of the problems and the solution and how this can best be implemented can be found in chapter 6.

To properly sum up and answer research question 2 it has been divided into two parts.

RQ2 **Part one**: *How can Spenncon Hønefoss improve procurement?*

The main problem with the procurement process at Spenncon is the dependency on buffer inventory. As shown in section 6.1.1, there is about a month worth of materials in inventory. There has not been found any real reason behind the decision to have this much inventory. It is believed that this is something that is embedded deep within the organizational culture and could to some degree be solved by committing to a mindset towards reducing the cost of goods in inventory.

If the purchasing department better utilizes Spenncon's ERP system iNetto the values of current inventory status and price of raw materials will be available to production planning and this could reduce the lead-time. This requires that the purchasing department is properly trained in the use of said system. The use of ERP in procurement requires a high degree of control, if the ERP system is properly used the tiniest mistake can cause ripple effects throughout the system.

Spenncon Hønefoss has deadlines on the design stages of the project planning. Five to ten workdays before production start, depending on the product. It is important that these deadlines are adhered to at all times. The purchasing department requires this time to order and receive the needed materials from the suppliers. If these deadlines are not met, or the drafters use nonstandard materials, it is important to convey this information as quickly as possible to the purchasing department. It cannot be stressed enough that communication between the links is paramount to the success of any supply chain.

Lastly there was observed that the order initiation process was lacking an established system. Current order initiation system can be seen in appendix 9.7. This should be addressed and a more organized method for order initiation should be considered. In appendix 9.8 an example of more failsafe method for order initiation is suggested and in appendix 9.9 a method including supplier interaction through ERP.

RQ2 **Part two**: *How can Spenncon Hønefoss improve inventory control?*

As said in the answer to part one of RQ2 the use of ERP requires an extraordinary high degree control. This also applies especially to inventory control. The biggest issue with the inventory control is that there is no real use of computer software to aid in managing procurement. Inventory accounting is done at the end of each month, by counting the materials. This is not tight enough control. By using an ERP system that registers the orders as they arrive and register the use of materials in the production, near real-time control of the inventory level can be achieved.

The key takeaways from the case study for Spenncon Hønefoss would be that they should reduce the amount and consequently cost of goods in inventory. This would increase the inventory turnover and decrease the lay time of raw materials. Doing this would increase the risk of not having the material in time. This risk should be migrated through increased supply chain flexibility. This can be achieved through a close supplier relationship and the use of faster data exchange solutions like ERP, at every echelon of the supply chain.

6.5.3 Enablers and disablers

The solutions are the suggested ways to obtain the desired solutions. In any process improvement there are those whom will strive towards the goal. These are the people that are the most motivated, usually the people who started the improvement process and have the most to gain from the improvement.

Management will be the biggest enabler in moving towards the desired state. It is more or less purely an economical gain that is achieved by the implementation of this state. The purchasing team is also a key aspect to the restructuring of the procurement process. It will be absolutely paramount to have them onboard.

"Progress is a nice word. But change is its motivator. And change has its enemies"

- Robert Kennedy

As with the enablers there are also disablers in any improvement process. These are the factors that will jeopardize the entire process of improvement. The management is its own worst enemy when it comes to implementing change. A poorly executed process of change achieves nothing. As mentioned in section 3.6.2 in the theoretical background there is a resistance to change inherent in people and organizations. Addressing this resistance is an important part in changing the organizational culture.

As stated in the summary of the Process Improvement section in the theoretical background, information is a key aspect in preventing this resistance. Informing the employees will be important in order to motivate staff towards the change. Most unwillingness to change comes from lack of knowledge. Proper training is also important the feeling of not mastering or understanding the skills needed can greatly reduce motivation. Proper ways pull this off can be found in theory on organizational change, like Lawrence & Lorche, Buckley & Perkins, Lewins, and John P. Kotter.

7 Summary and conclusion

In order to manage procurement and control inventory, ETO companies must be aware of the common challenges facing their type of industry. The challenges identified in this thesis are the high degree of uncertainty due to uneven customer demand, the decoupling point located at the design stage, which again makes forecasting difficult, the fact that in some cases design will make decisions without coordinating with procurement, lack of information sharing, both internally and with suppliers, and lack of trust in the supply chain.

Addressing the problems identified in the case study will help Spenncon Hønefoss improve procurement and inventory control. The problems and solutions are found in Table 16 on the following page.

7.1 Contribution

The literature review of Gosling and Naim (2009) shows that there is done little research on the subject of ETO supply chain management, and there is even less focus towards the precast concrete industry. This thesis will hopefully contribute to the subject on how ETO companies can manage procurement and control inventory, especially through the case study on a typical ETO company. Through literature we have identified several common challenges in such businesses in general. Some of these challenges have been confirmed in the case study, along with challenges specific for Spenncon Hønefoss. This thesis' suggested solutions have been evaluated from both an empirical and a theoretical viewpoint.

The work is presented in such a way that it should be relevant for any engineer-to-order and build-to-order businesses. It is believed that especially the precast concrete industry in general can benefit from this work.

As for Spenncon, this case study focused on the factory at Hønefoss but some of the knowledge gained form this thesis should be applicable over the entire range of Spenncon factories in Norway, and even factories across the Consolis group.

Problems and solutions

Process	Problem	Reason	Solution
Company	Poor information-sharing between departments	No established way of sharing information between departments	Make use of company-wide information-sharing through ERP
Inventory	High cost of goods in inventory	High lay times of goods in inventory	Implement JIT purchasing. Control with the help of ERP
	Low inventory turnover		
Production Planning	Drafters do not always use standard components	Increased lead-time due to longer time to acquire special components	Purchasing department must be allowed longer time to acquire special components
Procurement	Little utilization of the ERP system's potential in procurement	Lack of training in use of the ERP system.	Proper training and thorough implementation of the ERP system can provide more accurate procurement
	Quantity for material purchase unclear	Source for order quantity numbers uncertain	Use the ERP-system generated BOMs[11] for ordering
	Reason for material purchase unclear	No system for initiation of order	
		Source for minimum stock numbers uncertain	Minimum stock values no longer required with the combination of JIT and ERP
Supplier relationships	Poor information-sharing with suppliers	Lack of flexibility in the supply chain	Better information flow in the supply chain. Include all external and internal stakeholders
	Supplier contracts are lacking and outdated	Lacking control over product prices, delivery times, delivery cost, and quality	Develop new suppliers contracts stating price, delivery time, delivery cost
			Develop QMS[12] in collaboration with suppliers They perform quality control before shipping

Table 16: Problem Solution Summary

[11] Bill of Materials
[12] Quality Management System

7.2 Weaknesses

The scarce research on ETO SCM has made it difficult to find up-to-date sources on the subject. In addition the literature survey presented in this thesis is by no means exhaustive. Literary reviews on the subjects of ETO and BTO have been consulted in an attempt to get an overview of what kind of research is done on the subject. In addition to this our advisor has been consulted regarding established theory on the subject. It is possible that more aspects and challenges with ETO could have been discovered if we were allowed more time. Also, time limitation and distance to Hønefoss allowed us only to visit Spenncon a limited number of times.

It is not certain that this research would apply for other cases. But given the fact that most characteristics and challenges with ETO have been recognized in this case study it is most likely viable.

7.3 Further research

As stated earlier, there is done little research on the subject of ETO supply chain management. For future research a study can be made on the importance of coordination between departments in general ETO companies. The implementation of suggested solution in this thesis can also be a target for future research. In addition a similar study with the same research questions can be carried out other companies in order to confirm its relevance. Other ETO companies outside the concrete industry are also valid study objects in order to confirm that the results also apply for companies carrying different materials.

More specific for Spenncon, and in order to further argue for the use of ERP systems in ETO businesses, a best-practice analysis of a similar company could be done, perhaps Strängbetong in Sweden or E-Betoonelement in Estonia, who both have implemented an ERP system with success.

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9 Appendices

9.1 Interviews

Interview:
Date: February 22th 2012.
Location: Spenncon Hønefoss
Interviewers: Frederik Bratt Kjebekk, Jon Bjørnland
Subjects: Magnar Dammen, Terje Eriksen

Question: What goods are currently of greatest value in Spenncon?

Question: Is there any part of production that is standardized?

Question: Do you make forecasts?

Question: What are the suppliers of embedded steel components?

Question: How is the delivery time from these suppliers?

Question: What is Spenncon's lead time on a project?

Question: Why do you keep inventory?

Question: Is there any system for knowing when an item is out of stock in Spenncon?

Some questions were added as the interview went on.

Workshop and interview:

Date: March 29th 2012.
Location: Spenncon Hønefoss
Interviewer: Frederik Bratt Kjebekk
Subjects: Magnar Dammen, Terje Eriksen

Action: The making of a flowchart of the process of procurement at Spenncon Hønefoss.

Question: Are there additional suppliers of embedded steel products to the ones we already know about? Which and how many?

Question: Can we have inventory levels for January and February 2012?

Question: Regarding use of the ERP-system iNetto, what are the benefits and drawbacks?

Question: The supplier contracts are outdated. Who can we contact regarding this?

Question: What initiates a purchase order?

Question: What are the suppliers for reinforced steel?

Question: Tell me about the “Manual”.

Question: Why are there so many order deliveries from Pretec in 2011?

Some questions were added as the interview went on.

9.2 Informants

1. Gaute Hørlyk, Lean Communications
2. Magnar Dammen, Spenncon Hønefoss
3. Terje Eriksen, Spenncon Hønefoss
4. Staale Grosberghaugen, Spenncon Trondheim
5. Magne Aarsland, Spenncon Sandnes
6. Ingrid Folvik, Spenncon Sandvika
7. Einar Gjelsvik, Varde Consulting
8. Bjørn Ungersness, Lean Communications
9. Kjetil Nesset, Spenncon Norway
10. Suppliers
    a. Pretec AS
    b. SB Produksjon AS
    c. Halfen DEHA AB

9.3 The quality and validity of data gathered

This analysis is only as good as the data that lies as the foundation. Because of this it is important to evaluate the validity of this data. If the data is not valid the “AS IS”-model is void. It is necessary that the data is replicable by any other case study.

9.3.1 Financial data

The financial data is taken from a printout of the 2011 balance sheet, provided by Spenncon. The balance sheet was printed the 13th of January 2012, there is a possibility that all data from December 2011 still was not inn, and thus some of the data could be incomplete. To control this, a new printout was requested right after Easter and was received some time later. It was dated April the 24th, over three months (1 FQ) after the end of the fiscal year 2011. These two balance sheets were compared, no deviation was found.

9.3.2 Inventory data

All the data in this part is from Spenncon's own inventory-tracking document. The purchasing department maintains this document and it is difficult to verify this data in any way, since the data goes back many years. The data for December 2011 might be incorrect as this data deviated significantly from the normal. To validate, a copy of the complete inventory contents as of December the 31st 2011 were requested from Spenncon and compared. The only remaining reason to doubt the validity of this data is the 5 percent difference in the valued between the amount state in the balance sheet and the values calculated from the inventory-tracking document. How this was done and possible reasons for this deviation is presented and discussed in section 5.3.4.

9.3.3 Production planning data

The data used in the evaluation and analysis of the production planning is from the suppliers, from Lean Communications and from talking with the ERP-manager, who is in charge of iNetto in Spenncon, Norway. A demonstration of the iNetto ERP system was also given by Spenncon's ERP-manager, at UiA, March 28th 2012, in which the current capability, possibilities and limitations were explained.

9.3.4 Purchasing data

Data about the purchasing process was collected through interviews of Main Purchaser and Purchasing Manager, March 29th 2012, at Spenncon Hønefoss. Everything possible has been done to verify the statements from more than one source. Still, this is by far the weakest link in this analysis.

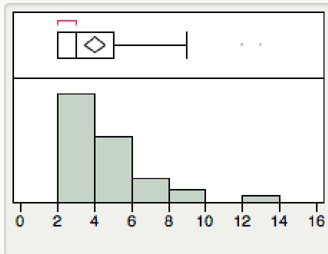
9.3.5 Supplier data

The supplier data has been sampled from both the supplies themselves and Spenncon. Invoice records for the year 2011 have been used identify purchase orders and deliveries. The delivery data have been crosschecked and there is no reason to believe that this data is in anyway corrupted or wrong. The definition of an order can differ some from the different suppliers, depending on how the invoice practice is.

9.4 Spenncon delivery distribution

Celsa Nordic

Days between deliveries



Quantiles

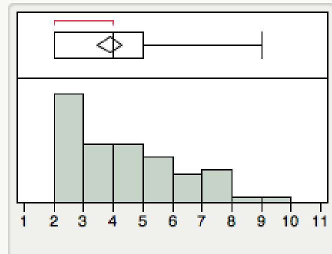
100,0%	maximum	13
99,5%		13
97,5%		12,1
90,0%		7
75,0%	quartile	5
50,0%	median	3
25,0%	quartile	2
10,0%		2
2,5%		2
0,5%		2
0,0%	minimum	2

Moments

Mean	4,0266667
Std Dev	2,2837459
Std Err Mean	0,2637043
Upper 95% Mean	4,5521089
Lower 95% Mean	3,5012244
N	75

FNSteel

Days between deliveries



Quantiles

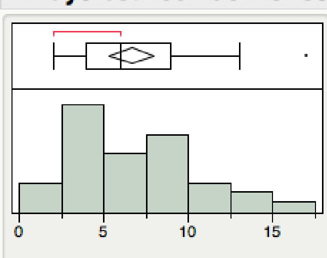
100,0%	maximum	9
99,5%		9
97,5%		8,1
90,0%		7
75,0%	quartile	5
50,0%	median	4
25,0%	quartile	2
10,0%		2
2,5%		2
0,5%		2
0,0%	minimum	2

Moments

Mean	3,88
Std Dev	1,8229765
Std Err Mean	0,2104992
Upper 95% Mean	4,2994288
Lower 95% Mean	3,4605712
N	75

Halfen-DEHA

Days between deliveries



Quantiles

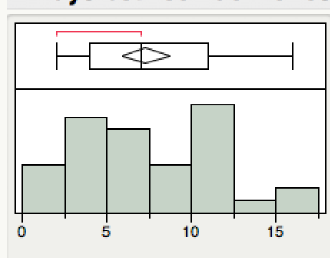
100,0%	maximum	17
99,5%		17
97,5%		17
90,0%		12,5
75,0%	quartile	9
50,0%	median	6
25,0%	quartile	4
10,0%		2,5
2,5%		2
0,5%		2
0,0%	minimum	2

Moments

Mean	6,6470588
Std Dev	3,6999783
Std Err Mean	0,634541
Upper 95% Mean	7,9380423
Lower 95% Mean	5,3560754
N	34

SB Produksjon

Days between deliveries



Quantiles

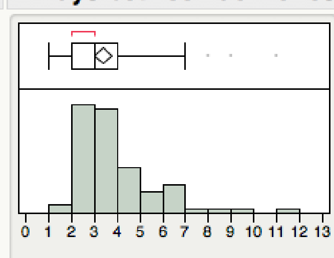
100,0%	maximum	16
99,5%		16
97,5%		16
90,0%		12,4
75,0%	quartile	11
50,0%	median	7
25,0%	quartile	4
10,0%		2
2,5%		2
0,5%		2
0,0%	minimum	2

Moments

Mean	7,2857143
Std Dev	4,0188631
Std Err Mean	0,6793118
Upper 95% Mean	8,6662421
Lower 95% Mean	5,9051865
N	35

Pretec

Days between deliveries



Quantiles

100,0%	maximum	11
99,5%		11
97,5%		8,625
90,0%		6
75,0%	quartile	4
50,0%	median	3
25,0%	quartile	2
10,0%		2
2,5%		1,375
0,5%		1
0,0%	minimum	1

Moments

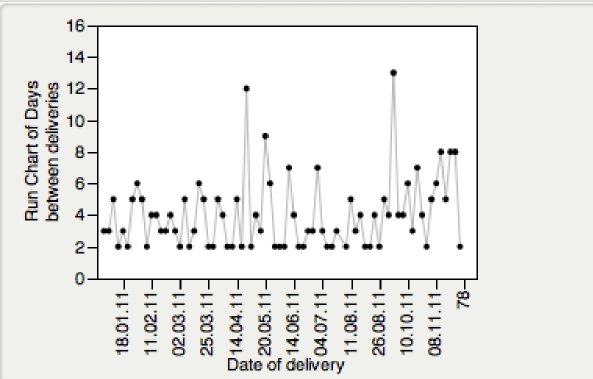
Mean	3,393617
Std Dev	1,7178261
Std Err Mean	0,1771802
Upper 95% Mean	3,7454619
Lower 95% Mean	3,0417722
N	94

9.5 Supplier Run Chart

These are plotted for deliveries to Spenncon. The sample excluded is the first order after summer (special cause variation).

Celsa Nordic

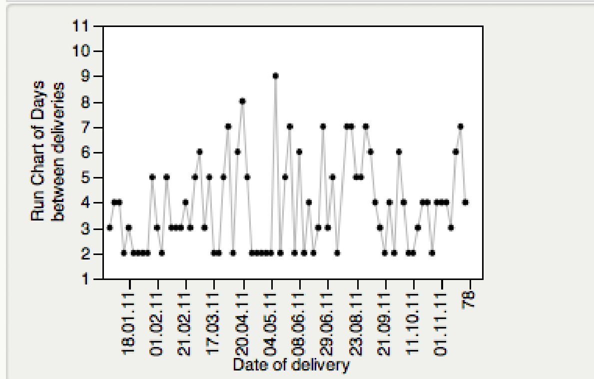
Run Chart of Days between deliveries



Note: 1 sample was excluded.

FNSteel

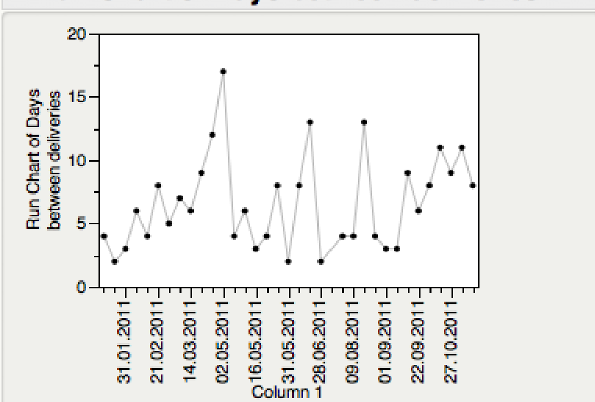
Run Chart of Days between deliveries



Note: 1 sample was excluded.

Halfen-DEHA

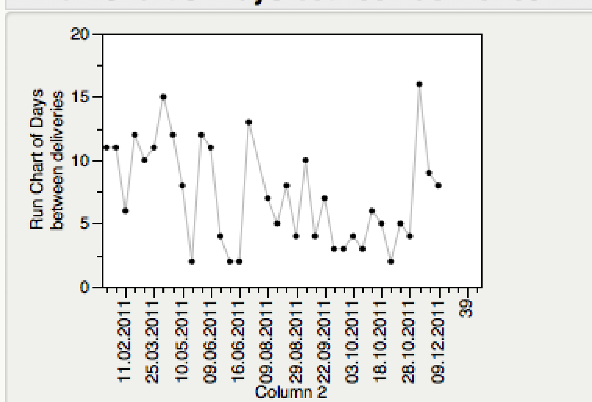
Run Chart of Days between deliveries



Note: 1 sample was excluded.

SB Produksjon

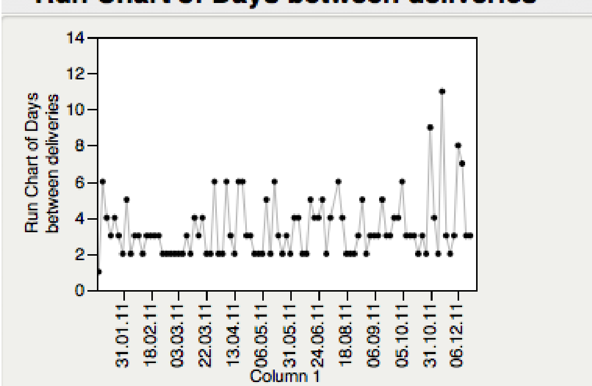
Run Chart of Days between deliveries



Note: 1 sample was excluded.

Pretec

Run Chart of Days between deliveries



Note: 1 sample was excluded.

9.6 Supplier key numbers

Celsa Nordic

- 105 orders
- 76 deliveries
- 13.5 million NOK
- Workdays between deliveries to Spenncon. Excluding special cause variation[13].
  - Mean = 4.03
  - Median = 3
  - Standard Deviation = 2.29

FN Steel

- 97 orders
- 76 deliveries
- 15.2 million NOK
- Workdays between deliveries to Spenncon. Excluding special cause variation.
  - Mean = 3.88
  - Median = 4
  - Standard Deviation = 1.82

Halfen-DEHA

- 38 orders
- Some planning in the ordering.
- 36 deliveries
- 200 000 NOK
- Workdays between deliveries to Spenncon. Excluding special cause variation.
  - Mean = 6.65
  - Median = 6
  - Standard Deviation = 3.7

Pretec

- 111 orders
- No significant planning in the ordering.
- 94 deliveries
- 2.5 million NOK
- Workdays between deliveries to Spenncon. Excluding special cause variation.
  - Mean = 3.34
  - Median = 3
  - Standard Deviation = 1.73

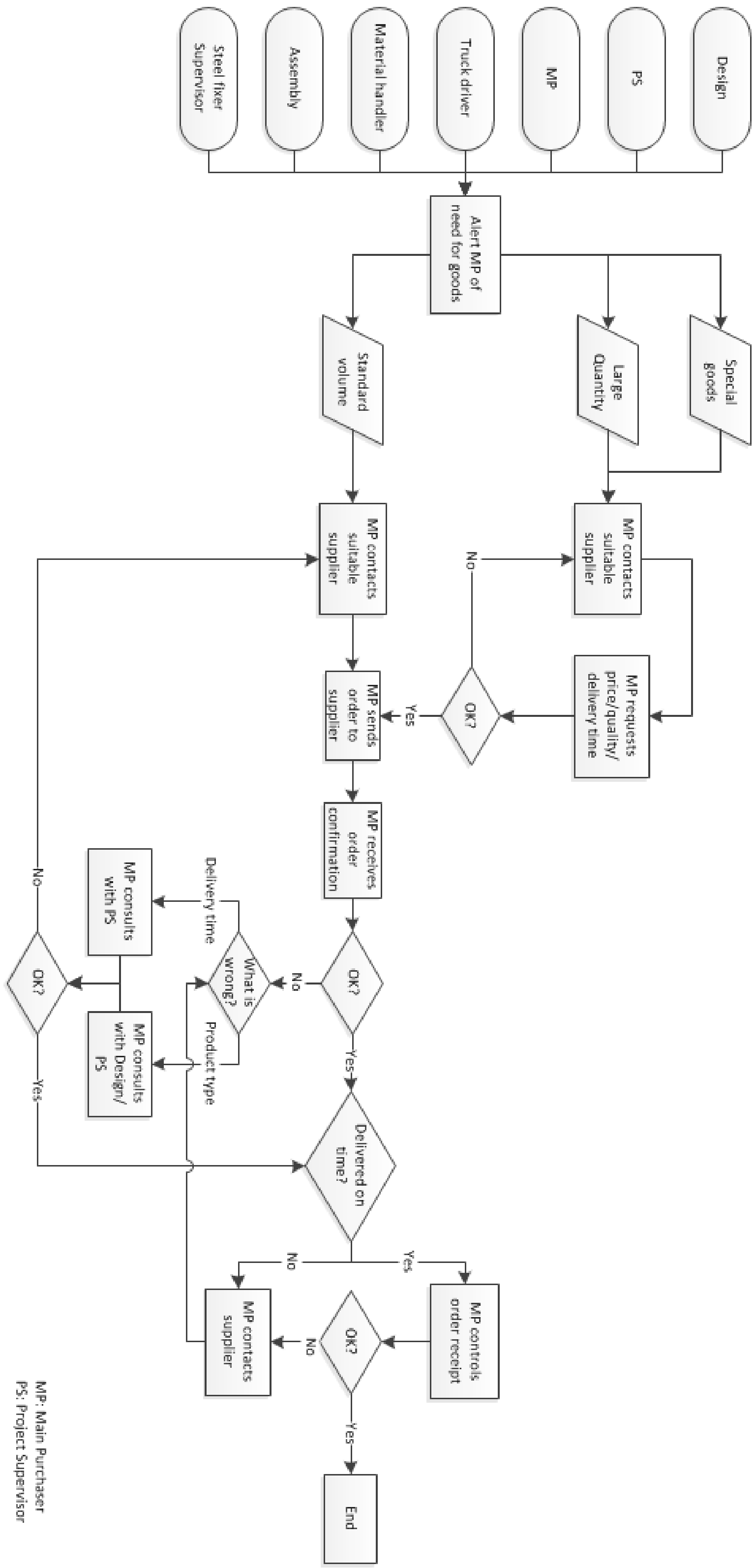
SB Produksjon

- 42 orders
- 6 preorders
- 35 deliveries
- 3.8 million NOK

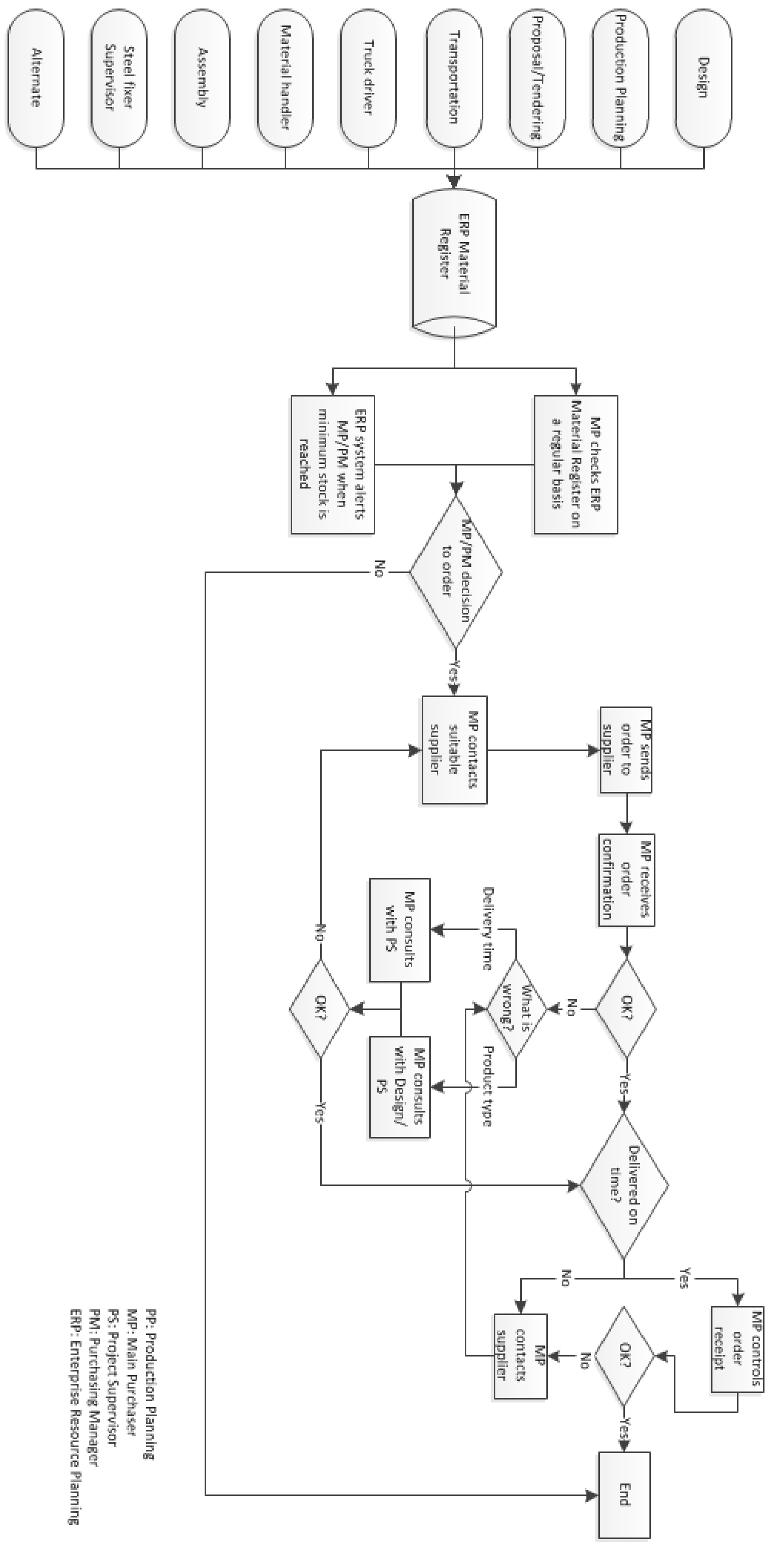
[13] Special cause variation is created by a non-random event leading to an unexpected change in the process output. An example of special cause variation is the first day after the summer holiday

- Workdays between each delivery to Spenncon. Excluding special cause variation.
    - Mean = 7.29
    - Median = 7
    - Standard Deviation = 4.02

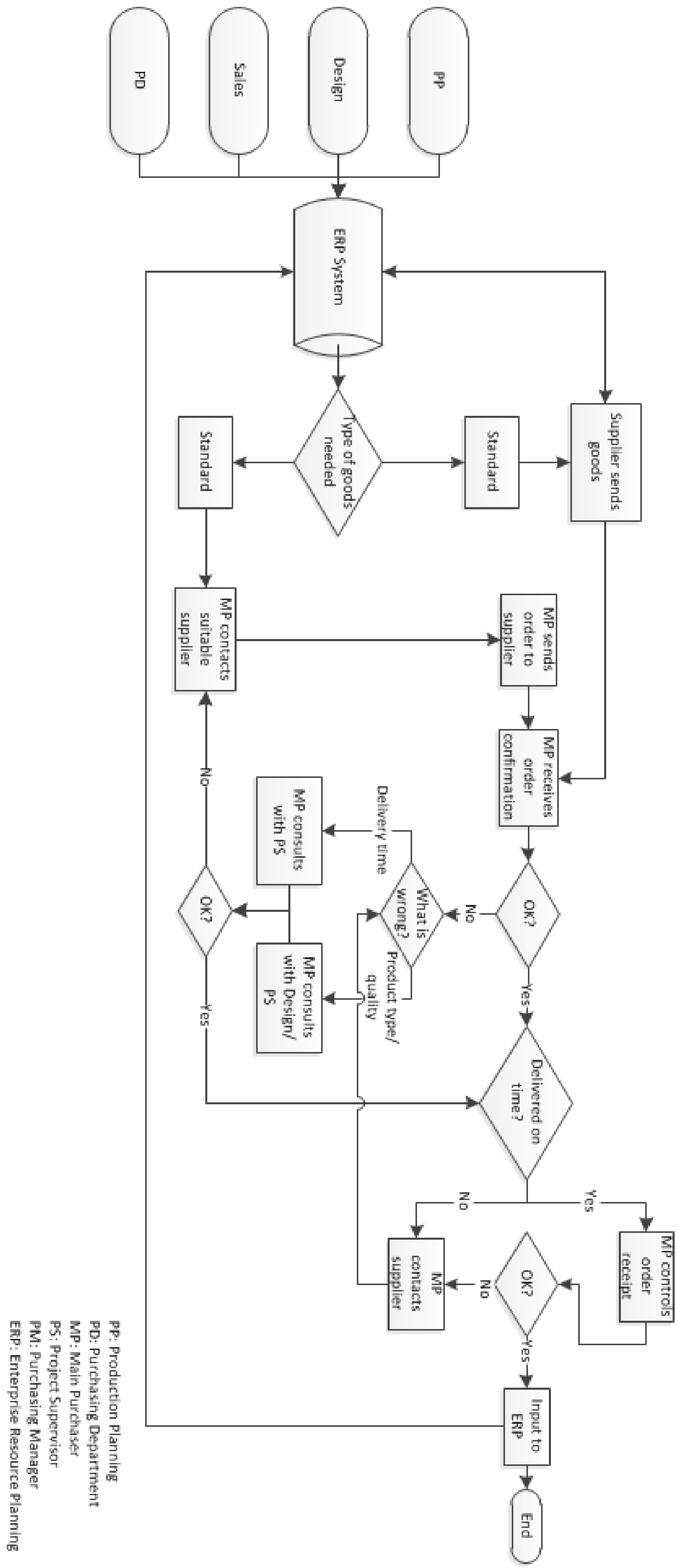
9.7 "AS IS"-model flowchart



9.8 Suggested solution



9.9 Suggested solution with supplier involvement



9.10 Total summary model