Master’s degree thesis

LOG950 Logistics

Uncovering and reducing the descrepancies encountered in the assembly processes for shell based construction projects for Spenncon AS

Håvard Jahre Frotvedt

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Acknowledgements

The author is deeply thankful to everyone that has contributed throughout the process of creating this master thesis.

This project has been undertaken in cooperation with Spenncon and Lean Communications. Both of these firms have answered questions and shared ideas with the author during the work on this project. Spenncon has also provided me with data and information during this paper. Thanks are sent to the production director Kjetil Nesset and factory manager Roberto Salice. Special gratitude is given to the montage leaders Øivind Ovesen and Brede Hella. Lean Communications have provided information, inputs and guidance throughout the thesis. Gratitude is sent to Jonas Wilson and special thanks are given to Gaute Hørlyk and Jørn Egil Tøien.

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Håvard J Frotvedt

Håvard Jahre Frotvedt

Foreword

In relation to carrying out this research there have been some challenges. Despite of this, the author feels like the process of making this paper have been highly instructive and valuable. The main challenge that has occurred during this research is that the topic has been changed several times. Initially it was thought that this research would look into applying lean practices to the production process. Then the topic was altered to look at ways to improve the procurement of supplies before it was changed to look into why changes in the montage plans occur during the construction projects. As a result of these initial changes considerable amount of time were lost. The author does not blame anyone for these mistakes and he also takes self-criticism for not pressing harder for conformation of interest from all the involved parties. Finally a last change of the topic was done by the author. The final topic was to look at the discrepancies that were encountered in relation to the assembly of elements to shell based construction projects. This change was done due to the shrinking time frame and challenges in obtaining data for the research. Another challenge has been obtaining answers when the researcher has been asking for help. This is due to the fact that the people from the firms that have contributed to this research have had to answer the questions in addition to their normal work tasks. It is important to note that all the important questions that have been asked have been answered. As a result the researcher must admit that this research has not gone as smooth as he had hoped. However, the researcher believes that all of these above problems can be seen as natural occurrences during a master thesis. The researcher does also admit that he has not been able to do everything he had hoped to do in relation to this research. One example is that the researcher has not been able to visit a construction site to observe the assembly processes and carry out interviews. However, the researcher is satisfied with the end result. Hopefully Spenncon, Lean Communications and the other involved parties are satisfied as well.

Abstract

This project is made for Spenncon; Spenncon is a producer of prefabricated concrete elements. The thesis is trying to uncover the main reasons for why discrepancies are encountered when Spenncon is assembling their products at building sites. Spenncon does only know that problems are encountered at the building sites, but not why these discrepancies are encountered. Spenncon is delivering a range of different products to different types of building projects. Looking into all kinds of projects would have been too complex so this thesis is looking into why discrepancies are encountered at the building sites where Spenncon is assembling their products in relation to shell based construction projects. In addition Spenncon have several factories in Norway and this thesis is only looking into one of the factories and, that is, the factory at Hønefoss.

In order to carry out this research, the firm has been studied and presented. This is done in the 1st chapter. A research methodology has been presented in order to have a blue print of how to carry out the research. This includes the four research questions that explain the aim of this research. This is presented in the 2nd chapter. Then a presentation of the problems that Spenncon can suffer when they are assembling their products in shell based construction projects is described in the 3rd chapter. In order to try and find some ways to reduce the problems that are encountered at the building sites, a theoretical framework is presented. In relation to this project lean was seen as a relevant theory. In this thesis one is looking into the value chain from production to assembly in the construction environment surrounding the building projects. As a result both lean production and lean construction is presented. Both these lean theories in addition to other relevant topics related to lean is presented in the 4th chapter. Next a data analysis is presented in order to see what the problems actually are when Spenncon is assembling their products. This data analysis is based on day reports made in relation to 2 different building projects that Spenncon participated in. It is also these day reports that uncovered what the main problems are for Spenncon during the assembly process. The analyses were made through the use of computer software inform of Excel and SPSS. Everything regarding these data analyses is presented in the 5th chapter. The main finding in this thesis was that Spenncon's own value chain was producing most of the deviations that were encountered at the building sites. In the 6th chapter recommendations are made in order to try and minimize the most iterative categories of discrepancies. These recommendations are based on the theory review presented earlier in the 4th chapter in addition to some supplementary theory. The tools suggested are the 5 whys analysis, Cross functional management, Poka-yoke

and Stop the line principle. Last but not least in the 7th chapter the conclusions regarding this research are drawn.

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1. Introduction:

In this introduction the firm that the research undertaken for is first presented i.e. Spenncon. Then the entire value chain for shell based construction is presented. Then a more detailed description of the outbound logistical operations i.e. the operations that are conducted in order to deliver the elements to building sites is presented. At last the entire operation from the planning processes until the elements are assembled at the building sites in relation to shell based construction projects are described. All of these descriptions are given in order to give an insight into all the operations that are done in order to deliver the prefabricated concrete elements to shell based construction projects.

1.1 Spenncon AS:

Spenncon is Norway's largest and leading supplier of shell construction based on prefabricated concrete elements. The firm delivers products and services for project development, project management, structural solutions, production and mounting for commercial buildings. In addition Spenncon delivers concrete elements to the transportation market and sleepers to the railway marked. These two last product groups (elements to the transportation market and sleepers) are outside the scope of this research as they are not used in shell based construction. Spenncon delivers a range of different prefabricated concrete elements to their customers in relation to shell based construction. The elements related to this category can be divided into three main groups. These are:

1. Hollow core. This is concrete elements that are used for the flooring and roofing of buildings. This is the main product for Spenncon.
2. Pillars and beams. These elements are made specifically to support the structure during the construction and lifespan of the building.
3. Walls and façade. Elements in this group are made specifically to be used as walls in the building or to be the front face of the building. These elements are produced in different configurations in order to provide support for other functions e.g. windows, doors, decorations etc.

Picture 1 Hollow core elements

Picture 2 Pillars and beams

Picture 3 Wall elements

Spenncon's main customers for shell based construction products are different contractors mainly: Skanska, NCC (A Swedish contractor that operates in the Nordic countries), Peab (A Swedish contractor that also operates in Finland and Norway) and Veidekke. Spenncon has delivered their products to well know buildings around in Norway e.g. Brann Stadion the stadium for the Norwegian premier league club SK Brann and St. Olavs Hospital in Trondheim. Spenncon is currently delivering products to the Norwegian Competence Center Maritime in Ålesund that will house different actors in the marine cluster in Sunnmøre (Spenncon 2011 and 2012).

Spenncon produces their products at six factories in Norway. These factories are located at: Hønefoss, Hamar, Sandnes, Bergen, Verdal and Hjørungavåg (Ålesund). These factories produce a slightly different product mix. This thesis only studies the factory at Hønefoss and a more detailed explanation about the other factories is therefore not given. Nevertheless this shows that Spenncon produces their products at different locations around in Norway. The factory at Hønefoss produces all the three products groups that are related to shell based construction (Spenncon 2011 and 2012).

Spenncon had an annual turnover of 1,4 billion Norwegian Kroner (NOK) in 2008. In 2009 and 2010 Spenncon had an annual turnover of approximately 930 million NOK. This decrease in turnover from 2008 to 2010 was mainly due to the downturn in the marked because of the financial crisis. Over this period from 2008 to 2010 Spenncon reduced their workforce from approximately 850 employees down to around 650 employees (Spenncon 2011 and 2012). The net profit for Spenncon was 78 million NOK in 2008 and 16 million in NOK in 2009 before they suffered a net loss of 15 million NOK in 2010 (Proff 2011). Spenncon believes that the market will recover after the downturn from 2008 to 2010. However, saying when the market has fully recovered is difficult to say but Spenncon have experienced a growth in demand over 2011. (Spenncon 2011 and 2012).

Spenncon is owned by Consolis which is one of the largest producers of prefabricated concrete elements in Europe (Spenncon 2011 and 2012). Consolis was formed when the Finnish company Consolis and the French company Bonna Sabla merged in 2005. Consolis main office is located in Brussels in Belgium, and from their main office they operates more than 130 plants in over 25 countries spreading from Scandinavia to North Africa and from UK to Russia. (Consolis 2011).

Spenncon has some competitors in Norway. Their main competitors producing prefabricated concrete elements in Norway are: Contiga, Ølen Bettong and Loe Bettongelementer. Contiga is a national competitor delivering more or less the same products and services as Spenncon. Ølen Bettong is a competitor in southern part of Norway delivering premade concrete elements to the shell based construction as well as premade concrete elements to the transportation market. Loe Bettongelementer is a competitor delivering premade concrete elements to shell based construction. In addition to their Norwegian competitors Spenncon is competing against foreign suppliers of premade concrete elements. Spenncon does also get some competition from substitute products i.e. alternative products to premade concrete elements that could be used for the same purpose e.g. steel for supporting structures or concrete that is steeped at the construction site (Spenncon 2011 and 2012).

1.2 Spenncon's value chain for shell based construction:

In relation to shell based construction projects Spenncon may not deliver all three of the product groups they are producing in relation to kind of construction projects. Spenncon may only deliver one or two of the products group's. One example can for example be that Spenncon delivers floor slabs (hollow core elements) and the walls to a construction project. While a competitor delivers the structural solutions for the project i.e. pillars and beams. These structural solutions delivered by competitors can be in form of both steel and concrete. What Spenncon actually delivers to the building projects does all depend on what Spenncon is able to sell to their customers and what kind of solutions the customers are looking for. So what Spenncon are delivering to the building projects will vary between the projects. In order to sell and deliver the products related to this assignment to their customers Spenncon has a value chain that enables these products to be made and delivered. The typical value chain for Spenncon when selling and delivering their products to the shell based construction projects is as follows:

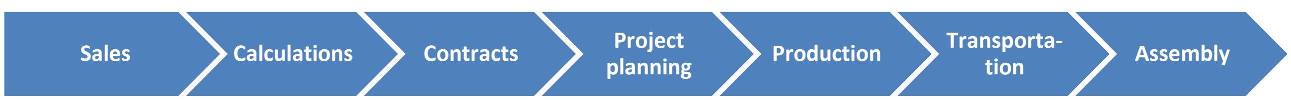


Figure 1 Spenncon's value chain

The value chain all begin with some sort of sale interactions between the sales personnel at Spenncon and their potential customers. The sales interaction can either be inform of the sales personnel at Spenncon contacting the potential customers or in the form of customers inviting Spenncon to contend in tendering processes. If the sales personnel is contacting the potential customers they are also trying to influence different solutions and designs related to the building process e.g. arrangements, structural solutions, assembly sequences and so forth. This is done so that Spenncon will have the best opportunity to be selected as the supplier to the building projects. Another reason why the firm is trying to influence these decisions is so the firm has the best possibility to deliver all of their products and services to the potential customers. The potential customers for Spenncon for this type of construction is normally different contractors like: Skanska, NCC (A Swedish contractor that operates in the Nordic countries), Peab (A Swedish contractor that also operates in Finland and Norway) etc. If there is some interest from the customers side some basic calculations are carried out. These basic calculations are carried out so that the potential customers can compare the different alternatives from the different bidders/suppliers against one another. These initial calculations are carried out by the sales organization at Spenncon (Spenncon 2011 and 2012).

If Spenncon is chosen as the supplier by the customer a contract is signed between the parties. At this stage the descriptions related to the project is not very detailed so the prices has been given with reservations to further clarifications as the project evolves. The prices are often given with a specific number of different elements accompanied with graphical tools to show what is included in the offer. These graphical tools consist of different drawings and a 3D model illustrating what is included. These graphical tools do also show the placement of the different elements and what type of elements is placed where. In order to deliver these offers to their customers, Spenncon has also carried out planning in relation to other processes than sales and graphical design. One example is that planning has been carried out in relation to the rigging and assembly process of the elements. This process encompasses finding the resources and time necessary to assemble the structure that Spenncon will be responsible for. This planning is done so that an estimated cost for the assembly process can be found. Other relevant processes that Spenncon will be responsible for in the building process are also being looked into at this stage. The reason for looking at these processes is to estimate all the costs for all the relevant processes that Spenncon will be responsible for in the building project (Spenncon 2011 and 2012).

After the contract has been signed and the general outlines for the project have been agreed upon the more detailed project planning process begins. This process uses the foundations from the initial sales calculation and the underlay from the architects to plan the building project in greater detail and carry out more detailed calculations. The usage of the earlier calculations is made under the assumption that building has not undergone major changes since these calculations were done so that these calculations still can be utilized. The calculations that are done at the project planning stage include load computations (calculations regarding the strength and stress on the building); so that the exact required specifications of the elements are found. The calculation process does also include finding the exact number of the different elements that is required to complete the project and have to be delivered to the project. In addition to calculations, this planning process does also consist of creating the general plans for the project e.g. finding the time frame, finding solutions to potential problems that may arise during the assembly process and so forth. This project planning stage is mainly done by the project department at Spenncon. All of these calculations and planning processes means that Spenncon is carrying out a considerable part of the technical planning related to the building project. So Spenncon is not only delivering products but also different services to their customers. After this general planning process is finished, a planning process consisting of more detailed planning commences. This detailed planning process consists of making the assembly plan, the project scheme and the production drawings and plans. Of these plans the assembly plan is made first and this plan do then direct the project scheme and production plan. This means that the project planning process also consist of planning how to carry out the production of the elements and how the assembly of the elements will be done. The assembly plan is also the most important plan at this stage since the montage plan influences the other plans (project scheme and production plan). So the project planning includes more or less the entire planning process for the part of the building project that Spenncon is responsible for. However, at this stage every detail regarding the building project has not been clarified. This means that the project plans have been made but these plans will be subject to changes as all the clarifications regarding the building project is made. These clarifications will occur closer to the time that the building project commences and/or during the building process (Spenncon 2011 and 2012).

After the project planning process is finished, the next step is to produce the elements to the building project i.e. the next step in the value chain is the production process. However, the project plans described in the planning process may have undergone changes as the clarifications regarding the project have been made. The first step in this planning process related to production is when the initial project plans have been made. At this stage the different projects are entered into a rough production plan so that the production department has a rough picture of how the production capacity is going to be utilized in the future. The production process itself will commence when the production plan requires the production to begin. Since Spenncon has several different construction projects going on at the same time, producing the right elements in the right order and at the right time could be difficult. Spenncon has therefor portfolio planners that plans production to the different building projects and makes the production plans. These production plans are made on the basis of when the different elements are required. This means that the portfolio planners use the assembly plans as a basis to find the delivery dates. The portfolio planners then use this delivery date to plan the production using reverse scheduling techniques. This assembly plan is made in two steps. The first assembly plan is made in the project planning process on the basis of what is known at this stage. As the clarifications regarding the building project are made, the original montage plan is subjected to coordinating efforts. These coordinating efforts are done so that a new and updated assembly plan that incorporates the clarifications is created. The portfolio planners then utilize this new assembly plan to plan the production (Spenncon 2011 and 2012).

The descriptions about the production of the relevant elements for this thesis could have been produced in greater detail than the actual description below. The core of this thesis is not related to production and production processes. As a result of this there will not be a need for a highly detailed description of the production and the production processes in this thesis. The production process will instead be described in a stepwise fashion so that an insight into the production processes can be given. This is done so that will be a general understanding of how the production of the elements that is relevant for this assignment is done. This will hopefully give an understanding of the different steps in the production processes related to the products that are delivered to shell based construction. This understanding is necessary to understand the entire value chain and the problems related to research in this thesis.

The production process of the 3 main product groups that are relevant for this thesis is done in two main ways. The hollow core elements are made through automated processes using machines on a highly automated production line. While the other elements (walls and façade and pillars and beams) are made through a more manual production process using dies and more manual labor on a less automated production line. The steps for producing the elements are similar for both processes, but the tools used are different between the two production processes. The first step in the production process is the mounting of the reinforcements that are needed to reinforce the concrete. The hollow core elements are made through the use of tension wires while the other products are made through the use of reinforcement bars or slack armoring. So the first step in making the hollow core elements is to stretch out the tension wires over the production line. The first step for the other products is the mounting of the reinforcements into the dies. The second step in the production process for the hollow core elements is to pour the concrete into the steeping machine. The steeping machine does then produce

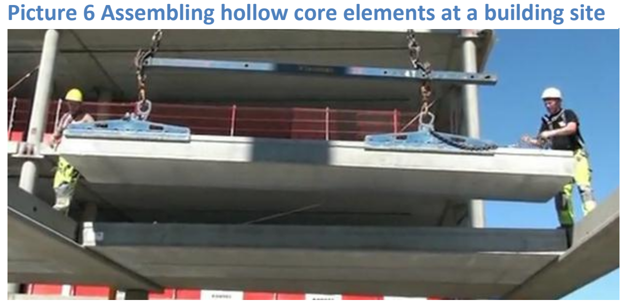
Picture 4 Steeping machine making hollow core elements on top of tension wires

the hollow core elements on top of the tension wires that already have been stretched out over the production line. For the other elements the second step consists of making the correct concrete mix before pouring this concrete mix into the dies where the reinforcements already have been mounted. Both of these processes are done so that the concrete can be steeped into the required shape and get the required characteristics for the different projects. When the steeping processes are finished the concrete is left to dry. The drying time varies depending on the amount of curing that is required. The amount of curing that is required depends on the desired strength and characteristics of the concrete. The time required in the hardening process is a minimum of 7 hours. When the concrete has dried, the hollow core elements are cut into the required lengths and the production process for the hollow core elements is finished. For the other products the last step of the production process consists of taking the elements out of their dies and cleaning them before the production process is finished (Spenncon 2011 and 2012).

Picture 5 Pouring concrete into a dies when producing beams

When the products have been produced and the production process has ended the finished products are transported out from the production facilities and put into the finished goods inventory also known as the rail track. Here the elements are stored until they can be delivered and transported to the construction site for final assemblage. When the elements are needed at the building site, they are made ready for transportation at the rail track. When the preparation process is finished the elements are transported to the building site. When the elements arrive at the building site, the transportation process is finished and the assembling process begins. This assembling process consists of removing the elements from the transportation equipment before lifting the elements into the required position and then securing them. When the elements have been properly secured in the right position, the value chain for that element is finished. When all the required elements have been mounted and secured into place, the value chain for Spenncon in relation to the building project is finished (Spenncon 2011 and 2012).

Picture 6 Assembling hollow core elements at a building site



1.3 The value chain for the delivery of elements to building sites:

The goal of this thesis is to uncover the problems encountered at the building sites when the elements are assembled together. The problems may not only come from the value chain presented earlier they may also come from the outbound logistical processes that are undertaken in order to deliver these elements to the building sites. These logistical processes were not described in detail earlier and as a result of this a more detailed explanation of the value chain for these processes must be presented. The problems encountered at the building sites can come from mistakes that are done from the planning face of the building project until the elements are assembled at the building sites at the different building projects. The value chain for the outbound logistical processes from production until assemblage at the building site where Spenncon is responsible for the assembly of their products at the building site is described below:

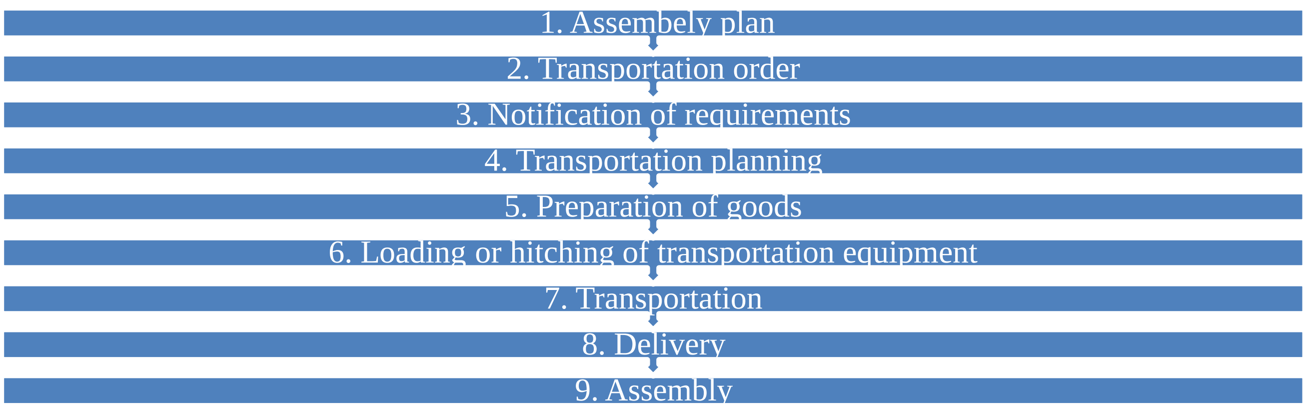


Figure 2 Value chain for the delivery of the elements to the building sites

The starting point for this value chain is the assembly plan, then the transportation order is made, before the transportation requirements is notified, then the transportation plan is made, before the goods are prepared for transportation, in the next step the goods are loaded and/or hitched to a vehicle before the products are transported to the building site, then the products are delivered to the building site and then finally assembled in to place. This was a short introduction to the value stream, but a more detailed explanation is needed in order to give an insight into what is being done at the different stages in the value chain. The different steps in this value chain consist of the following:

1. The assembly plan is the plan that describes how the assembling of the different elements in the building projects are to be done i.e. it is the plan that describes how to assemble the

different elements together and make the structure of the building. In addition to this description the assembly plan also shows the time that each element is scheduled to be assembled. This plan is made by the montage leader for the building project at Spenncon. This assembly plan is made two times. The first time is during the project planning process which is done prior to all the clarifications regarding the building process is made. Then after the clarifications regarding the building process are made, a second and updated assembly plan is put together. The assembly plan is not only used in the assembling process, it is also used by the portfolio planners. The portfolio planners have the responsibility to plan and coordinate the production of elements to all of the different building projects that Spenncon is involved in. The assembly plan is used as a planning tool by the portfolio planners in production so that the right elements can be produced in the right order at the right time so that the assembling process can commence according to plan. In order to achieve this, the portfolio planners utilize reverse scheduling techniques. This means that Spenncon operates in a make-to-order environment i.e. the elements are only produced after the specifications are clear. This also means that Spenncon is utilizing the pull principle i.e. that no production is done before there is demands for the actual product. Since the assembly plan works as a planning tool for both the assembling process and the production process, the changes that are done in the assembly plan will have an impact both on the assembling process and on the production process. So even if the assembling process is furthermost upstream process in the value chain, it has an impact on the downstream production process. This is why the assembly plan is so important for Spenncon and why this research to look into the problems encountered at the building sites when assembly of the elements is done. The problems encountered at the building site can have a direct impact on if the assembly plan can be followed or not. The problems encountered at the building site are also the last process in the value chain i.e. it allows all the mistakes done in previous processes in the value chain to be uncovered. Further the assembly plan is looked at when the transportation process is planned. This will be explained below. So the new assembly plan is used in the montage process, the production process and during the planning of the transportation process.

2. Transportation order is the process of sending over a transport booking from Spenncon to the carrier of the goods Bolkan. This transportation order is nothing more than a

notification of one transport assignment from the transportation office at Spenncon to the transportation company Bolkan. This order is issued 3 days before the transportation services are needed by Spenncon. This transportation order is made by the transportation office at Spenncons factory at Hønefoss. The transportation office is responsible for organizing the transportation of Spenncons products from the factory at Hønefoss to the different building sites served by this factory. Spenncon produces most of their product range at the different factories spread around in Norway, and as a result of this most of the deliveries are done by the factory located closest to the building projects. This means that the factory at Hønefoss mainly serves the building projects in its closest geographical area i.e. eastern Norway. Bolkan is a transportation company that specializes in specialized transportation of concrete elements and steel products. Bolkan has their main office in Verdal and has offices in Namsos, Bergen and at Spenncon facilities at Hønefoss. Spenncon has chosen Bolkan as their sole provider of transportation services from the factory in Hønefoss to their building projects.

3. Based on this transportation order, the transportation office at Spenncon issues a notification of the requirements for the transportation order that has been assigned to Bolkan. This is done so that Bolkan will have a rough idea of what is to be transported and when the equipment will be needed to carry out the upcoming shipments. The transportation office finds the details about what is to be transported by looking at the assembly plan.
4. After these two initial communication steps between the transportation office at Spenncon and Bolkan is finished, the transportation planning process commences. This is the planning of the entire transportation requirements for the transportation order and notification of the requirements that was sent from the driving office to Bolkan initially. Spenncon carries out most of the planning related to this process i.e. the planning of which elements that is to be transported, make the calculations of the weight of the load that is to be transported, suggest the load carrier to be used etc. The details regarding what is to be transported are found by the looking at the assembly plan. When the planning process is done by Spenncon, Bolkan attaches the necessary resources (driver, vehicle and load carrier etc.) that are needed to carry out the transportation assignment from the factory in Hønefoss to the building site.

Picture 7 Rail track

5. When the planning process itself is finished and the transportation process is about to commence, the goods are prepared for transportation to the building site by Spenncon. This means preparing the goods that is to be transported in the finished goods inventory also known as the rail track. If the required load carrier is available on sight, the load carrier is typically also loaded during this process. If this is done the vehicle that is assigned to the load can just hitch up to the load carrier when it arrives on site.
6. Loading or hitching of transportation equipment. At this step the load carrier and vehicle arrives on sight, before the load carrier is loaded and hitched back on the vehicle. If the loading process has already been done as described in the previous process the process just consists of hitching the load carrier to the vehicle.
7. When the loading or hitching process is finished, the goods are transported to the building site by Bolkan. This transportation process consists of physically transporting the goods to the building sites.
8. The transportation process is finished when the goods arrive at the building sites. The transportation equipment is then unloaded at the building site i.e. the goods are delivered to the building site. When this is done the outbound logistical processes are finished.
9. When the outbound logistical operations are finished the assembling process begins. This assembly process consists of moving the elements from the place that transportation equipment has unloaded the elements and lifting the elements into the required position and securing them. When the elements have been properly secured in the right position, the value chain for that element is finished. When all the required elements have been mounted and secured into place, the value chain for Spenncon in relation to the building project is finished (Spenncon 2011 and 2012).

1.4 The value chain from the planning stages until the assembly process:

So far the company in this research i.e. Spenncon have been presented along with the entire value chain related to shell based construction project for the firm. In addition a more detailed explanation of all the operations that are undertaken in order to deliver and assemble the elements to shell based construction projects has been described. These explanations have been presented to give a total view of everything that is done by Spenncon in relation to this assignment. These explanations have been given in order to give a total insight into what is done when Spenncon is delivering their products and services to shell based construction projects. All of these explanations have been made so one is able to see the complexity of all these operations. These explanations have now been done and a more specific explanation of the processes that are done in relation to the topic of thesis is now presented. This encompasses all the relevant processes that are undertaken from the planning stage until the assembling processes are carried out at the building sites. This is done so that one can see all processes that can have produced errors until the elements are mounted at the building site hence find the potential reason for why Spenncon have problems assembling the elements at the building sites. All the upstream processes can have an impact on the activities undertaken at the building sites if they are not conducted properly. At the next page all of these upstream processes are described graphically before these processes are explained further.

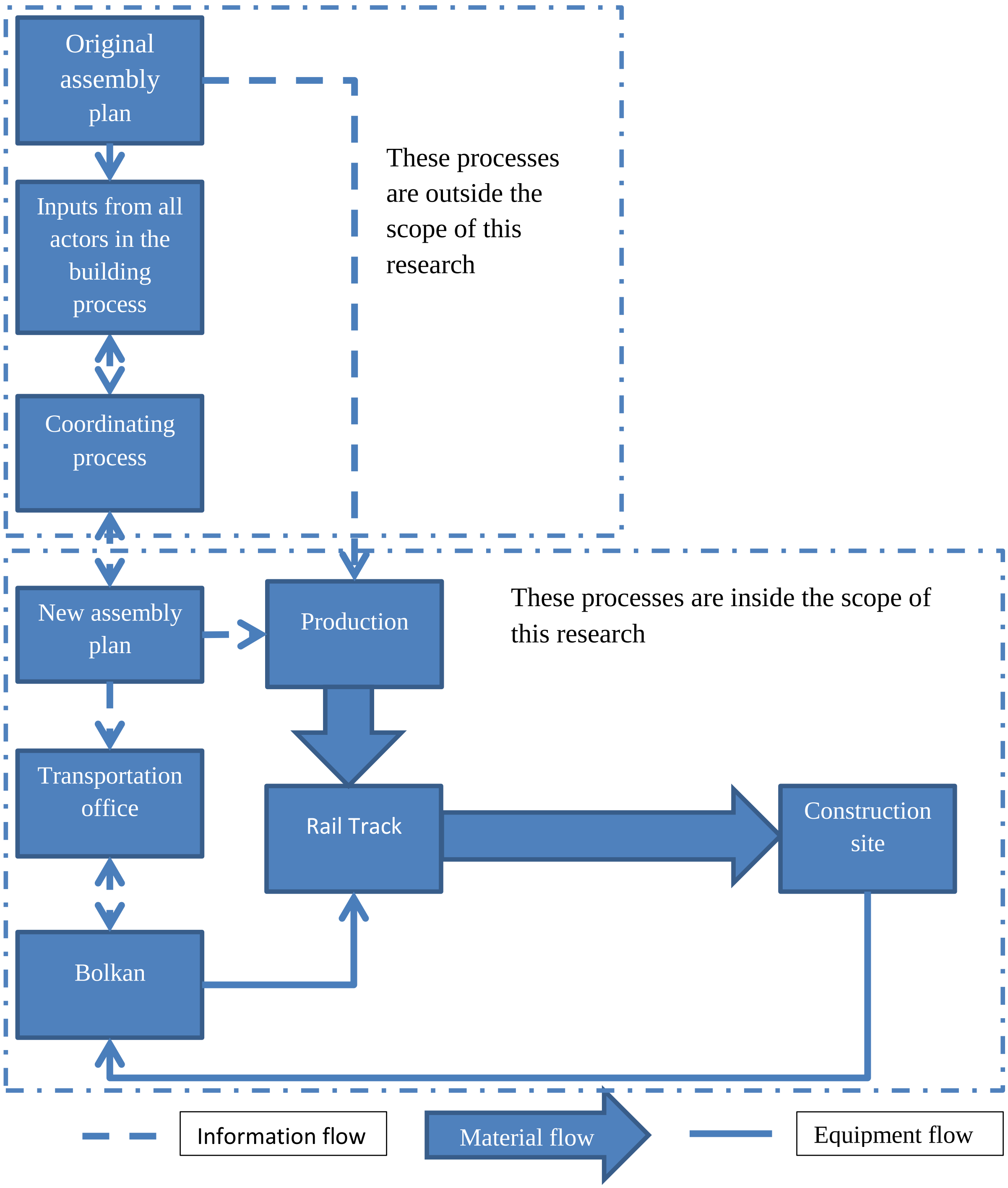


Figure 3 Value chain form the planning stages until the assembly process

The starting point for all the activities that are undertaken in relation to deliver elements to shell based construction is the original assembly plan made by Spenncon. This is the plan that is made during the project planning process i.e. prior to all the clarifications regarding the building process is clarified. This original assembly plan is also used by production department to make a rough production plan so that production has a crude picture of what is going to be produced in the future. This is why there is an information flow to production from the original assembly plan. The original assembly plan is subjected to the inputs from all the different actors in the building process. These inputs from the other actors do for example deal with the clarifications regarding the building process itself. As described earlier, the assembly plan is made by Spenncon in the project planning process but this plan is subject to changes as the clarifications regarding the project is made. This is why this box is called inputs from all the different actors in the building process. Further details regarding the different actors are presented later in this sub-chapter. From the inputs from all the actors, the information flow continues to the coordinating process. This coordinating process incorporates the inputs from the other actors into the original assembly plan and the outcome is the new assembly plan. The parts described here are all seen as natural occurrences during a building project by Spenncon (Spenncon 2011 and 2012). The changes that are made during this stage are therefore out of the scope of this research from Spenncon view. Looking at the changes in the plans that occur naturally due to the complexity of building projects is therefore not meaningful in relation to this research.

Then we are entering the part of the illustration that actually is in the topic of this thesis since this is where the actual planning process regarding the building project starts. This planning process starts with the new assembly plan that is made after the clarifications regarding the building projects are undertaken. From the new assembly plan the information flow splits up and goes two ways. One flow goes to the transportation office at Spenncon that corresponds with Bolkan in order to organize the transportation of the elements from Spenncon's factory at Hønefoss to the building sites. The second flow goes from the montage plan to the production department so that the portfolio planners are able to plan the production of the elements. This planning process is undertaken so that the right elements can be produced at the right time as they are required at the building site. Based on the production plan the production process commences and the elements are being produced. The materials then flow from the production to the finished goods inventory also known as the rail track. The material flow will then continue from the rail track to the construction site. In order to be able to move the elements from the rail track to the building sites there has been coordinating efforts between the transportation office at Spenncon and the carrier of the goods Bolkan. Information has been sent out from the transportation office at Spenncon to Bolkan inform of a transportation order and the notification of requirements. The two parties have then embarked on the more detailed transportation planning process so that the transportation assignments can be planned in detail. When this is done the elements that are to be transported to the building site can be prepared at the rail track. This also means that transportation equipment can flow from Bolkan to the rail track so the transportation process can commence and the elements can be delivered to the building site. When the elements have been delivered at the building site the transportation equipment returns back to the place where Bolkan requires them to go in order to carry out more transport assignments. When the elements have been delivered at the building site the actual mounting process begins (Spenncon 2011 and 2012). It is from the assembly process that all the defects can be found and traced back to its source. As a result it is at the assembly processes that the value chain in relation to this thesis ends. The relevant value chain for this thesis goes from the new assembly plan until the assembly process is carried out. From the assembly process all the mistakes that are done in the upstream processes can be spotted.

In the building project environment there are several other actors involved in the building process that creates the building. There is a main contractor that has the overall responsibility for the building project. There are also subcontractors working for the main contractor, not only Spenncon. This means that there will have to be put efforts into coordinating the activities between the different actors and allocate the resources (crane capacity, discharge opportunities, storage space, coordinating assembly activities etc.) between the actors. This means that original plans made by Spenncon in the project planning process may have to be changed since all the details regarding the resources were not available when the plans were made. The original plans may also have to be changed so that the assembly processes that Spenncon is responsible for corresponds with the other activities carried out by the other actors in the building process. As said before this is all natural occurrences due to the clarifications that have to be made in relation to the building project. Further the involvement of different actors can also mean that there are potentials for the plans that have been clarified between the different actors to be changed due to unforeseen circumstances as the building process commences. So even if plans have been clarified between the different actors, there is always a risk of these plans to change (Spenncon 2011 and 2012).

The power between the different actors in this environment is regulated by the contracts that have been signed between the different actors. Despite of these contracts the basis for solving problems in this environment is that there should be cooperation between the different actors that are involved in the building process. This cooperation should assist in the making of the plans related to the building project and secure the advancement in the building project. There is also a basis that any problems that occur during the project should be solved in cooperation by the different actors that are involved in the process where the problems arises. However, the main contractor will probably be the most powerful actor in this environment since the overall responsibility is assigned to the main contractor. Further it is also the main contractor that has negotiated the contracts with the different sub-contractors. As a result of this the actor with the most power in the building projects will be the main contractor (Spenncon 2011 and 2012). This discussion about power and decision power in the building projects that Spenncon is involved are undoubtedly important questions. However, conduction a thorough discussion about this subject at this stage will not be appropriate. I will return to these discussions later if it turns out that power and decision power is a problem for Spenncon.

The involvement of different actors can also be described graphically as done on the next page. Please remember the previous figure about the value chain form the planning stages until the assembly processes to shell based construction projects when looking at this figure. This figure describes the environment that serves as an input in to the value chain from the original assembly plan until the elements are assembled by Spenncon.

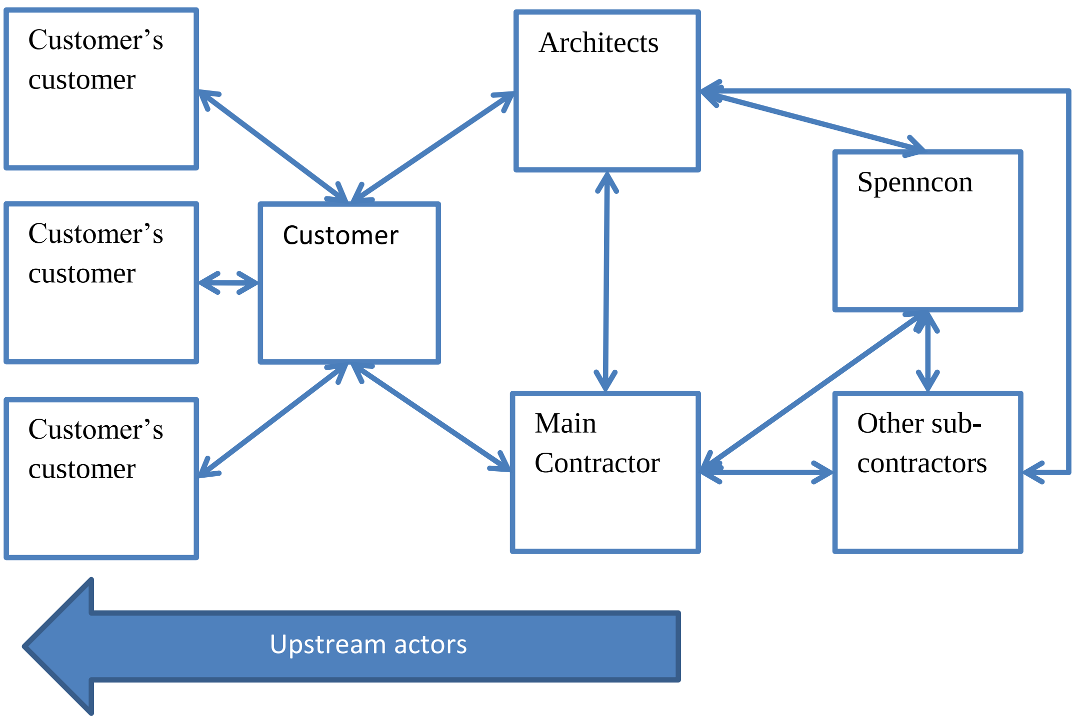


Figure 4 Actors in the value chain

In this building project environment Spenncon is not able to have full control over the building process they are involved in due to the involvement of other actors. In addition the involvement of other actors in the building project can cause changes to the building itself or the building process itself. This also means that even if Spenncon is planning their internal processes before the project starts, there are bound to be changes. These changes will occur due to the building process itself, the change of requirements from the customer side and the fact that all aspects related to the building project have not been clarified before the building project commences. In addition the changes can also occur due to external factors which none of the participants have any control over such as for example weather conditions. So there are a lot of factors that can influence the building project and cause changes. These changes will then successively cause changes to the internal processes that are carried out at Spenncon side. These problems will be presented and discussed in greater detail in chapter 3.1 Problems that can occur during the building process.

2. Methodology:

This methodology chapter is built up using the second edition of the book: Case study research design and methods by Robert K. Yin published in 1994. This chapter follows the same sequencing as Yin has used in his book since the descriptions and explanations in this book are done in a good and clear fashion. The second edition has been utilized in relation to this thesis since newer editions have been difficult to obtain. However, the information in newer editions relative to the edition used in this thesis has not been found different by the author when studying the newest edition. So the usage of this edition relative to newer editions should not present any source of bias in relation to the methodology chapter in this thesis.

This chapter is divided into three different subchapters. The first subchapter consists off the research problem including the explanation of how this research came about and the research questions asked in relation to this thesis. Then the research strategy is presented in the following subchapter before the last subchapter consisting of the research design is presented.

2.1 Research problem:

The basis for this research came about when Spenncon presented 5 different topics for potential master theses for the students at Molde University College. After conducting several meetings with Spenncon we found a different topic for this thesis than the original five topics presented in the original outline. As said in the foreword the topic for this thesis has been changed several times. The final topic we came up with after all these meetings was to look at the changes that occur in the new assembly plan after the clarifications regarding building projects are done. Further the goal was to see what influence these changes had on the value chain for the outbound processes from the finished goods inventory until the products are delivered to the building site. This topic came about in relation to a project called: “Lønnsomme bygg i fra Hønefoss” i.e. “Profitable buildings from Hønefoss”. This project was started due to low profitability at Spenncon’s factory at Hønefoss. The project aims to ensure the long term profitability by introducing lean in the production of premade concrete elements at this factory. This project is looking into all functions and departments at Spenncon’s factory at Hønefoss. Despite of all of these efforts related to the project “Profitable buildings from Hønefoss” Spenncon feel that the outbound logistics processes from their factory in Hønefoss have not been studied thoroughly enough and as a result they wanted this research to look at this topic. Spenncon does also suffer large deviations from the montage budget related to the assembly of buildings and these deviations are reducing the profitability of their projects. Spenncon does also have economic incentives for conducting a study of the outbound logistical processes related to the montage budget and the montage plan.

During the research it became clear that looking into the changes in the new assembly plan and studying the impact that these changes has on the outbound logistical operation became too comprehensive for this thesis. As a result of this the scope of the research were altered to look at the deviations/discrepancies that Spenncon are encountering at the building sites when they are assembling their elements instead. By the deviations/discrepancies encountered at the building sites it is meant the factors that influences the assembly activities undertaken by Spenncon at the building sites and obstruct these activities from being done without hindrances. This can for example be late delivery of elements to the building site or products that are not produced as specified in the production plans. The aim of this research is to find the reason for the deviations to occur and how these deviations can be reduced or eliminated from occurring. The scope of this research is to look into all the deviations that occur at the building site. These deviations can come from any operation that is undertaken from the new assembly plan is made until the products actually are assembled at the building site. However, this research does not aim to reduce all the discrepancies that can be encountered at the building sites it only aims to reduce the most iterative discrepancy.

There are set some limitations regarding this research. These limitations were set due to the aim of this research, namely find the reason for the deviations encountered at the building sites. There will hardly be any activities at the building site conducted by Spenncon if Spenncon is not responsible for the assembly of the elements at the building sites. So this research is only looking into the deviations that are encountered by Spenncon at the building site. This limitation is also set so that data collection will be possible. If Spenncon is carrying out this process they will have the required data at hand that shows what kind of deviations that are obstructing their activities at the building sites. The aim is to reduce or eliminate the most iterative discrepancies from occurring during the assembly process. As a result all the processes that are carried out from the products have been planned until the products are assembled at the building sites have to be looked into. The starting point for this value chain and the research in thesis is the new assembly plan. All the operations that have been conducted until they are assembled at the building site have already been explained and so has the entire value chain related to Spenncon's products. Please look at the previous subchapters for these descriptions.

Spenncon feel that the current outbound logistical processes and production are functioning in a good way as they are organized today. The problem for Spenncon is that their new assembly plan is changing all too often and Spenncon do not know why these changes are occurring. The goal of this research is to find the reasons why the deviations at the building site are occurring. This is done so that some parts of the deviations regarding the new assembly plan can be found. If the deviations at the building sites is reduced or removed there will be fewer factors causing changes to the new assembly plan. If the activities are going as planned at the building sites there will be fewer reasons for deviations regarding the assembly of elements hence there will be fewer factors influencing the new assembly plan. In order to find out why the deviations at the building site are occurring the reasons for the discrepancies have to be found. When reasons for these deviations are found it will be possible to make suggestions on how to remove or reduce these discrepancies from occurring. It will also be possible to make suggestions on how these recommendations can be implemented. This is done so that the all the factors that influences the premade concrete elements from the planning face until the elements are delivered at the building sites could be done more efficient relative to the discrepancies encountered at the building sites. Aiming to reduce all types of deviations will be too ambitious for this thesis and as a result this thesis is only aiming to reduce the most iterative discrepancy/discrepancies. Please bear in mind that this thesis is only looking into projects from the factory at Hønefoss and different building projects served by this factory. My suggestions can hopefully also be implemented and produce benefits for the rest of Spenncon's other factories in Norway. This can also be seen in connection with the project "Profitable buildings from Hønefoss" where the lessons learned at this project at Hønefoss will be implemented at Spenncon's other factories in Norway as well. Please do also bear in mind that this project has looked into all functions and departments at the factory at Hønefoss including planning and production of elements. As a result of this there will probably be more to gain by looking at the outbound logistical operations since this project has not looked into the outbound logistical operations. However, this is just a calculated at guess at this point. The data analyses done in chapter 5 and recommendations made in chapter 6 will reveal the problem areas.

When conducting research there are various steps that need to be undertaken. The first step is to find out what we want to study i.e. finding the research questions. (Hancock and Algozzine 2011). According to Yin (1994) defining research questions is one of the most important steps taken when doing a research study. As a result time and effort should be used in order find and formulate these research questions. These research questions can also be used to find the appropriate research strategy for undertaking the studies (Yin 1994). The research questions in relation to the research carried out in this thesis will be as follows:

1. Why do most of the discrepancies encountered at the building sites occur?
2. What part in the value chain from the assembling processes to the planning processes do these discrepancies originate from?
3. How can the most iterative discrepancy/discrepancies at the building site be reduced or eliminated and which measures can be used to achieve this?
4. How can the suggested measures be implemented and utilized by Spenncon?

2.2 Research strategy:

The research questions formulated in relation to this research consist mostly of "how" and "why" questions. There is also a "what" question that seeks to explain the relation of the previous explanatory question within the value chain. This means that the questions being asked in this research is of an explanatory kind. Due to the explanatory nature of these questions they tend to favor the use of explanatory research i.e. case studies, histories and experiments as the research strategies. This can be explained by the fact that these explanatory questions dealing with operational links that needs to be traced over time. This means that there are 3 different potential research strategies to choose from based on the research questions. A further distinction from these 3 strategies must be found in order to find the appropriate research strategy. This distinction can be found by looking into if the researcher has access to the events that are being studied and if the researcher has any control over the events that is being studied. In this research the researcher will have no control over the events that are occurring since the events are controlled by the actors that are involved in the building process. The events that are being studied are currently ongoing and as a result of this the researcher has access to the events that is under investigation. Based on these 2 points it is clear that the environment in this research is best suited for using the case study strategy. In the case study strategy the researcher can rely on documents that are both primary and secondary in addition to: artifacts, observations and interviews (Yin 1994).

According to Yin the technical definition of case studies begins with the scope of the case study (This is the first part of Yin's definition of case studies). The scope of the case studies are empirical investigations that look at contemporary occurrences in their real life context. This goes especially for investigations where the border between the occurrences and context are not clearly evident. This means that case study methodology would be used when the researcher wants to look at contextual conditions believing that these conditions can have highly relevant impact on the occurrences in the study. Secondly the conditions and occurrences in the contemporary research are not always possible to separate from another, a whole set of different technical characteristics becomes a part of Yin's technical definition of case studies. The case study enquiry deals with the unique situation where there can be many more variables of interest than the data points. The outcome from this is that case studies can rely on several different sources of evidence that contains different forms of data that can be triangulated. When the data have been triangulated one conclusion can be drawn and this conclusion can also be verified by the data triangulation. This leads to another result, namely that the benefits from the earlier developments of the theoretical proposals can be used to guide the data collection and the analysis. This means that the case study research strategy consist of an all-encompassing methodology for incorporating specific approaches to data collection and data analysis. As a result the case study approach is not a data collection tactic or design feature alone, it is a comprehensive research strategy (Yin 1994).

In this particular research the interest lies in the deviations encountered at the building sites. The research will like to get insight into why these deviations are occurring and the underlying reason why these deviations are occurring. The researchers are not interested in creating general theories or generalize the findings to a broader population. The research design in this particular research is therefore of intrinsic nature and can be described as an intrinsic case study (Hancock and Algozzine 2011). Further this research is interested in finding where these deviations originate from in the value chain from planning to assembly. In addition there is an interest in undercover how these deviations can be reduced or removed from occurring so that there will be fewer deviations encountered at the building sites for Spenncon in the future. This means that there will be made suggestions on how these deviations can be reduced. Last but not least is there is also an interest in proposing how these suggestions can be implemented. Please bear in mind that this thesis only aims at reducing the most iterative discrepancy/discrepancies and not all types of discrepancies.

Using the case study methodology as the research strategy has both advantages and disadvantages. According to Meredith (1998) the advantages are that the occurrences can be studied in their natural setting. The outcome from this is that meaningful, relevant theory can be produced by studying the occurrences in their natural setting. The case method does also allow the researcher to investigate cases which are unknown or little is known. The case study methodology does also allow the researchers to look at specific occurrences that are not fully understood and the researcher can then carry out research so that a relatively full understanding of the occurrences can be found. The case study methodology may also allow rich explanations and potential testing of hypothesis for well described and specific situations (Meredith 1998).

There are also some disadvantages when using the case study strategy as the research strategy. There are the requirements of direct observations of the actual ongoing situation. This can lead to large sacrifices in relation to cost, access and time. The need for using multiple tools, methods and objects for triangulation as well as the lack of control over the situation and the complexity of the situation that is being studied, does all add to the complexity for conducting a case study. Another disadvantage for using the case study as a research strategy is the lack of knowledge about the techniques employed and thoroughness of the studies carried out by using this research strategy in academia. One example presented by Meredith (1998) is the perceived view on qualitative research. Since it is believed that conducting qualitative research can produce: errors, poor validation and questionable generalizability (Meredith 1998).

2.3 Research design:

According to Yin the next step after finding the research strategy is to find the research design. In case studies this design has 5 especially important components and these are:

1. Study questions. Also called research questions and this component have already been described under chapter 2.1. These are the questions related to specify the research so that the nature of the research can be found. They are also questions that are used as a tool to find the appropriate research strategy (Yin 1994).
2. Study propositions. The second component is to present study propositions if it is possible to make any propositions in relation to the study. The rationale behind presenting study propositions are to direct attention towards what should be examined in the research. These study propositions are in other words meant to push the research in the right direction, reflect on the theoretical issues and make the researcher look for relevant evidence. However, some studies can have genuine reasons for not having any study propositions and this is a typical condition for explanatory studies such as this thesis. Studies of this kind should state a purpose and criteria for which the exploration of the study can be judged successful or not (Yin 1994). In this particular research the purpose of the research is to uncover why deviations in the activities at the building site are occurring. Secondly there is an interest in uncovering where these deviations have taken place in the process from the new assembly plan until the assembly activities at building site is undertaken. The criteria that will judge if this research were successful or not is whether the reasons for these deviations are uncovered or not. As a further challenge the research is also trying to come up with suggestions on how the most iterative discrepancies can be reduced or removed and how these suggestions can be implemented.
3. Unit or units of analysis. This is the third component and this component is related to the problem of describing what the case actually is all about. Once the definition of the case has been found, the clarifications regarding the unit of analysis becomes important so that the boundaries for the research can be made. The unit of analysis does also check if your primary research questions have been properly made or not. If it is not possible to pin point the exact unit or units of analysis based on the research questions made initially, the questions that have been made are either too vague or too numerous. If either of these problems arises, the results can be that it will be troublesome to conduct the actual case study (Yin 1994). The unit of

analysis in this research is the deviations that are encountered in the assembly process at the building sites. These deviations will be found by studding the day reports from two building projects.

4. The logic of linking data to propositions and interpret the findings. This is the fourth step in the research design and this represents one of the two steps to analyze the data in case study research. The analytical steps should lay the foundations for carrying out the analysis required in case studies. These steps of analyzing the data is also the least developed steps in the research design for case studies. This logic of linking data to propositions and interpreting the findings is what the names implies namely linking the data to the different propositions and interpret the findings. This can be done in numerous ways using different tools and/or techniques that can analyze the data (Yin 1994). As said on the previous page under point 2 this research does not have study propositions. This research does instead have a purpose. As a result the aim of this research is to link the data to the purpose of the study and interpret the findings. In this research one will look at the data in the day reports from two different building projects. The data from these day reports have been collected and entered into computer software inform of Excel and SPSS. The computer software has then been used to carry out some different analyses to uncover why deviations are occurring at the building sites. In other words computer software has been used to link the data in the day reports to the purpose. The output from the computer software has then been interpreted by the researcher in order to find the problem areas for Spenncon. How the findings were interpreted by the researcher is further explained in the next point.
5. The criteria for interpret the findings in the research. This is the fifth and last step in the research design and represents the second and last step on how to analyze data in case study research. This step is what the name indicates i.e. finding the criteria for how to interpret the findings in the research. This can be done in different ways. One way to interpret the findings could for example be through the use of statistics and statistical criteria's. It can also consist of reaching and discussing other explanations that do not support your explanations for the findings in the research (Yin 1994). In relation to this research a crude data analysis was done in order to look for trends in the data material. The researcher looked for general connected trends between the building projects. The researcher used graphs and percentage figures to look for these trends. Next Fischer's exact test was used to look for significance between the

different categories of discrepancies. Statistical criteria's were used to look for evidence of significant differences between the categories in relation to this test. After that there were made some estimations in order to uncover the main problem areas in the assembly process. Graphs and figures were used to illustrate the problem areas. Finally the data material was studied once more and the most iterative discrepancy/discrepancies encountered in the assembly processes were uncovered. The most iterative discrepancies stood clearly out in the data material when the researcher studied the data material for the most severe category in the estimations closer.

3. Descriptions:

In this chapter the building project environment that Spenncon is working under in relation to shell based construction is described. Some of the problems that Spenncon can encounter during the assembly process at the building site are also described. Last but not least the focus in this research is further clarified.

3.1 Problems that can occur during the building process:

The previous descriptions of what is done by Spenncon from the planning stages until the elements are assembled at the building sites make these processes seem like a straight forward practice. It all starts with Spenncon making their own plans of how to conduct the project based on the information they have at hand at that time. These plans are then subjected to changes as the aspects regarding the building process itself is changed or clarified. This information is then shared between the different actors involved in the building process. When all the information has been shared, there are put in some coordinating efforts between the different actors involved in the process. This is done so that all the changes that are required are coordinated between all the actors. When these coordinating efforts have been carried out and all the information is out in the open, Spenncon modifies their original plan to encompass these coordinating efforts. When these coordinating efforts are done, Spenncon ends up with a new assembly plan that is up to date. This new assembly plan is sort of "the mother of all plans" for Spenncon since this new assembly plan is used as a basis for all other operations that are undertaken in relation to that building project. If Spenncon is able to follow these plans they should be able to deliver the products and services that the customer desires. If they manage to follow all the plans, produce the different elements and erect the elements according to the plan, the entire building process goes very well as far as Spenncon is concerned. However in practice this is not as easy as the description above suggests.

In this building project environment Spenncon is normally working for a main contractor (e.g. Skanska, Peab etc.). This means that Spenncon is normally working as subcontractor for the main contractor. In addition to Spenncon there are also several other subcontractors involved in the building project. In this environment the main contractor has the overall responsibility for the entire building project. Spenncon has the responsibility for the specific part of the shell structure of the building that they are delivering while the other subcontractors have their own specific areas of responsibility. The main contractor works for the customer that has ordered the building that is being built. In addition there are also architects involved in this environment delivering the initial drawings for the building and designing changes in the plans if changes are required. This means that if there for some reason are made changes to the plans after the different aspects regarding the building project have been clarified, the information of these changes has the potential to travel all the way from the customer via the main contractor and/or architect before it's delivered to Spenncon. This means that information from the customer or architect potentially has a long way to travel before the information is received by Spenncon. Changes in the plans for the building can be done due to several reasons. Information sharing between the different actors in this environment is very important. One hypothetical example that illustrates the difficulties and challenges regarding the information sharing can be as follows: The customer requires changes to be made to the building. As a result of this the customer contracts the architects and the architects then incorporate these changes into the design of the building. These changes are then sent from the architect to the main contractor. The main contractor then sends the information regarding these changes to Spenncon. When Spenncon receives these modified plans, it is clear that the solutions that are proposed by the architect are impossible to accomplish in practice. The plans are therefore sent back to the architect via the main contractor so that the blueprints can be altered into a solution that is possible to conduct in practice. When the plans have been altered by the architects, the information has to travel back from the architects to Spenncon via the main contractor. Even if information sharing is important in this construction environment, there are often delays in the information sharing between the different actors. If we use the hypothetical example, we can see that the information sharing process will take time in practice. So if this information is not shared in timely fashion problems will arise since the different actors will not be sitting with the right information about the building project. If the actors are not sitting with the right information about the building project the activities carried out by the actors in relation to the project will be wrong. As a result the right products and services will not be delivered to the building sites. Information sharing and keeping information up to date is clearly important aspects in relation to building projects. If we in addition add that rework of the drawings and designs can occur during this change process, it is clear that this information sharing process can also be extremely difficult. If we use the same hypothetical example as earlier about the plans that were made by the architects before Spenncon had found that they were impossible to conduct in practice as earlier. If in addition add that these plans has been altered by the architects before the information from Spenncon saying that the initial plan is impossible to accomplish, there will have to be done even more rework at this stage. This means that the information sharing becomes even more difficult and even more critical during these change processes (Spenncon 2011 and 2012).

This process regarding information sharing and keeping information up to date can be even more complicated than the previous descriptions. There is a possibility that even more actors can be involved in creating these changes. The changes in the plans for the building can also arise due to changes in requirements from actors further upstream in the value chain than the customer that have order the building. The customer can for example suddenly receive a new tenant to the building that is being constructed. The outcome from this can be that there suddenly are different requirements for the building causing changes to be made in the plans (Spenncon 2011 and 2012). This means that there are potentials for actors outside the building process itself to cause changes to the plans for the buildings. This involvement of parties outside the building process can result in that information has to travel between more actors. This could lead to longer lead time in the information flow and creating an even greater chance of that Spenncon or other actors is sitting with the wrong information. Further this also means that it is a possibility for even more delays in the information sharing process. It also means that there are extra potential and additional factors influencing and causing changes to the plans.

The discrepancies that occur at the building sites can occur due to problems somewhere in Spenncon's entire value chain from the planning stages until the elements are assembled at the building sites. In extreme cases the problems encountered somewhere in this value chain can cause havoc in all activities from planning to assembly activities at the building sites. One example of this can be that the assembly of elements suddenly change direction sequence i.e. the assembly direction change from moving from west to east. The impact of these changes can be that the elements for continuing the assembly process westward already have been produced and put into the rail track. These elements were due to be assembled if the assembly process had continued according to the new assembly plan. However, due to the changes in the direction of the assembling process, the elements that have already been produced have to be moved out of the train track and kept in another inventory until they can be transported to the building site. The production plans for the entire building process have to be changed to facilitate the change in the assembly sequence. Urgent production and/or urgent deliveries may have to be organized in order to secure the delivery of the right elements to the building site so that the assembly process can continue. The impact from all of this can be: increased production cost, increased mounting cost and increased logistical costs for Spenncon. This could threaten the economy of the entire project for the company. These changes could also lead to that the building sites are not supplied with any elements for shorter periods causing the entire building site to lay idle. This will lead to further escalation of costs and in extreme cases delaying entire building projects causing large costs and leading to fines for Spenncon. The change in assembly direction can also influence other building projects. If there is little or no extra production capacity to handle the surge in production capacity that is required to get back on track after the sudden change in assembly sequence, the capacity has to be taken from somewhere. As a result other projects can be affected and influenced by the sudden change in assembly direction. This means that the change in assembly direction can influence both the construction project that is subject to the change but also other construction projects. This means that there is a potential for a ripple effects from one project to other projects. Problems encountered somewhere in Spenncon's value chain in relation to shell based construction can certainly cause major difficulties for Spenncon (Spenncon 2011 and 2012).

When changes happen during the building process, clarifying all the aspects of who is responsible for the changes and who is to bear the costs related to these changes are not easy to clarify. When the clarifications regarding the building process is done and the plans have been verified by the main contractor, Spenncon is trying to secure the plans with the main contractor. This is done so that Spenncon can secure what is called a documented change notice from the main contractor. This means that if changes are made by the main contractor Spenncon will be able to secure and cover their costs if changes are made by the main contractor. If the plans are not tied up and secured with the main contractor, the outcome is normally that Spenncon have to carry the costs related to these changes themselves. This can lead to large escalations of costs for Spenncon. So securing the plans and tying them up to the main contractor is an important part of the process after the clarifications regarding the building project have been done (Spenncon 2011 and 2012).

In this environment there are clearly many potential reasons for the building process that Spenncon is responsible for to change. The reasons for these changes to occur could both be external and internal. Some of these changes are natural occurrences e.g. weather conditions. Weather conditions can influence the building process in various ways. The weather can become so bad the assembly process have to stop or slow down thus causing delays in the building processes. Weather conditions can also postpone, delay or hinder transport assignments thus creating delays in delivers that again can create delays in the assembling process. These natural occurrences may be difficult to prevent from occurring, but one can at least take some measures to try to reduce their influence on the assembling process. Some occurrences seem to have an unnatural reason for the changes to occur e.g. the shift in assembly direction from east to west. This change in direction can have internal cause e.g. that something went wrong in the assembling process that Spenncon is responsible for. The result from this can be that the assembly process cannot continue westward before the problems are solved. This causes the assembly process to shift and continue eastwards instead. The change in direction can be caused by external factors e.g. that the crane that should lift the elements in the westward direction has suffered a major breakdown thus forcing the change in assembly direction. The change in direction can also be caused by other actors e.g. that one of the other actors involved in the building process have not have not finished their building activities on time. This can also cause the assembly direction to shift since it is impossible to continue moving westward before these activities have been finished. No one knows exactly why all of these changes are occurring but the cost related to these changes could be large. So looking into these problems encountered at the building site is important for Spenncon.

The discrepancies encountered when Spenncon is assembling their products will be found by working with Spenncon and looking at the day reports from two building projects. These day reports are reports from the building sites that says what kind of work that have been accomplished in one day. These reports also tells what kind of discrepancies that have occurred during the work day and if any discrepancies have occurred. Las but not least these reports do also tell if any extra work have been carried out by Spenncon personnel. These daily reports are made by Spenncon and the responsible foreman at the building sites. By looking at these daily reports it will be possible to go back and find the cause for these discrepancies encountered at the building sites. This is due to the fact that Spenncon is controlling the entire operations regarding their elements from the planning processes until the elements are mounted at the building site. This means that the company can give a complete overview and provide an insight into all the operations that are conducted and undertaken until the elements are assembled at the building site. However, if one is able to trace the mistakes that Spenncon has done it will be difficult to trace the mistakes that other actors have done. In relation to the shell based construction projects Spenncon may only be responsible for parts of the shell structure that will be created during the construction project. Spenncon may for example only be responsible for the flooring in the building i.e. producing, delivering and assembling hollow core elements. Other actors may be responsible for the other structural parts or framework of the building i.e. pillars and beams and walls. So Spenncon may not necessarily control all the activities that are done regarding the shell structure in the building projects. This means that there may be other actors involved in the activities undertaken to create the shell structure of the building. If Spenncon had been the only responsible actor controlling the entire operation regarding the shell in the shell based construction projects it would enable the study to look at an environment and value chain with as few conflicting goals as possible. Within an environment with one responsible firm there would be the fewest numbers of actors possible thus there will be the fewest numbers of conflicting goals. If other actors are involved in this environment and working in this environment, there will probably be different objectives, targets, viewpoints, motives etc. between the actors. This will then drag the operations in different directions creating conflicting goals thus creating problems and disturbances within the building project environment.

The involvement of more actors in this setting does also mean that obtaining data for this research could become more difficult. If more actors are involved in this process, this would also mean that more actors must have been contacted in order to get all the data. This again means that more time would have to be spent communicating with these actors in order to be able to obtain data from all actors. In addition these actors would have to agree on letting me carrying out this research and their gatekeepers would have had to give me access to the data. In order to achieve all of this, more time has had to be spent on getting data and finding data. One can argue that obtaining all this data from all actors would probably lead to larger data set with more information. However, this increase in data material and information would not necessarily provide the research with more relevant information. As a result more time could have to be spent on studying the data, sorting the data and analyzing the data i.e. more time have had to be used on the data sets. In addition the outcome from this extra time would probably not have led to any improvements in the outcome of the analysis. Looking at the problems that the other actors are encountering will also mean that the scope of this thesis becomes more extensive. The topic in this thesis is already extensive enough so there is no need for including more problems to look at in this thesis. So in relation to both conflicting goals and the problems regarding getting all the data this thesis will only look at the problems that Spenncon encounters at the building site. What kind of problems the other actors involved in the different building projects encounters is not of interest in this research. In addition these problems are not of interest to Spenncon or the researcher. However, the problems that the other actors endure or produce may influence Spenncon since the activities influences Spenncon's activities as explained earlier. By only looking at the problems that Spenncon are encountering will greatly reduce the sacrifices that have to be made in relation to getting the data and analyzing the data for this research. This will also reduce the sacrifices that needs to be undertaken to get the time and access to conduct the research. In addition by only looking at the problems that Spenncon is encountering will also greatly reduce the losses in relation to obtain access to the data. This means that conducting the research this way would reduce the arguments against using the case study methodology in this thesis. It will also greatly reduce what can be seen as the Achilles heel of the case study methodology i.e. the large sacrifices that may have to be taken in relation to cost, access and time. This means that one is able to reduce some of the problem areas that were explained in relation to case studies under chapter 2.2 Research strategy. So there are good arguments from many different viewpoints to only undertake this study with Spenncon's problems in focus.

4. Literature review

In this chapter the theory that will be utilized in relation to this thesis is presented, that is, lean. In relation to the previous descriptions in this thesis it is clear that both lean construction and lean production can be utilized to reduce the discrepancies that are encountered at the building sites. This is due to the fact that the problems that are causing the discrepancies at the building sites can be due to mistakes in the processes related to both production and construction. In order to try and build a literature review that covers all the possible improvements areas for Spenncon from a theoretical standpoint both of these lean theories are presented. In addition the data material that would be analyzed in relation to this thesis had yet been received when this literature review was made. It was therefore impossible to specify the reasons why discrepancies were encountered at the building site and subsequently present only one of these theories. As a result both of these lean theories are included in this literature review. Further describing both lean production and lean construction can increase the understanding of lean.

The outline for this chapter is as follows: The background behind lean is first presented before lean production is presented and then lean construction is presented. Then the similarities and difference between lean production and lean construction is discussed. Before the two important terms in lean namely value and waste are presented and discussed.

4.1 Background to lean

Lean can be traced back to the Toyota Production System (TPS) and Taiichi Ohno work at Toyota after the Second World War (Melton 2005). The Toyota Production System follows the ideas from scientific management (Taylor system) and mass assembly (the Ford system). Even if the TPS follows some of the ideas from other production management systems, it would not be overstating to say that the TPS was a revolutionary production management system (Monden 2012). The idea behind the TPS is to produce the units that are needed at the right quantity and at the time they are needed. This is done so that inventories at all levels are as low as possible. Said in other words the main idea behind TPS is to eliminate waste and trough this waste elimination they will achieve a cost advantage (Shah and Ward 2007). The result of TPS was that Toyota was able to produce a wide variety of cars in relatively low volumes at competitive costs and at high quality. The connection between TPS and lean can be seen in coherence base on the following: when TPS started to attract attention during the first oil crisis in 1973 researchers also started to become interested in the future of the automobile industry. A part of this research was dedicated to look at the advantage that the Japanese car manufacturers had obtained over their European and American competitors. It was during the benchmarking process of the Japanese car manufacturers that the term "lean" was used for the first time. The term lean production was first used by Karfcik in 1988 and the term became known when Womack, Jones and Roos published the book The Machine That Changed the World in 1990 (Holweg 2007).

4.2 Lean production, lean manufacturing and "lean"

Lean production, lean manufacturing and "lean" are three labels used interchangeably throughout the literature about lean but they all refer to the same. In this text these three terms are used interchangeably as well. Lean can be seen as a management philosophy or production philosophy, a long term strategy and a business model (Bhasin and Burcher 2006). Lean has become a very popular philosophy over the last few decades. Due this popularity one should believe that the lean philosophy would have a clear definition, but this is evidently not the case. Different authors have tried to define lean and others have asked if lean is clearly defined but they have not found a clear definition (Pettersen 2009). Even if there is no common definition of lean, researchers have been able to agree that there are some common elements to the label lean and these are:

- Lean focuses on eliminating/reducing waste in all the processes that is carried out in order to deliver a product or a service to the end customer. Lean does also focus on removing all processes that do not add value to the end customer.
- Lean aims to remove waste from the entire system and not only parts of the system.
- In lean it is the end customer's preference that determines what is to be considered as value and as waste.
- In lean the activities in the production and the supply chain are driven by the demand from the end customers i.e. the activities are pull driven.
- The approach to production management in lean is based on a focus on processes and the flow of the processes.

These points do not give a description of the totality of lean, but they give an insight into what is considered common elements in the literature about lean (Jørgensen and Emmitt 2008). In order to explain the totality of the lean concept the focus in this text is placed on one definition of lean. This definition is then used as basis for this explanation of the totality of the lean concept. The definition chosen to explain lean is made by Shah and Ward (2007): *"Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability."*(Shah and Ward 2007, p. 791).

Lean is often associated with the elimination of two different kinds of waste. The first type of waste is often associated with having excess capacity either in form of machine capacity or human capacity, and the second type of waste is often associated with having excess inventories. The reduction in inventories can be achieved by having excess capacity or by lowering the throughput time in the system. Having excess capacity is waste according to lean thinking so reducing the throughput time has to be the preferred way to reduce inventories according to lean (Shah and Ward 2007). However, even if Shah and Ward (2007) argues that the preferred solution to reduce inventories are a reduction in the throughput time, the author believes that stating that having excess capacity only generates waste would be drastic. The reduction in throughput time will reach its limitation at a certain point in time, so at some time other measures have to be utilized in order to further reduce inventories. In addition to this limitation natural variability and/or stochastic variation will also play a part in the throughput times in a production system. These variations will be difficult for firms to reduce and remove. This discussion about variability will be continued later in this subchapter. As a result of these limitations in the throughput times the author believes that there will be a need for other solutions to further reduce the inventories in addition to the reductions in throughput time. As a result of this it will be difficult to completely discard the option of having extra capacity. However, if a firm is having excess capacity that is never utilized, then this unused capacity will only create waste. So to have no extra capacity in a production system will probably not be a desirable solution or a wise choice. As a result of this the author believes that having some extra capacity in form of extra production capacity in a production system will be a good choice. The author is not saying that reducing the throughput time is not a good solution, but other alternatives have to be looked into as well. Shah and Ward (2007) continue by stating that the desired reduction in throughput time can be achieved by having a production process that flows continuously without frequent stops and starts. This thinking of continuously flow in lean is the opposite thinking of traditional economies of scale production systems which produces everything in large batches in order to achieve the wanted level of economy of scale. In order to be able to achieve this continuously flow of processes, a firm needs a flexible, dedicated and engaged workforce. As a result of all these points a firm that wants to become lean and minimize inventories, has to be able to manage variability in demand, processing time and supply. This will again require lean firms to be able to effectively control both their social and technical systems at the same time as explained in the next paragraph (Shah and Ward 2007).

In order to be able to manage the variability in demand, processing time and supply, firms must be aware of that these irregularities exist. The firms must also be able to find the underlying causes for these irregularities. The reason for needing this knowledge is that in order to find the underlying causes of the variability, one has to get to the root cause of the problem. One needs to find to the root cause in order to eliminate the reason for the variability to materialize in the first place (Shah and Ward 2007). One tool that is often used in lean in order to find the root cause of a problem is the 5-why analysis. This is a tool that was developed by Taiichi Ohno the father of the Toyota Production System. Ohno observed that when mistakes occur in a production process, the workers normally blame each other for the mistake that is conducted. He also witnessed that it is almost impossible to foresee all the mistakes before they materialize. As a result Ohno realized that the best way to act upon these mistakes is to identify their root cause and act accordingly. By asking 5 why questions it was possible to get to the root cause of the problem and find the corrective actions that is necessary to prevent these mistakes from occurring again. Conducting the 5 why analysis and asking these 5 why questions can be everything from a difficult process to a straightforward process. No matter the difficulty of asking these questions, they are efficient tool to get to the root cause of the problem if they are applied correctly. As a result of this the 5 why analysis has become a widely used tool in lean (Murugaiah et al. 2010). Shah and Ward continue by arguing that the variability in demand, processing time and supply has to be eliminated and that lean have a wide variety of tools and practices to eliminate all these variability's. This does all sound reasonable, but it gives us a few questions that need to be answered. What can be the cause of this irregularity that needs to be managed? Why is this irregularity a cause for concern? How can this irregularity be reduced or removed? (Shah and Ward 2007)

The variability in supply happens when a supplier is not able to deliver the right quality and/or right quantity at the right time. There are two main ways to reduce the variability in supply. The first alternative is to create long term contracts with a few key suppliers. The second alternative is to provide suppliers with regular feedback on quality and delivery performance and help the suppliers to develop their performance further. If one is able to reduce the variability in the supply, there will no longer be need for holding buffers to handle the variability in the supply. The outcome from removing these buffers is a reduction in waste since there will no longer be a need for holding these inventories to counteract the variability in the supply (Shah and Ward 2007). This implies that the suppliers are able to provide the customer with the materials needed just as they are needed. This again means that there will be a need to have small and frequent deliveries from nearby suppliers. This is done so that inventories which are seen as waste according to lean thinking can be removed from the system. Inventories are seen as waste in lean since no value can be generated from units that are just kept in the inventory. In addition inventories are creating waste inform of tying up capital, use of space and so forth. This kind of supply strategy also means that suppliers have to be situated close to the producer and they have to be able to deliver what is needed when it is needed etc. If the suppliers are not able to do so, or not willing to do so, there will be no possibility to achieve the wanted levels of reduction in inventories.

Shah and Ward (2007) suggest two solutions that can be implemented in order to be able to achieve this kind of supplier and buyer relationship. One can always debate the question of whether a supplier will be willing to go into this kind of relationship with their customers. So this willingness to enter this kind of relationship is a question that needs to be raised regarding the possibility to reduce the variability in supply. If the suppliers do not agree to this type of relationship, it will be impossible to achieve the needed supply strategy. By reducing the supplier base and enter a close relationship with only a few suppliers will reduce the amount of possible suppliers to procure supplies from. This can increase the risk of disturbances in supply, since if one of the few chosen suppliers is not able to deliver materials as promised, there will be fewer suppliers that can deliver these materials. However, even if one is able to achieve this kind of supplier relationship and accomplish this reduction in inventories the firm would become more vulnerable for disturbances in the deliveries of materials. There will no longer be any inventories or at least there will be reduced inventory levels to absorb the effects from the disturbances in supply if these disturbances take place. If these disturbances do transpire, the outcome can for example be that production has to be stopped since there are no longer any buffers of materials available to continue to feed the production processes. So in relation to the reduction in inventories and the subsequent reduction in waste does undoubtedly have a potential to reduce costs, waste or both. This does however come with the potential to create havoc in the entire production process if disturbances in relation to supply occur. So the reduction in inventories may not only have positive sides to it. This means that some sort of inventories may have to be kept in order to manage the potential disturbances. So achieving a system with no inventories can be difficult. This also means that there are risks related to the reduction in inventory levels and this risk has to be considered when inventory levels are reduced.

Variability in the processing time means that the time it takes to carry out processes varies from time to time e.g. sometimes it takes 5 minutes to carry out a process, next time it takes 7 minutes and so forth. This variability leads to a disruption in flows, and this creates waste in the form of variability. There are many practices or tools that could be used to minimize the process time variability. For example specifying work to the smallest detail enables the processes to become standardized and the processing time becomes less variable. A detailed specification of how to conduct the different processes means that the work will be carried out in exactly the same way each time thus reducing the variability. If the variability in the processing time is reduced, the flow will become smoother, thus reducing wastes inform of holding work in process inventories or buffers. Other tools that can be used to reduce waste in a process could for example be a good quality assurance system. A good quality assurance system will reduce the need for rework and therefore reduce the variability in processing times. Cross training employees is another tool to reduce variability. If the workers are able to carry out more than one work task, they are able to step in for absent coworkers without disrupting the flow in the production. All these examples presented above are part of lean practices and minimize the processing time variability. There are many more tools and practices that can be introduced, but these presented here are some of them and gives us an idea of what can be done in order to reduce the process time variability (Shah and Ward 2007). However, there will always be some variation that is difficult to manage even if lean tools are applied. Even if one specifies the work processes in the smallest details, the workers can still cause variability in the processing time. One example can be that if a worker suffers from some sort of personal problem. This can result in that he or she can be more occupied mentally with his or her personal problem than the work processes that he or she is conducting. This can result in that he or she can be less efficient in conducting their job tasks thus causing variability in the production process. Another problem related to variability can be that machines still suffers breakdowns even if one has implemented a good maintenance system. Machines can still suffer breakdowns even if the most appropriate maintenance plans are followed and carried out in practice. A third factor related to this variation in processing time can be that even if one has a good quality assurance system, mistakes and deviations can still occur. The result of these mistakes and deviations can for example be that rework must be undertaken in order to resolve these mistakes, and this causes variability in the processing time. There are undoubtedly much potential for variation to occur in the processing times even if lean tools are applied. The author is not saying that lean and lean tools are not able to reduce the variability in relation to the processing times, but rather saying that there will always be some sort of variation in the processing times, even when lean tools are applied. So to totally remove all sorts of variability in relation to the processing time seems almost impossible. However, even if this is the authors view, the author still believes that lean and lean tools undoubtedly have the potential to greatly reduce the variation in the processing times.

Demand variability can have a huge impact on the production process and cause turmoil in the production processes and the production schedule. In order to be able to counteract the effects of demand variability, lean has a number of tools. One tool that is often used is to focus on takt-time which makes the entire production process march in one pace i.e. that all the production steps are done in one rate. Another production smoothening tool that is often used is "heijunka" which works in a similar way by smoothening out the production pace. One could also smooth out the demand over some specific time intervals using demand management technics (Shah and Ward 2007). In relation to this thesis, there can probably be another factor that adds to the complexity around the demand variability. As described in chapter 1.2 Spenncon has a sales division and this division is most likely not preoccupied with reducing the variability in demand. The focus in this division will be selling Spenncon's products and not smooth out demand variability. This sales organization will probably increase the demand variability through their sales and marketing efforts. In addition to this smoothening issue, the sales organization will probably not be preoccupied with the balancing the available production capacity against sales. So balancing the marketing and sales efforts from the sales organization against production and production capacity can also be important in relation to the variability in demand. This means that the sales organization indirectly can influence the production processes and the production schedule by overselling Spenncon's products to the potential customers in good times. If there is no more capacity available, selling more elements to customers will not be desirable either for the potential customers or Spenncon. The opposite situation can also occur in difficult times if the sales organization is underselling Spenncon's products to potential customers. So balancing the sales and marketing efforts against production and production capacity can probably also be a good option to reduce the demand variability in relation to reduce demand variability for Spenncon.

As one can see from this explanation of lean, the overall goal is to reduce waste trough reducing variability in demand, processing and supply. If a firm only focuses on reducing waste in one of the three irregularities the firm will not be able to reduce all types of waste. For example if a firm reduces the variability in their production process but not in supply, the firm will still need to hold inventories in order to counteract the variability in the supply thus creating waste. The waste reduction in lean is achieved through a variety of different mutually reinforcing tools/practices that aims to reduce the waste in specific ways (Shah and Ward 2007). One example of this in mutually reinforcement can be seen through achieving a reduction of work in processes inventories. In order to reduce the work in processes inventories one need to have a production that flows without changeovers which again could be achieved by having a flexible, dedicated and engaged work force. This will then lead to a reduction of waste in the processing, but in order to reduce waste in the entire system, one need to focus on reducing waste in all other processes as well. This way of thinking represents the totality viewpoint of lean thinking i.e. that the entire system must be improved and not only parts of the system.

However this explanation by Shah and Ward (2007) that has been presented above in this subchapter, lacks an important aspect of lean based on the bullet points about the common aspects of lean presented earlier. Becoming lean is not something a firm can achieve overnight. Lean is a continually improvement process that is aiming towards achieving zero waste so that every processes is only adding value in the eyes of the end customer and not creating any waste i.e. perfection is the only goal (Pettersen 2009). Since lean thinking is seeking perfection, the improvements are never ending and ends up as a continual cycle seeking perfection (Melton 2005). This continually improvement is normally achieved by setting improvement goals, and when these goals are met, one is setting new and more ambitious goals. This is a process that will go on indefinitely since the ultimate goal is perfection (Chen and Meng 2010). Another important aspect of this continually improvement is the involvement of the workers in this improvement process. In lean workers are encouraged to contribute in the continually improvements by coming up with solutions to solve problems and make suggestions on how to improve the processes. This means that the workers are also given increased responsibilities and autonomy (Panizzolo 1998). So in addition to focus on eliminating waste, lean is focusing on continually improvements so that the processes in the end only add value for the end customer without creating any waste. The involvement of the workers is an important part of this continually improvement process and must not be forgotten. This aspect of continually improvements and worker involvement has not been discussed in great detail by Shah and Ward (2007). These two topics have therefor been added to this explanation of lean by the author. Lean is searching for an ideal state with no waste, can explain the discussions that were added by the author in this subchapter. Due to the viewpoint of this ideal state where no waste is created, the goal in lean is clearly to have no form of waste in the entire system. As a result of this lean and theory presented in this subchapter is searching for a way to achieve this ideal state. However, the author is not trying to argue against this viewpoint but rather trying to discuss alternative solutions until this ideal state in lean is reached. These discussions have therefore been added by the author in this subchapter.

4.3 Lean construction

Lean construction started to attract attention a few years after lean production started to be implemented in the western world. As a result of this, the field of Lean construction is not as mature as the field of Lean production. Even if it is so, there are many similarities between the two lean philosophies. One of the similarities is the understanding of waste and value. In both lean construction and lean production the end user defines what value is and what waste is. In addition there should be generated as little waste as possible and there should be as little variability as possible in the processes that are carried out. However, structures such as bridges; tunnels, apartment buildings, shopping centers etc., that is, constructions have a longer life span than products made under production processes, that is, cars, TV's, mobile phones etc. Structures or buildings can last over hundred years or more and they can also have a wide range of owners and users over their lifespan. As a result of this the meaning of value and waste becomes more complex in lean construction than in lean production.

Another similarity between lean construction and lean production is the lack of a common definition of the terms. There are also some other differences between lean production and lean construction. Lean production is applied to highly standardized and repetitive production processes while lean construction is normally focused on project based and low volume production technics (Jørgensen and Emmitt 2008).

According to Eriksson (2010) lean construction consists of six core elements.

1. **Waste reduction.** As in lean production waste reduction is the most important element in lean construction. This can be done through housekeeping i.e. keeping the building site tidy and clean. Waste reduction can also be achieved through JIT deliveries i.e. deliveries of the materials needed when needed so that there will be no form of waste in inventories. The use of IT systems to correct mistakes before they actually occurs e.g. the usage of 3D modeling. This 3D modeling allows errors to be detected before the construction activities starts thus reducing waste. The use of offsite manufacturing or prefabrication can also be used to reduce waste, construction time and improving the work environment and so forth. The usage of pre manufacturing makes lean construction more similar to lean production since this will mean that the construction process will consist of more repetitive processes connecting these prefabricated elements together (Eriksson 2010).

The use of prefabrication can also result in that parts of lean construction actually consist of repetitive production processes. Since the making of these prefabricated inputs into the construction process will be done over and over again in standardized processes i.e. the inputs are made through repetitive processes. This means that the production process of these prefabricated inputs into the construction projects can be done under a lean production environment and be improved by lean production techniques. So the prefabricated inputs into the lean construction environment can be made through the use of lean production techniques. Lean production techniques can also be used in relation to other aspects of construction project using prefabrication. One example is the assembly process since these processes of putting these prefabricated elements together also consist of repetitive processes. As a result of this one can say that both lean techniques i.e. lean construction and lean production can be used by the actors in the construction environment using prefabrication to improve their processes.

2. **Process focus in production planning and control.** The focus on processes and generating flow in the processes is also a key part in lean construction. The goal is to have efficient planning and control over the construction process. If this is achieved the construction process can be done according to the specified time frame. If the processes are not finished on time, the root causes for the problems that cause the delays have to be found. When the root cause is found, one can prevent similar failures from happening again. This is done so that next time plans are made, it will be a greater chance of following the plans and keeping the wanted schedule. A key tool that is used in lean construction to achieve the wanted levels of control and planning is the Last Planer System (LPS) (Eriksson 2010).
3. **End customer focus.** End customer focus is another key element in lean construction since it's vital to maximize the value for the end customer in lean construction. The value created will be in form of the end product delivered to the customer i.e. the products and services delivered during the construction process. As a result the end customer must be included early in the construction process so that end product will meet the requirements of the end customer's needs. Involving the end customer in the building process will also create understanding of what the end customers' needs are. This will reduce the needs for rework in the construction at a later stage thus reducing waste (Eriksson 2010).

4. **Continues improvements.** Continues improvements are important in lean construction as in lean production. The aim is to increase the efficiency and reduce the waste in the construction process over time. This continually improvement can be achieved through the use of long term contracts. Further it is important to measure the performance against preset targets to see that the construction process is improving but also to assure that corrective actions are taken if goals are not met. Workers from different disciplines and companies should share their knowledge and expertise to improve the continually improvements in lean construction. Workers and employees should also be encouraged to suggest new ideas and solutions to the problems encountered at the building sites. It is also important that these suggestions are taken seriously in order to increase the workers commitment to continuous improvements (Eriksson 2010). So the involvement of the workforce in this continual improvement effort is an important part in lean construction.
5. **Cooperative relationships.** This point is about the relationships between the different actors involved in the construction process. It is important to assure that there will be integration between the different actors in the construction processes since subcontracting is widely used in construction and during building projects. If there are no cooperation and understanding between the actors involved in the project the outcome of this sub-contracting can be production of waste, increased lead times and adverse relationships. As a result the relationships in lean construction projects should be managed using a lean contracting approach to reduce the possibility of creating this type of waste (Eriksson 2010).
6. **System perspective.** The goal of lean construction is to improve the overall efficiency of the system and avoid sub optimization. As a result all the processes have to be looked at from at entirety viewpoint or from a total system perspective and not from an individual view point. The workflow in the entire system is more critical than the individual activities. As a result of this the overall improvements in lean construction can only be achieved by looking at the design, operations and construction at the same time (Eriksson 2010).

Based on the six points above and the previous description of lean presented earlier we can see that there are a lot of similarities and some differences between lean construction and lean manufacturing.

4.4 Similarities and differences on lean production and lean construction

As said earlier there are a lot of similarities between lean construction and lean production, but what do these similarities consist of and are there any differences? I believe that the clearest similarities can be seen in form of the focus on waste reduction, the fact that end customer defines value (end customer focus in lean construction) and the focus on continually improvements. The involvement of the workers and the workforce in the continually improvement is important for both lean production and lean construction (as seen in point 4 in the previous subchapter). One example of this is that workers are encouraged to participate and make suggestions on how to improve the processes. However, the points 2, 5 and 6 presented earlier under lean construction can also be seen in the description of lean production. The focus in production planning and control in lean construction can be seen in lean production in the description of variability since both focus on generating flow and reduce the variability so that activities/processes are finished in time. Cooperative relationships under lean construction can be seen under lean production in the focus on reducing supplier variability since both focuses on building cooperation to reduce waste. Both lean construction and lean production wants to utilize long term relationships to create improvements between the actors. Lean production focus on the entire production system and lean construction does also focus on the totality of the system and not only on parts of the system. So there is a mutual agreement that the improvements in the respective system have to be undertaken by looking at the entire system and not in parts of the system. Both systems do also aim to get to the root causes in discrepancies and carry out corrective actions so that mistakes will not occur again later. Based on all of these points the conclusion that can be drawn is that the philosophy and underlying ideas behind both lean production and lean construction is the same.

The main differences between lean construction and lean production have to come in the form of the way production is carried out. Lean construction is normally applied to a one of a kind construction project and is therefore project based. Lean production on the other hand consists of producing similar units trough repetitive processes that are producing the same products over and over again. The tools used in the lean construction and lean production are also different. One example of this difference can be seen in the use of Value Stream Mapping (VSM) that is normally used in lean production while Last Planner System (LPS) is normally used in lean construction. Lean construction can also have a more complex view on value than lean production due to the long lifespan of buildings compared to the more standardized products made in lean production. The use of sub-contracting does also seem to be a normal occurrence in lean construction while it is not mentioned in the lean production theory. However, one can say that this view on sub-contracting is partially included in lean production due the focus on supplier relationships, but the theory does not say anything about outside actors that are directly involved in the production process. So in relation to the field of subcontracting and the direct involvement of other parties in processes that creates value for the end customer there are some difference between lean production and lean construction. However, as said earlier, both systems are utilizing long term relationships in order to create improvements between the actors.

So the conclusion has to be that underlying philosophy behind lean production and lean construction is the same. This is the case even if the value creation is carried out in different environments in the two topics since lean production is consisting of repetitive processes while lean construction is project based. Due to this different value creation, the tools used are different, and this difference is also the main difference between the two topics. The complexity of the term value can also be greater in lean construction than lean production due to the long life span of buildings/structures that is made in lean construction. The usage of subcontractors is also different between the two theories since sub-contracting is widely used in lean construction while it's not mentioned in the theory related to lean production. However, the usage of subcontractors may exist in relation to lean production but the author has not seen any examples of it in theory or practice. There are also many similarities between the two lean theories, there is a mutual focus on creating value for the end customer and remove waste from the systems, both theories focuses on continuously improving the activities, reducing the variability, generating flow etc.

In some cases both lean construction and lean production can be applicable in the same environment. One example of this is the company of focus in this text, Spenncon. The firm produces pre-fabricated concrete elements to the construction business and these elements are produced through a production processes that is repeated over and over again. These productions processes can be repeated several times in relation to one building project but also in relation to other building projects. Some would probably argue and say that all the elements are different to the different projects. However, even if the products are not exactly the same in relation to each project there is at least some similarities between them e.g. the process of making the elements and cutting the elements will more or less be the same regardless of the specifications given in the different projects. So the production processes of these prefabricated concrete elements do clearly consist of repetitive operations. It would probably be correct to call the production method for the different types of elements a generic production method. The reason for this is that the production of the different types of elements is done more or less in the same way regardless of the wanted characteristics of the different types of elements. This means that even if the characteristics of these elements are different the way for producing them is more or less the same. As a result of this one can say that the production of the elements is generic.

The production of these elements is done in a lean production environment and can be improved using lean production techniques. Even if the characteristics of the different products will be different the process of making the elements will more or less be the same. The elements produced by Spenncon are used in the construction business and the construction environment that has been described in both the lean construction review and the descriptions regarding this thesis. These elements are used as inputs into the structures or buildings that can have a long lifespan and several owners during the lifespan. As a result of the difference in perception on the time that value is measured, there can be different views on value on the elements that are produced by Spenncon. Nevertheless, this problem can be overcome by looking at the production process as a separate process with separate spectacles on value relative to the construction process. However, the different views in the two lean theories do not only add to the distance between the two theories and the usability of these theories for Spenncon. The usage of prefabrication which is exactly what Spenncon is performing, makes lean construction more similar to lean production. The use of prefabrication means that there are more repetitive processes both in relation to production, outbound logistics and the assembling processes for Spenncon. So even if there are some differences for Spenncon in relation to these two lean theories, both of them are clearly applicable for Spenncon and the business and business processes that they are conducting. In fact there are more similarities than differences between the two lean theories. In addition the underlying ideas and philosophy are the same behind both theories. This means that the two theories cover broader area and increases the possibilities to improve the processes conducted by Spenncon. It also means that there will be a wider "tool set" available to improve the processes relevant to this thesis.

Lean construction and lean production can be summarized excellent by using the words of Dr. Hermann Glenn Ballard. He defines lean as follows: "*Lean is a philosophy of management, a philosophy that pursues the lean ideal (provide customers exactly what they need to accomplish their purposes, and do so with no waste), applying principles in pursuit of that ideal (such as only do work on request; also known as 'pull'), and using methods to apply the principles (for example, Last Planner is a method that applies the principle to do work only on request).*" (Ballard 2012). This quotation both show and sum up the fact that the underlying idea and philosophy behind lean construction and lean production is the same. The main difference between the two theories comes from the way that value is created. Lean production is consisting of highly standardized repetitive processes while lean construction is normally consisting of a one of a kind building projects. As a result of this the tools utilized by the two theories are different. However, even if this is the case, lean production can be utilized as inputs into lean construction projects as illustrated earlier in the case of the company of focus in this text i.e. Spenncon. In relation to this assignment and the aim of the research, that is, to reduce the discrepancies that are encountered at the building sites related to shell based construction for Spenncon. The production process, outbound logistical processes and assembling processes are repetitive processes i.e. it is processes that are repeated over and over again. These processes are linked up to different construction projects and the construction environment described under lean construction and different descriptions regarding Spenncon in this thesis. One example of this construction environment is the involvement of other actors and the use of sub-contractors in these building projects. For example that Spenncon use another actor, Bolkan, in transporting the elements to the building site. Another example is that Spenncon is working as a sub-contractor in the building project and that Spenncon have their own area of responsibility in relation to this project. The activities that Spenncon is conducting at the building sites have an influence on other activities that other actors are conducting at the building site and vice versa. As a result of this argumentation one can see that both lean production and lean construction is relevant and applicable theories for improving all activities for Spenncon. Both of these lean theories have therefore been included in the theory review in this thesis.

4.5 Value and Waste

The terms value and waste is important aspects of both lean production and lean construction. As a result both terms have been widely used in this text. However, these terms have not been described in detail. Since these two points are important aspects in both lean production and lean construction, these terms will need to be described further and this is done in this chapter.

Value is the starting point for everything in lean thinking. Value can only be defined by the end consumer. The producer of a good, a service or both is supposed to create value for the end consumer. This value creation is the reason, and the only reason, for the producer to exist in the eyes of the end consumer. However, it is very difficult for the producers to accurately define value. The term value can only be meaningfully expressed in relation to a specific product (a good, a service or a combination of both) and its relationship with the customers' needs at a specific price at a specific time. Value can be defined as: *"a capability provided to a customer at the right time at an appropriate price, as in each case defined by the customer."* (Womack and Jones 2003, p. 353)

In addition to creating value for the customer, lean is also about the elimination of waste i.e. the elimination of everything that does not add value for the end consumer. All work that is undertaken in delivering a product to the end consumer can be divided into three different categories. The first category is the value adding work, that is, the essential activities that is done on a good or service that the customer is willing to pay for. The second classification is the work that is required to deliver the product or service, but doesn't necessary add any value for the customer. The third category is all the activities that is not necessary nor add any value for the customer i.e. activities that only generates waste (Chen and Meng 2010). Based on these three different groups it is easy to see that one of these activities can be removed without any form of discussion. Since having activities that just add waste is against lean thinking in relation to both lean production and lean construction. It is also against common sense to carry out activities that do not create any value for the customer. However, in order to say something specific about what is to be removed and what is to be kept, a more detailed explanation of what waste actually is, is needed. In manufacturing there exist 7 different types of waste (Hicks 2007). These 7 different wastes are:

1. **Overproduction:** This occurs when the production is continued when there is no more demand. The result of this is overproduction i.e. the production is higher than the demand. As a result of this overproduction the products are made to early and have to be placed in inventories thus creating waste (Hicks 2007).
2. **Waiting:** Can also be referred to as queuing. Waiting can occur when downstream activities have to wait because upstream activities have not been delivered on time. It can also occur when idle downstream processes are used on activities that do not add value or create overproduction (Hicks 2007).
3. **Transport:** Is the pointless movement or motion of materials. One example can be work in process (WIP) inventories that is being moved from one process to another. In general there should be as little transportation as possible since transportation only adds time to the process. The transportation process itself gives little possibility to create any value. Extra transportation and handling does also create additional risk of damage to the product or products (Hicks 2007).
4. **Extra processing:** Is the extra processes that is unnecessarily carried out in order to deliver the products to the customers e.g. storage, reprocessing, rework and handling due to overproduction, unnecessary inventories or defects. All of this extra processing does not add any value for the end consumer and as a result this extra processing only creates waste. In other words things should be done correct the first time so that this extra processing never occurs (Hicks 2007).
5. **Inventory:** Is all inventories that is not directly necessary to fulfill the customer orders. This includes: finished goods inventories, WIP inventories and raw material inventories. Unnecessary inventories mean additional handling, increased capital costs and it also means usage of unnecessary space and extra processing (Hicks 2007).
6. **Motion:** Is the unnecessary steps taken by machines or staff to accommodate: defects, overproduction, reprocessing, ineffective layout or excessive inventories. Motions only contribution to the process is by creating non value adding time to the products or services and should therefore be removed (Hicks 2007).
7. **Defects:** are all of the finished goods or services that are not in accordance with the specifications that have been set. It can also be products or services that fail to meet the customer's expectations hence creating customer dissatisfaction (Hicks 2007).

Womack and Jones have in addition to these seven deadly wastes identified one more category. This extra eighth category is the underutilization of the employees, their creative inputs and their creative ideas that can improve the practices and processes that are undertaken to create value for the end customer (Hicks 2007).

In relation to these 7 different types of waste it seems that removing some types of waste in certain situations would be meaningless. If one for instance has a standardized product were demand is highly dependent on seasonality and the demand is easy to predict. It seems irrational to state that building up inventories in front of the peak season would be waste. In relation to lean this can be seen as overproduction since one should only produce what there actually is demand for according to lean thinking. In addition this would also be waste according to lean thinking since this means a buildup of inventories which also is seen as waste. The alternative solution to this buildup of inventories would be to invest in additional production lines that can handle the surge in demand when the seasonal demand occurs. This would mean that one have to invest heavily in these new production lines, hire more people in the peak season etc. and the outcome would probably be increased costs. In addition one would end up with having unused production capacity through most of the year. As discussed in relation to chapter 4.2 having unused production capacity will also be waste according to lean. In addition increasing costs would not be meaningful in relation to lean thinking. So removing waste without thinking about the consequences would not be wise. One has to think about the totality of situation and the impact the choices will have on the entire system before doing something. Just rushing into waste removal without thinking about the totality will not yield a positive improvement. Further one could have discussed the impact that the other forms of waste inform of waiting, transport etc. would have and what the consequences of removing them would have been. However, continuing on this debate would not be appropriate at this stage.

The knowledge about value and waste can also be important in order to be able to use and understand the various lean tools such as for example: LPS, VSM, Kaizen, Heijunka, etc. In order to be able to use these tools, one must have the knowledge to identify and eliminate waste. This is due to the fact that in general the various lean tools focuses on removing waste and improving the specific areas they are applied to. So if one is to improve the process this understanding of waste is critical. Hicks (2007) goes as far as stating that the critical factor to successful lean transformation is the fundamental understanding of waste (Hicks 2007). However, if one is to know what processes to retain one does also need to know what value is. Since lean is not only about removing waste but also about generating value for the end customer.

This discussion of waste and continually pursuit of waste reduction is seen as a somewhat pointless endeavor by the author. Since if a firm is able to create the required value for the customer at a satisfactory price, why should the customer care about the firms waste? If a firm is chosen as a supplier, this also indirectly means that the customer believes that the firm is delving the most value for the price that the customer has to pay for the product or service. So if a firm is chosen by a customer this indirectly means that customer believes that the firm is delivering most value and the lowest amount of waste of the suppliers he or she has to choose from. One can argue that in order to stay competitive and keep the marked position the firm has to reduce waste. None the less this relentless search for waste in all functions and departments than lean aiming at seems somewhat unnecessary in order to stay competitive. So the author believes that one can question the relentless search for waste in relation to lean. In some cases and situations the resources spent searching for waste can be better utilized in other areas to enhance value for the customer. This search of value can be just as lean as the search for waste. This argument is based on the fact that the outcome from this search for value could produce a greater total gain for the end customer by looking at other aspects to enhance value rather than just looking at the possibilities to reduce waste. This view is somewhat different than the view in the theory presented earlier since the view in this theoretical framework is the focus on continually improvement seeking perfection by reducing waste. However, this new view may be just as relevant as the focus on reducing waste in the long term. At some point it will probably be more to gain by creating more value for the end customer by looking into alternative solutions for value enhancement rather than just looking into the possibility to reduce waste. The reduction in waste will probably become less effective as waste is being removed from the system since the possibilities to improve will become less and less as more and more waste is removed. This is illustrated in the figure on the left side. At the same time the alternative solutions for value creation that has yet to be explored, will not have be subjected to this drop in improvement possibility as the waste reduction. This is down to the fact that these alternatives have not been looked into, and as a result these

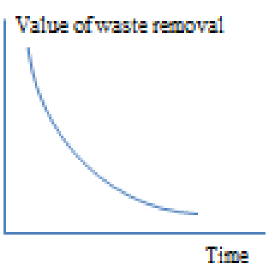


Figure 5 The potential for waste removal over time

alternatives have not been subjected to the reduction in possibilities as waste reduction. Based on this argumentation one should also look into alternative solutions to enhance value for the end customer and not only just search for waste and ways to reduce waste. So looking into alternative solutions to enhance value can also be an effective way to increase the total gain in the eyes of the end customer and not only remove waste, since the creation of value is the only reason for the producer to exist in the eyes of the end consumer in the first place.

The view on waste can also be looked at from a slightly different view. According to Dr. Hermann Glenn Ballard from the University of California, Berkeley, waste can be seen as a cost of any kind that occurs during a building project or a production process, that is, costs that are not generating any value for the customers. This cost can for example be: financial cost, cost in form of stress for the workers involved in the building project or production process, cost related to customer dissatisfaction and so forth (Ballard 2012). In other words waste is anything that has a cost of any kind that can be eliminated without reducing value. If we use this explanation by Dr. Ballard, the relentless search for waste makes more sense. This explanation adds to the totality regarding the search for waste since this means that waste is everything that is unnecessary to deliver value to the end customer. This means that everything that does not add value for the customer can be removed and as a result of this view, there will be a greater area to apply lean practices to and remove waste from. This can somewhat reduce the criticism from the author regarding the relentless search for waste in lean. Since this will mean that there will be a greater area to apply lean and lean techniques in this view presented by Dr. Ballard due to the fact that one is not only searching for waste since one is also looking at the question about value. As discussed earlier, this relentless search for waste in lean is due to the fact that lean is searching for the ideal state, meaning that everything is produced without waste. However, even if this is the case, the author still believes that one shall look at the opportunities to generate more value for the end customers in addition to the search for waste to achieve the ideal lean state. Since the value creation for the end customer is the only reason for the companies to exist in the first place. So looking into ways to generate more value for the end customer has to be just as lean and just as much in accordance with lean thinking as waste reduction. This view means that one has two opportunities in lean when improving the activities i.e. reduce waste and enhance value creation.

5. Data analysis

In this chapter the data material sent over by Spenncon in relation to this thesis is analyzed. The data material was day reports from two building projects that Spenncon were involved in from October 2011 until respectively February and March 2012. These two building projects are both shell based construction projects and fits into the previous descriptions given in this thesis. Both of these building projects is located in the eastern part of Norway and were both served by Spenncon's factory at Hønefoss.

These two building projects were first studied by the author trough reading all of the day reports that were sent over by the montage leaders at Spenncon. Then all of the discrepancies that had been reported in relation to the day reports from the 2 projects were collected and grouped into 5 groups based on what the underlying problem behind these discrepancies were. This was done before these discrepancies were analyzed through 3 different analyses. These 3 analyses were done in order to try to say something about what seems to be the main problems encountered in the assembly processes for Spenncon in relation to shell based construction projects. The first analysis that was done was a crude analysis to look for trends in the data material. Further a statistical analysis was done in order to look for significance in the data material. Then some estimations was made in order to try and say something about what number of discrepancies can be expected over a one year period. All of these steps will be presented further in the subchapters in this data analysis chapter. The idea behind doing these analyses is to answer the 1st research questions in this thesis i.e. find out why most of the discrepancies at the building site occur. In other words the idea behind doing these analyses is to get an understanding of what the discrepancies encountered in the assembly processes are so that one can answer 2nd, 3rd and 4th research questions.

5.1 Information about the day reports and the data material

Day reports are reports that are explaining how the daily progress is going at the different building projects that Spenncon is involved in. These reports explain which work activities that have been accomplished at the building site during a working day. In addition the day reports describe the discrepancies that may have been encountered during the workday in addition to the descriptions of additional work that Spenncon personnel may have had to carry out. Further these reports contain extra information about the building project regarding the workforce, weather conditions and overtime. In addition there are information about which project the day report belongs to, date, project number and so forth. These day reports are written by Spenncon's responsible foreman at the building sites. These reports are sent from the building sites to different employees with different roles within Spenncon's organization including the assembly leader for the different projects. This is done so that the assembly leader and other relevant personnel are able to see the progress that is made at the different building sites. This is also done so that everyone involved in the projects can have an overview over how the building projects are going, if there are any problems, if any corrective actions have to be carried out and so forth. Examples of daily reports are attached as appendixes; please look at appendix number 1 and 2 for these examples.

When the author was reading the day reports from the different building projects it became clear that it was difficult to fully understand everything written in these reports. The language used in the reports is difficult for an outsider with limited knowledge about both the construction industry and the company to fully understand. This is due to the fact that these reports contain: abbreviations, technical terms and tribal language that are used within the company. In addition the handwriting in these reports was in some areas very difficult to interpret and clearly understand. As a result much time had to be spent reading and studying the information within these reports. It was not easy to get an understanding of what these discrepancies were, which actor the discrepancies originated from and what caused for the discrepancies to occur in the first place. The researcher did also try to acquire help from the company in order to understand all aspects regarding these reports. The company was also contacted so that the researcher could verify that the discrepancies that had been registered had been understood. This also led to that time had to be spent in relation to make this verification and control. The personnel at Spenncon had to answer the questions from the researcher in addition to their regular work assignments. As a result it took some time for the personnel to be able to answer these questions.

In order to carry out the analysis of these daily reports, the research had to look into all the deviations that were reported by the responsible foremen at the building sites. In order to do so, all of the day reports were read thoroughly by the author at the beginning of the analysis. Then all of the discrepancies that had been reported were written down and entered into an Excel sheet. In order to easily separate the building projects from one another, one Excel document per building project was made. This process of registering every discrepancy was done so that all the data material could be systemized before starting the data analysis. This registering process was also done so that the researcher could send the data over to the personnel at Spenncon in order to verify and control the data. This extra verification was done so the data material would be as accurate as possible. One deviation entered into the Excel files equals one deviation written by the responsible foreman in the day reports i.e. one reported discrepancy by the responsible foreman equals one discrepancy in the data material.

In relation to this process of entering the information about the reported discrepancies into the Excel sheets one problem was encountered. In some occasions multiple deviations that were encountered at the building sites, were reported as one discrepancy by the responsible foreman. This means that even if there were multiple problems encountered at the building sites these problems was in some occasions written down as one problem. As a result one discrepancy reported from the building sites can contain both multiple and single discrepancies. However, the multiple deviations that was encountered and reported as a single discrepancy, does all seem to have the same underlying problems behind them. As a result the impact from this problem is reduced, but it means that the total number of deviations that actually were encountered in relation to each building project has not been possible to collect. This is due to the fact that the number of discrepancies that has been reported can contain both multiple and single discrepancies.

In relation to the way that the data have been reported and utilized, some will probably argue that the data material is inappropriate and inadequate for conducting a further analysis. However, the author believes that utilizing this data material for further analysis will be appropriate since the reporting methods will not stop the appearance of any trends in the discrepancies from being seen in the general terms. It can however mean that conducting an analysis using some forms of detailed statistical methods on the reported discrepancies would be less meaningful. This is due to the fact that the data material that the researcher has at hand does not cover the entire population of discrepancies encountered at the building site for each building project. However, going into the data material and try to modify the data material will not be meaningful since this may lead to that the data material becomes incorrect and becomes an unnecessary source of bias. The routines for reporting discrepancies in the two projects seem to be the same, and as a result the impact will be the same in relation to both projects. The only hindrance this reporting method will have on an analysis is a skewness in the data material. This skewness will occur inform of that mistakes that contains multiple sources of discrepancies will not stand out to be as clear as it would have if each and every discrepancy had been reported. As a result one has to keep this skewness in mind when doing the analysis of the data material reported in relation to this research. Some will probably also argue that the researcher should try to uncover the entire population of discrepancies reported in relation to these two building projects. The researcher believes that trying to alter the data material only will create an opportunity for bias to arise. The researcher does not have the in-depth knowledge that is required to look into and change the reports that have already been made. The assembly activities for Spenncon in relation to these building projects have also been finished so go and observe these building projects will not be possible. The researcher would have liked to go and study the assembly operations at other building projects, but this was not possible due to the time frame set for this thesis. The researcher would also have liked to have analyzed 1 or 2 additional building projects in this data analysis but this was not possible due to the time frame and the changes that were made in the topic during this master thesis. In relation to changing the data in the day reports, it would not have been meaningful for the researcher to try and alter the work that already has been undertaken by the responsible foreman at the building sites. This would also have undermined the work that already had been done in relation to these building projects. As a result the data material has been utilized as it is in the data analysis.

After all the discrepancies for the different building projects had been entered into their respective Excel documents, they were grouped into groups or parameters depending on the reason for the discrepancy to occur. This was done so one could distinguish the reasons for the discrepancies to occur allowing for a crude analysis to be prepared. When this crude analysis was done, one could get an overview over the crude reasons behind the origin of discrepancies that occurred at the building site. This crude analysis would again mean that one could uncover the crude reasons behind why the discrepancies occurred in the first place. The idea behind this crude analysis was to see if one could find that there was a clear trend in the data material. One example of a trend that the author believed could be observed was the Pareto 80:20 rule i.e. that 80% of the discrepancies would have its origin in 20% of the parameters. This means that if some sort of a general trend were found in the crude analysis, this would give a clear indication of where most of the mistakes originated from. If a clear trend was encountered, this would lead the research in the direction of where the main part of the discrepancies originated from. This would then again mean that one had found the most severe parameter that caused most of the problems encountered at the building sites. This would then again mean that the remaining research could be aimed at these few activities that caused most of the problems. However, before undertaking this analysis, the data was sent to the assembly leaders for the projects that are looked into for Spenncon. This would be done so the data set could be controlled and verified by someone with in depth knowledge about the different activities. As said earlier this was done in order to assure that the data was labeled correctly and that the discrepancies had been put into to the right classification. The data was also sent over to the assembly leader so that the researcher could get inputs on the classifications he had made on the discrepancies. This would then help this classification process by getting inputs on how the classification process could be improved. Before the data was sent over to the employees at the company the classifications was as follows:

1. Spenncon mistakes. This means mistakes that are done by Spenncon or other actors operating on behalf of Spenncon in their value chain. This can be mistakes that have occurred from the planning stages until the assembly process of the elements. In this group the mistakes done by Bolkan, Spenncons transportation provider, is also included. This is due to the fact that this is an actor that is carrying out services related to Spenncon value chain i.e. conducting operations on the behalf of Spenncon. The discrepancies that are reported in relation to Bolkan can be due to problems that Bolkan encounter or cause themselves such as: driving to the wrong location, heavy traffic and so forth. In addition the discrepancies reported related to Bolkan can be due to delays at other building sites where Spenncon is working or delays at the rail track at the factory at Hønefoss. So the mistakes related to Bolkan can be caused by Bolkan, Spenncon or other actors. The

reason why Spenncon can cause problems for Bolkan is that Bolkan is using their transportation equipment to carry out transportation services for different projects that Spenncon is working at during the working day. As a result these discrepancies that are reported in relation to Bolkan may also originate from other mistakes done somewhere in Spenncon's value chain or by other actors working at other building sites.

2. Mistakes done by other actors. By this it is meant mistakes that are done by other actors that are involved in the building project. For example other subcontractors, the main contractor, architects and so forth. This is activities that Spenncon has no control over but the operations that are done by these actors can influence the activities that are done by Spenncon at the building sites. One example of a discrepancy belonging to this category can be that another subcontractor has not finished their activities at the building site on time. As a result Spenncon has to wait for that specific activity to be finished before they are able to continue the assemblage of their products.
3. Other factors. This is other factors that are influencing the building project that none of the actors involved in the building project has any control over. Examples of this are that a crane driver, a coworker or a driver oversleeps; but it can also be other factors such as weather conditions, union strikes and so forth.
4. Unknown. This is mistakes that for some reason are occurring during the building project but the reason for the mistake is unknown or impossible to pin point. As a result it is impossible to say who is to blame for the mistake, and as a result these mistakes have to be seen as unknown.

After the data sets had been read, controlled and verified by the montage leaders at Spenncon the researcher and montage leaders came up with an additional 5^{th} classification. This classification is as follows:

5. Problems in the planning process. This is problems that occur sometime during the planning process of the shell structure. Even if these mistakes are done prior to the assembly process, they do first show up during the assembly process of the shell structure of the building. These mistakes do occur because some aspects of the communication process between the parties involved in the making of the shell structure have gone wrong. This can occur since the construction drawings for the project have been made

with mistakes, communication problems between the actors have occurred or that there are misunderstandings between the involved parties regarding clarifications of the building projects. In relation to these problems it is not possible to pin point who has the responsibility for the mistakes to occur, but the mistake is done by one of the actors that is responsible for the shell structure of the building i.e. Spenncon or another subcontractor responsible for making the shell structure of the building plus the main contractor.

After the Excel files had been returned by the montage leaders the crude data analysis for the different building projects began. The results of these crude analyses are presented in the next three subchapters.

5.1.1 Crude analysis for the AKA project

The AKA project was a building project that Spenncon participated in from the 31st of October 2011 until 2nd of March 2012. This building project is currently ongoing and it is due to be finished in December 2012. The building site for this project is lying in near vicinity of the factory since it is also located at Hønefoss. In this building project Spenncon was delivering walls (wall elements) and floor slabs (hollow core elements). Another actor was delivering the structural solutions (pillars and beams) in steel to this project (Spenncon 2011 and 2012) so Spenncon was only delivering parts of the shell structure. This particular building project was conducted for the company called AKA. AKA is an actor that has its main business in lending out commercial properties to commercial actors mainly in eastern Norway (AKA 2012).

In relation to the AKA project the responsible foreman at the building site reported a total of 38 discrepancies occurring from the work begun in week 44 in 2011 until the work finished in week 8 in 2012. However, all reports for all of these weeks have not been made due to sickness at the building site in week 49 and 50. As a result there were no data available for these 2 weeks when conducting the analyses regarding this project. All of the discrepancies that were reported from the building site can be categorized as seen on the next page. Please bear in mind the classifications presented earlier since the discrepancies are classified according to these classifications.

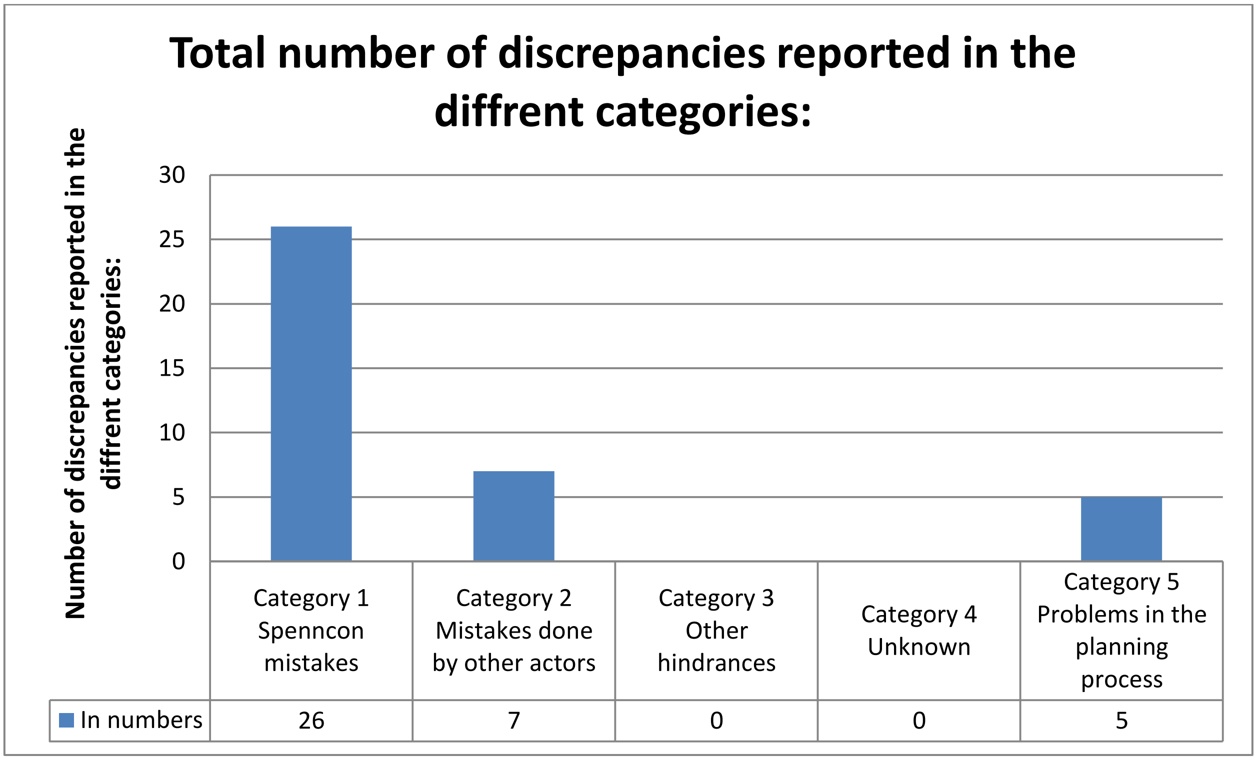


Figure 6 Bar chart for the discrepancies reported in the AKA project

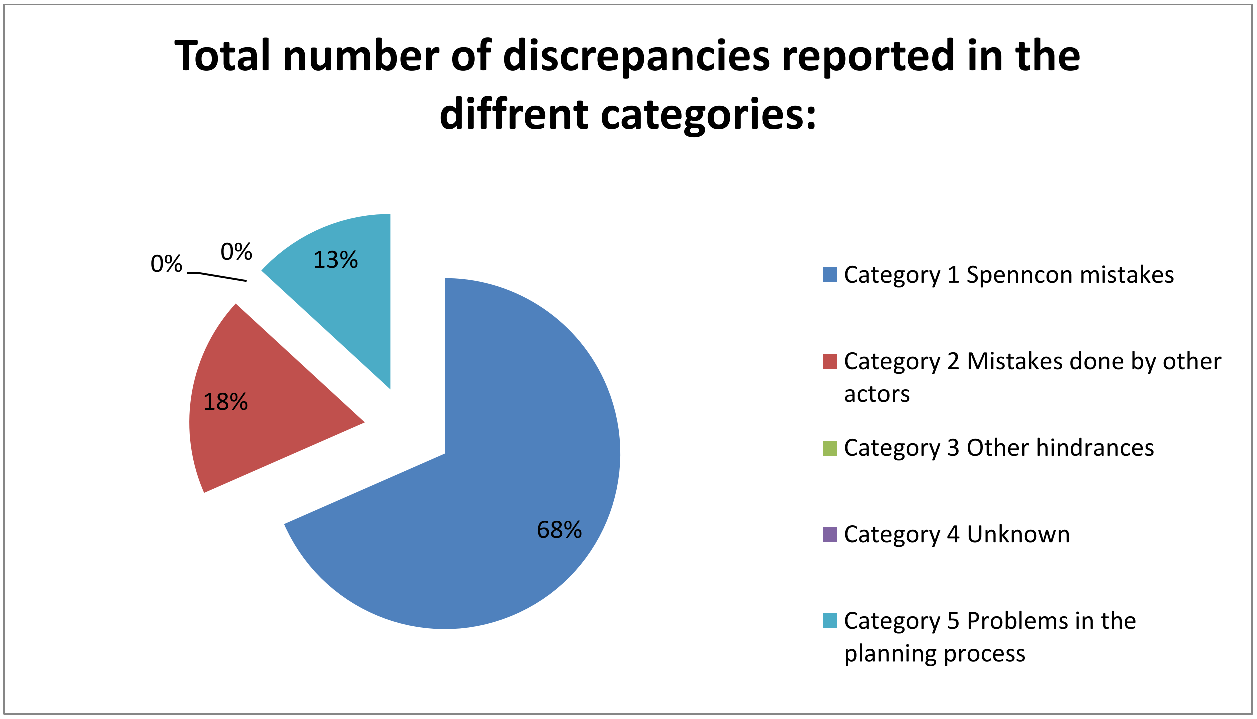


Figure 7 Pie chart for the discrepancies reported in the AKA project

In relation to this project we can clearly see that most of the mistakes were in the 1st category i.e. mistakes that were done by Spenncon or actors working on behalf of Spenncon in their value chain. 26 of the total 38 discrepancies reported belonged to this category. That is equal to 68 % of the total discrepancies. The second largest category containing discrepancies reported was mistakes done by other actors involved in the building project. 7 mistakes or 18 % of the total number of discrepancies reported, belonged to this category. The third largest category of discrepancies was the mistakes that were done in relation to the planning process of the building project. In relation to this specific category 5 mistakes or 13 % of the total problems reported belonged. For the two other categories no discrepancies were reported from the building site. This means that in relation to the AKA project most mistakes were done somewhere internally in Spenncon's value chain. Almost 7 out of 10 mistakes that were reported from the building site belonged to this category.

Based on this initial analysis it seems to be a trend in the data material for the AKA project. It seems to be a clear trend that most of the mistakes are done by Spenncon or actors working on behalf of Spenncon somewhere in their value chain. That means that this initial basic analysis suggests that the focus of improvements are best served by looking at improving the activities carried out by Spenncon or other actors working on behalf of Spenncon in their value chain. However, to draw any conclusions based on this analysis alone and at this stage is not appropriate.

5.1.2 Crude analysis for the Miele project

The Miele project was another shell based construction project that Spenncon participated in. In relation to this project Spenncon delivered: pillars, hollow core elements, steel angles and the façade to the shell structure. While another actor, SOAS, delivered steel beams to the project. While the main contractor, HENT, delivered shafts and walls to the underground parking area and these products were made through the use of poured-in-place concrete. So in relation to this building project there were 2 other actors involved in the making of the shell structure of the building. Spenncon was involved in activities at the building sites from 24th of October 2011 until 3rd of February 2012 (Spenncon 2011 and 2012). This building project is undertaken for the producer of domestic appliances and commercial equipment Miele (Miele 2012). The building site is laying in Asker and the building project is planned to be finished in September 2012 (HENT 2012).

In this building project the responsible foreman delivered all of the daily reports for all workdays that Spenncon worked in the project. The author received all the day reports from week 43 until week 4. This means that all reports for this project except the reports from the last week i.e. week 5 have been studied by the author. The reports for week 5 were not sent over by the assembly leader since no discrepancies were reported during this week. In total 28 discrepancies were reported in relation to this project. The discrepancies were reported in the classifications as shown on the next page.

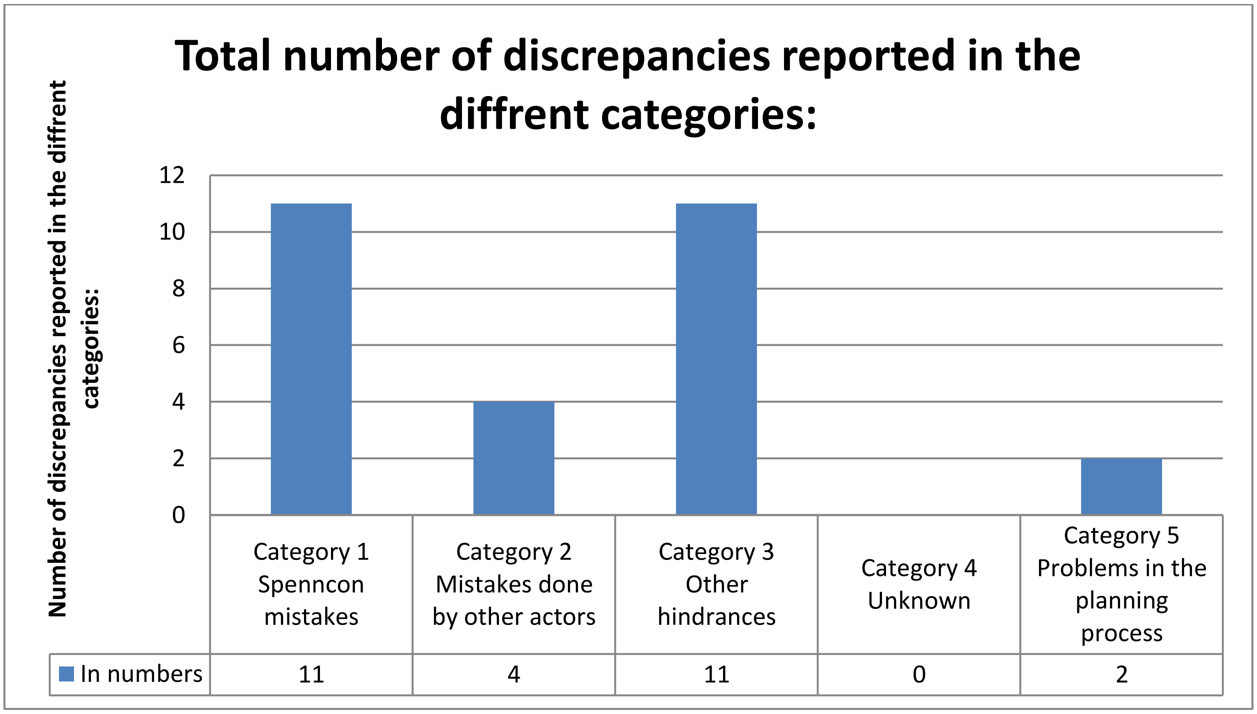


Figure 8 Bar chart for the discrepancies reported in the Miele project

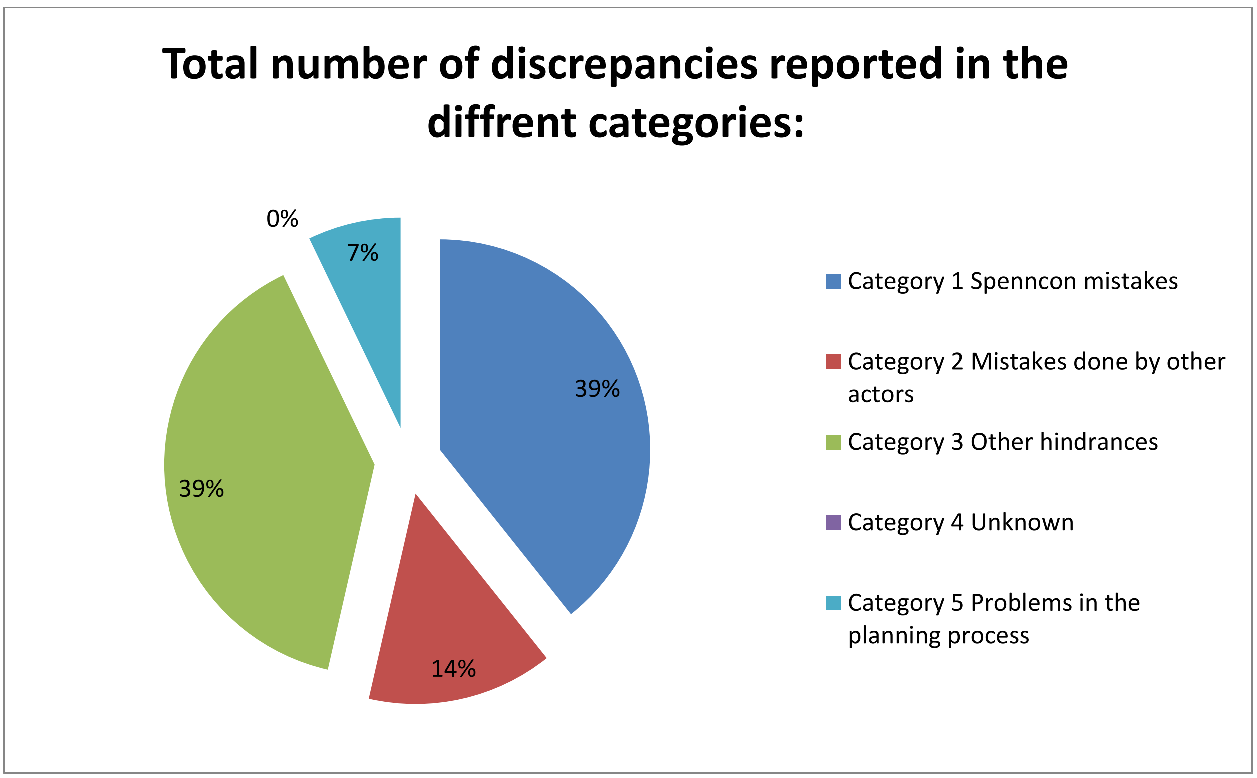


Figure 9 Pie chart for the discrepancies reported in the Miele project

In relation to this project one can see that 11 out of 28 discrepancies equal to 39% of the discrepancies are due to mistakes done by Spenncon or actors working on behalf of Spenncon in their value chain. The same figures can be seen in relation to category 3 other hindrances i.e. factors that none of the actors involved in the building project has any control over. While 4 out of 28 the discrepancies reported in the Miele project are due to mistakes that are done by other actors that are involved in the building project. The figures for the 5th category i.e. problems in relation to problems in the planning process 2 discrepancies were reported. None of the discrepancies were due to the 4th category, that is, unknown reasons.

By looking at the figures and graphs for this project, they suggest that there are no special trend in the discrepancies encountered in this building project. This is due to that none of the categories of discrepancies that were encountered in relation to this project is particular larger than the other categories i.e. none of the reported categories clearly stand out to be larger than the other categories. The trends that can be seen in relation to this project are that the 1st category and the 3rd category of discrepancies are the largest reported categories and of similar size. Further one can see that the 2nd and the 5th category also are of similar size but these are smaller than the previous two categories. Finally one can see that no discrepancies are reported in relation to the 4th category.

One thing that stands out in relation to the diagrams for the Miele project compared to the AKA project is the 3rd category and this difference is therefore commented upon in this paragraph. The author believes that this major difference cannot be left uncommented at this stage. This 3rd category stands out to look significantly larger in the Miele project compared to the AKA project. In fact in the AKA project no discrepancies were reported in relation to this category while 11 discrepancies was reported in the Miele project. If one studies the data material from the Miele project closer it is clear that the forces of nature have caused most of the discrepancies reported in this category i.e. other hindrances. The forces of nature have interacted in relation to this project in form of low temperatures and snowfall. Out of the 11 discrepancies related to this 3rd category 8 of the discrepancies are caused by ice or snow. 7 out of these 8 discrepancies are of hindrance to the assembly process while 1 discrepancy is of hindrance to the transportation process. Of the last 3 discrepancies reported in this relation to this category 1 of the discrepancies is caused by a memorial gathering for the foreman at the building site that passed away during the building project. While the 2 remaining discrepancies are caused by someone involved in the building project in the form of personnel oversleeping.

5.1.3 Comparison of the crude analysis Miele project and the AKA project

By studying the diagrams presented earlier for these two projects, it seems like there is no connected trend between them. This is due to the fact that the data material for the AKA project suggests that there is a clear trend to be seen, namely that Spenncon and other actors in their value chain causes most of the discrepancies. In the Miele project this trend is also evident in the data material since the mistakes that are done somewhere in Spenncon's value chain is the largest category. However, this trend does not stand out to look as significant as it did in the AKA project. One can also see that this 1st category has to share its position as the largest category in the Miele project with the other hindrances category i.e. category nr 3. These trends can best be seen in the pie charts for the two projects. In the AKA project the mistakes done in Spenncon's value chain stands for 68 % percent of the discrepancies reported. In the Miele project the same category only stand for 39 % of the discrepancies reported. However, as said earlier, this category has to share its figures with the 3rd category i.e. other hindrances. So in relation to the Miele project there does not seem to be a clear trend in the data material that were seen in the AKA project. In the AKA project there was a clear trend that Spenncon or someone working in Spenncon value chain, stands for most of the discrepancies encountered at the building site. This is not the case in the Miele project.

This unevenness in the distribution between the categories is not evident in all of the figures for the two projects. For the AKA project the 2nd largest category of reported discrepancies is the 2nd category, that is, mistakes done by other actors with 18% of the discrepancies reported. In relation to the Miele project the figures for the same category is similar with 14 % of the discrepancies reported. One can also see these similarities for the third largest figure in relation to the AKA project, that is, problems in the planning process between the actors with 13% of the discrepancies reported. The same category stands for 7 % of the discrepancies reported in the Miele project. However, this similarity is not only shared between the 2nd and 5th category. It is also shared in relation to the 4th category i.e. unknown hindrances. Since none of the building projects had any discrepancies reported in relation to the 4th category.

All of these comments regarding trends can best be seen when comparing the discrepancies reported in one common graph. This common graph can be seen on the next page. When looking at this graph please bear in mind that the total number of discrepancies for these projects is different so looking at the count over the discrepancies when comparing the projects will not be meaningful. Please do instead look at the percentage labels when comparing the reported discrepancies for the two projects. This is also the reasons why percentage figures is used when one have compared the two projects earlier.

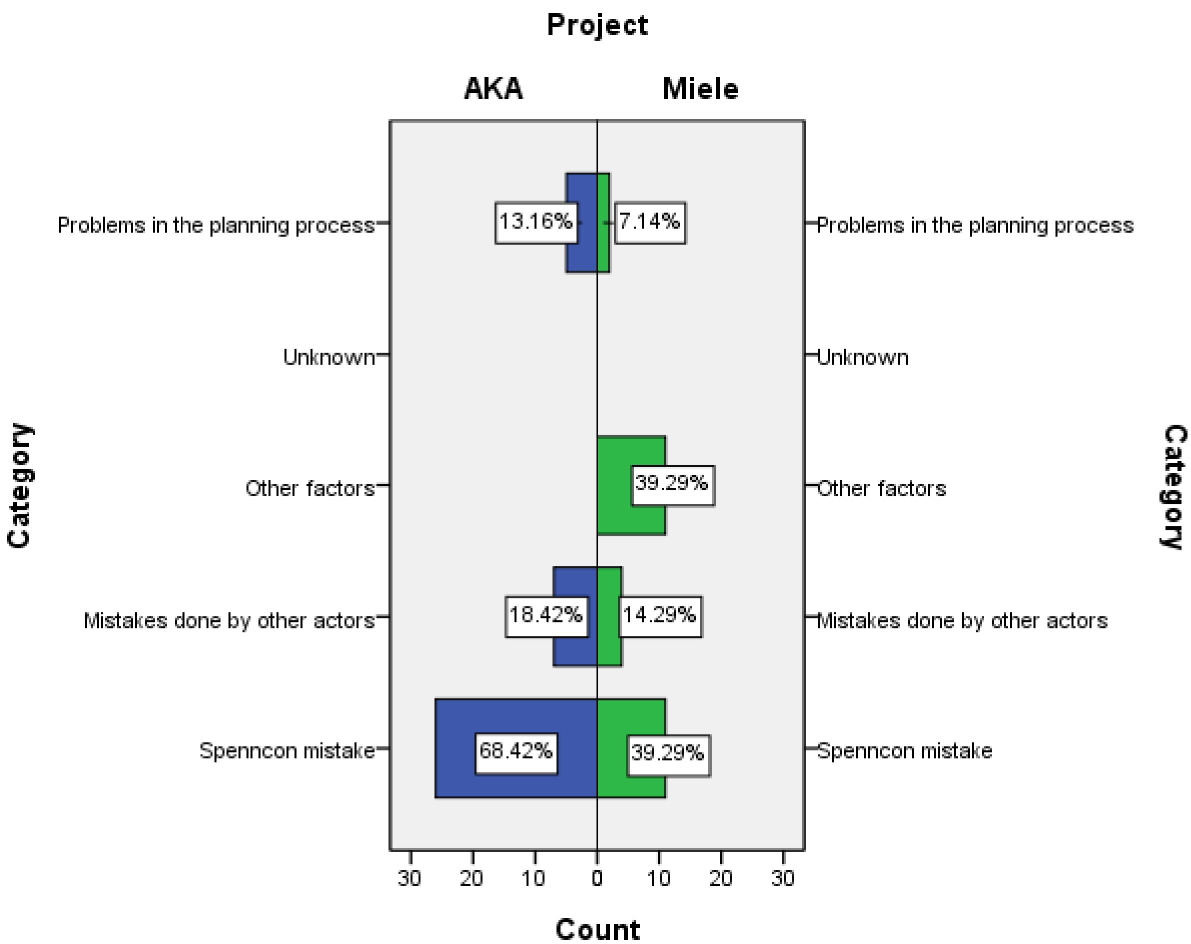


Figure 10 Bar chart for discrepancies for both the AKA project and Miele project

The trends described on the previous page can clearly be seen in the graph above, and as a result one can draw the conclusion that there does not seem to be a common connected general trend in the discrepancies reported for the two building projects. So in relation to this crude analysis one is not able to draw the conclusion that it seems to be a common similarity in the discrepancies reported in the two buildings projects. Said in other words when studying these graphs presented earlier there does not seem to be any connected trend for the reported discrepancies between the data material for these two projects.

5.2.1. Statistical analysis of the entire data material for the two projects

In the crude analysis one was not able to find any general connected trends between the two building projects. Categories 2, 4 and 5 had identical or similar percentage figures, but despite of this, there were no connected general trends to be seen between the two projects. Even if there does not seem to be any connected trends between the data material for the two building projects, it would be interesting to do a statistical analysis. This statistical analysis will be done in order to see if there is any statistical evidence suggesting that there are significant differences between the different categories in the total data set for the two building projects. This will give an answer to if there is significant difference between the reported categories of discrepancies in the data set from the two projects. If there is evidence of significant difference between the categories, it would mean that one can conduct further analysis on the data material. It would not be interesting to carry out further calculations on the reported discrepancies if there was not any evidence suggesting that the different categories were different. If this had been the case one would not have any evidence for difference between the categories and one could not prove that there were any difference between the categories.

If one looks closer at the figures reported for the two projects, one can see that no discrepancies were reported in the 4th category i.e. unknown reasons for the discrepancies to occur. Since no discrepancies have been reported in this category, it has not been included in any of the further calculations because it will be impossible to do any calculations on a category that is not containing any information in any of the building projects.

In order to see if there was any evidence for difference in the data material reported from the two projects, the entire data set was tested for significance. In order to look for significance in the data material one statistical tool has been utilized, namely contingency tables or cross tabulation. This tool has been chosen due to fact that the data set that has been collected for the two projects has different underlying characteristics behind the different discrepancies to occur. As a result it would be wise to cross classify the discrepancies in order to test if there is association, dependence or difference between the characteristics. One test that can be utilized to test if there is significant difference between the different parameters is the Person Chi-Square test. This test can be used to examine if the characteristics behind the discrepancies are similar or different. This can be done by testing the null hypothesis that there is not a difference between the characteristics against the alternative hypothesis that there is a difference between the characteristics. To test which of these hypothesizes that is the correct one, one can ask how many observations of the different characteristics would be expected if the null hypothesis was true (Newbold, Carlson, and Thorne 2010). These calculations have not been done by hand or use of formulas but through the use of the statistical software SPSS. As a result of this no calculations have been made by the author since all calculations in relation to this test have been done by the statistical software. As a result no detailed explanations are made regarding the calculations in this statistical analysis. The output form SPSS was as follows when utilizing the cross tab function on the collected data material:

Project * Category Crosstabulation

			Category				Total
			Spenncon mistake	Mistakes done by other actors	Other factors	Problems in the planning process	
Project	AKA	Count	26	7	0	5	38
		Expected Count	21.3	6.3	6.3	4.0	38.0
		% within Project	68.4%	18.4%	.0%	13.2%	100.0%
	Miele	Count	11	4	11	2	28
		Expected Count	15.7	4.7	4.7	3.0	28.0
		% within Project	39.3%	14.3%	39.3%	7.1%	100.0%
Total		Count	37	11	11	7	66
		Expected Count	37.0	11.0	11.0	7.0	66.0
		% within Project	56.1%	16.7%	16.7%	10.6%	100.0%

Table 1 Observed and expected numbers for the different characteristics

This table shows the actual counted discrepancies in the data material for each category for the different projects plus the total sums for all categories and the total figures for both projects. Further this table shows the same figures for the expected count of the discrepancies for the different categories within the two projects. In addition the table shows percentage count within the projects for the different categories. Nonetheless, this table does not show if there is significant difference between the reported categories of discrepancies. As a result more output from the software must be examined to say if there is a significant difference between the categories in the data material. The rest of the output from SPSS is presented further down on this page. However, this table presented above is not completely meaningless since it gives an insight into what kind of figures that could have been expected if the null hypothesis was true (Newbold, Carlson, and Thorne 2010). So it gives some insight to the figures behind different the outputs presented below.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	18.085[a]	3	.000	.000		
Likelihood Ratio	22.145	3	.000	.000		
Fisher's Exact Test	19.080			.000		
Linear-by-Linear Association	2.404[b]	1	.121	.128	.075	.023
N of Valid Cases	66					

a. 4 cells (50,0%) have expected count less than 5. The minimum expected count is 2,97.

b. The standardized statistic is 1,550.

Table 2 Chi-Square Tests

This is the output that SPSS produced in relation to the calculations for the cross tabulation of all the discrepancies for the two projects. As one can see here, SPSS has made a footnote in relation to the Person Chi-Square test. This footnote have been made by SPSS since this test uses an approximation that only is accurate if less than 20% of the estimated expected numbers is below 5 (Newbold, Carlson, and Thorne 2010). The expected figures can be seen in the table that was presented on the previous page. In this case we can see that the expected numbers that is below 5 is above the 20% limitation set for the accuracy of the Person Chi-Square Test. The expected numbers that is below 5 is in this case 50% and as a result another test has to be utilized. This means that one cannot utilize this test that was initially thought that could be utilized to test for significance in the data material. The test that has been utilized to test for significance is instead the Fisher's Exact Test. This test works in a similar way to the Person Chi-Square test, but it does not use an approximation as the Person Chi-Square test. The exact test is instead using exact two sided p-values for any given frequency table (Preache and Briggs 2012). This test will not be described in greater detail, but it works in a similar way to the Person Chi-Square test. The difference is that Fischer's Exact Test is using exact figures compared to an approximation that is done by the Person Chi-Square test. The Fisher's Exact Test is more accurate than the Chi-Square test when we have low expected numbers as we have in this particular data set (McDonald 2009).

In relation to the test results we can see that the p-value or "Exact Sig. (2-sided)" value is 0,000 for the Fischer's Exact Test in the output from SPSS. This means that the null hypothesis is rejected while the alternative hypothesis is kept. The null hypothesis stated that there was not a difference between the characteristics while the alternative hypothesis stated that that there was a difference between the characteristics. This means that there is statistical evidence in the data material supporting that there are a significant difference between the categories in this test. This means that there is evidence for that the reported categories of discrepancies is different. As a result one can do further analysis on the data material collected and try to quantify the discrepancies so that the data material can be related to something. Presenting the figures in the form as they are in now, will not give any deeper meaning and as a result these figures are therefore tried to be quantified into figures that can be related to something. This is done in the next subchapter.

5.2.2 Quantifiable analysis on the entire data material collected

In relation to the statistical analysis one was able to find evidence for significant difference between the reported figures for the different categories in the complete dataset for the two building projects. However, the figures in the statistical analysis do not say much in relation to the discrepancies that actually occur at the building sites that are served by the factory at Hønefoss. So the researcher thought one could try to quantify the findings from the data material collected in the two building projects in order to say what the data material actually suggests are the main problem encountered at the building sites. In order to try and quantify the data material one has many possibilities. The researcher believes that this quantification effort should yield a result that everyone could relate to. The researcher believes that saying something about what number of discrepancies that can be encountered in the assembly processes served by Spenncon's factory at Hønefoss over a 1 year period would be a figure that people could relate to. This means that one will utilize the data material that have been collected in order to try and say something about what number of discrepancies that can be expected to occur in the assembly processes served by the factory at Hønefoss over one year period. This is done under the assumption that the data material collected from the 2 building projects is representative for all the projects that Spenncon's factory at Hønefoss is serving over a 1 year period.

In order to do this analysis one will utilize the means of the number of discrepancies reported from the two projects per category per week. To complete this calculation one also has to have the estimate total number of project weeks that Spenncon's factory at Hønefoss is serving over a one year period. This figure was estimated after talking with the montage leaders at Spenncon. In order to come up with all these figures some calculations had to be undertaken. The foundation behind these calculations is first presented, then the results are shown and illustrated before the results are discussed.

The estimated discrepancies per week per category were estimated by the researcher through the following steps:

1. First the total number of discrepancies reported in each category was found. This figure was found by utilizing the data material from the crude data analysis. The figures were found by adding together the reported discrepancies from each category from the two crude analyses.

2. Then the total number of day reports received for each project was found. This sum was found by looking at all the day reports that was received from each week and noting the number of day reports that was made in each of the weeks. These figures were then added together to find the number of day reports that were reported in total per project.
3. Next the total number of day reports for both projects was found. This figure was found by adding together the total number of day reports reported in each of the projects.
4. After that the average number of working days conducted in the two projects was found. This figure was found by taking the total number of day reports received and divide it by 2.
5. Then the average number of working days in a working week for each of the two projects was found. This was found by taking the total number of day reports made for each project and divide it by the total number of working weeks that these day reports was made over in each of these projects.
6. Subsequently the average number of working days in a working week for both projects was found. The average figures for the working days in each of the two projects was summed up and divided with 2.
7. Next the average number of working weeks in the day reports that was received was found. This was found by taking the average number of working weeks in the two projects divides the average number of working days in a working week for both projects.
8. After that the average number of discrepancies reported in the different categories per project was found. This was found by taking the total numbers of discrepancies reported in each category divided by two.
9. Then the average number of discrepancies reported in each category per project per week was found. This was found by taking the average number of discrepancies reported per project in the different categories divided by the average number of working weeks per project.

The total number of project weeks that work were conducted at the building sites served by the factory at Hønefoss per year were found. This figure were found trough the following steps:

1. First the number of working weeks that one assembly team is working at Spenncon in one year were found.

2. Then the average number of assembly teams working with assembling products made by the factory in Hønefoss was found.
3. Then these two factors were multiplied together and the total estimated number of project weeks served by the factory at Hønefoss over a year was found.

Then the average number of expected discrepancies encountered per year per category was calculated. This figure was calculated by taking the estimated total number of project weeks that Spenncon's factory at Hønefoss is serving over a year multiplied by the average number of discrepancies reported per category per week. This process was then repeated for all of the 4 categories to find the expected number of discrepancies for all of the categories. When this was done the expected number of discrepancies reported per category per year was found. The outcome from some of these calculations is shown in the table on the next page.

Total number of discrepancies encountered	66,00
Total working days in both projects	135,00
Average number of working days per project	67,50
Average number of working days in a week for both projects	4,82
Average number of working weeks per project	14,00
Total number of discrepancies reported in category 1	37,00
Total number of discrepancies reported in category 2	11,00
Total number of discrepancies reported in category 3	11,00
Total number of discrepancies reported in category 5	7,00
Average number of discrepancies reported in category 1 per project	18,50
Average number of discrepancies reported in category 2 per project	5,50
Average number of discrepancies reported in category 3 per project	5,50
Average number of discrepancies reported in category 5 per project	3,50
Average number of discrepancies reported in category 1 per project per week	1,32
Average number of discrepancies reported in category 2 per project per week	0,39
Average number of discrepancies reported in category 3 per project per week	0,39
Average number of discrepancies reported in category 5 per project per week	0,25
Average number of assembly weeks served by the factory at Hønefoss in a year	470,00
Average number of discrepancies reported per year in category 1	621
Average number of discrepancies reported per year in category 2	185
Average number of discrepancies reported per year in category 3	185
Average number of discrepancies reported per year in category 5	118

Table 3 Excerpt of the calculations regarding the estimated discrepancies encountered over a 1 year period

Above an extract of some of the calculations undertaken to say something about the discrepancies that can be expected based on the data material from the two projects is shown. As one can see from the calculations discrepancies reported in the 1st category stands out to be the largest category with an estimated 621 discrepancies per year. The 2nd and 3rd categories are both share the position as the 2nd largest categories with an estimated 185 discrepancies. Category 5 has the lowest number of estimated discrepancies with 118 estimated discrepancies. The average number of discrepancies reported per year in each of the categories is best shown in a graph. This graph is shown at the next page. Further comments regarding the results from these calculations will also be done there.

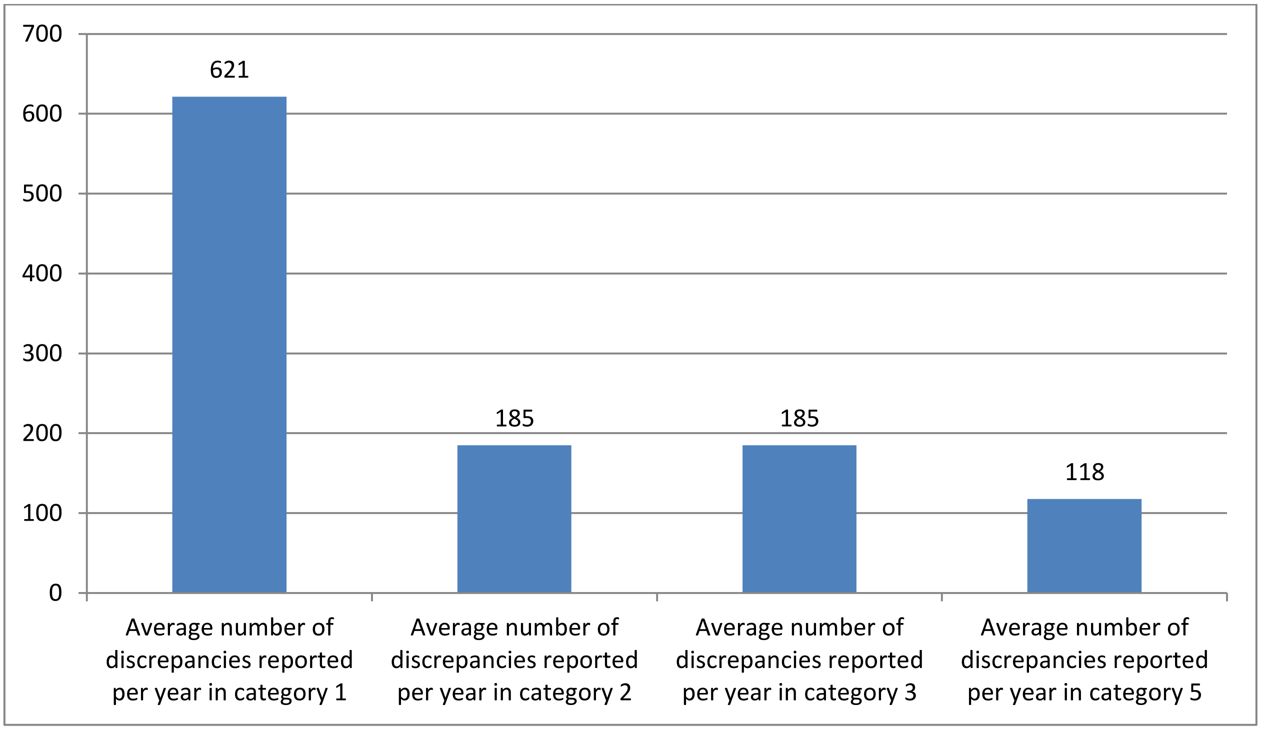


Figure 11 Bar chart illustrating expected number of discrepancies encountered at the building sites over one year

The bar chart above is illustrating the expected number of discrepancies that can be expected over one year based on the data material collected and the assumptions taken regarding these calculations. The different categories are as follows:

- Category 1. Spenncon mistakes i.e. mistakes that are done somewhere in Spenncon's value chain. This is mistakes that are done by Spenncon or other actors operating on behalf of Spenncon.
- Category 2. Mistakes done by other actors involved in the building process.
- Category 3. Other factors, that is, factors that is influencing the assembly process but none of the actors has any control over.
- Category 5. Problems in the planning process between the actors involved in making the shell structure of the buildings.

As one can see from these calculations there is one category that stands out from the other categories. That is the 1st category. This category is over three times the size of the two categories that share the second largest share namely category 2 and 3. Category 5 is the 4th largest category with the lowest number of estimated discrepancies. Please bear in mind that the 4th category has not been included in this analysis since no discrepancies were reported in this category in the two building projects i.e. no discrepancies was caused by unknown reasons.

Based on the figures from the calculations regarding the data material from the two building projects that have been looked at and previous analyses regarding the same projects, it seems clear that the 1st category causes most of the problems at the building sites. This means that operations that are done in Spenncon's value chain are causing most of the deviations that are encountered at the building site. This means that the answer to the 1st research question is that most of the deviations at the building sites are caused by mistakes done by Spenncon. As a result Spenncon should focus on reducing discrepancies that are caused by Spenncon and other actors working on behalf of Spenncon in the value chain.

During the crude analysis one problem became apparent. The problem was that some of the discrepancies reported from the building sites, were reported as a single discrepancy even if multiple discrepancies were encountered. The author believed that this would lead to a skewness in the data material collected. This skewness was due to the fact that the reported discrepancies containing multiple problems would not stand out as clear as they would have if each of the discrepancies had been reported. In relation to this problem it seemed that most of the discrepancies containing multiple problems belonged to problems that were caused by production errors. This means that there is even a stronger support in the material behind the data analysis suggesting that most of the problems encountered at the building sites belong to this 1st category. So the problems that were encountered in the beginning of the data analysis should not have had any influence on the conclusions that was drawn out of the quantifiable data analysis and statistical analysis. It may however have influenced the results in the crude data analysis by not making the 1st category stand out as the problem area already at that stage. So the conclusion will be that this reporting method should not have influenced the end conclusion that is drawn from all the data analyses in this thesis.

6. Recommendations

In this chapter the recommendations for improving the problem areas uncovered in relation to the 1st research question is answered. However, before presenting these recommendations the backdrop behind these recommendations are presented. This is done so one can answer the 2nd research question i.e. what part of the value chain from the assembly process to the planning process does the discrepancies originate from. This is done so that one can give specific recommendations of how to improve the problem areas. After this backdrop have been presented, the specific recommendations of how to improve the problem areas are presented and how these recommendations can be implemented. That means that the 3rd and 4th research questions are being answered at this particular stage of the thesis. The answers to these questions are based on the previous descriptions and theory presented. In addition supplementary theory and theoretical background are given to support the findings and recommendations given. All recommendations that are given in this chapter are based on the theory behind lean but since these problem areas were not uncovered before the data analysis were finished, additional theory have been presented to give additional recommendations to Spenncon. So please bear in mind the previous descriptions regarding Spenncon's value chain in chapter 1 and chapter 3 plus the descriptions about lean in chapter 4 when reading this chapter.

6.1 Backdrop for the recommendations given to Spenncon

The results from the estimated discrepancies encountered at the building sites served by the factory at Hønefoss showed that most of the discrepancies were created somewhere in Spenncon's own value chain. That means that most of the estimated discrepancies had their origin in the 1st category. This can be mistakes made by Spenncon or other actors involved in their value chain i.e. their transport provider Bolkan. Stating a recommendation that Spenncon have to focus on improving all their activities in their value chain would not be a meaningful suggestion. This will be a too vague recommendation to give. Further it will not give Spenncon any real suggestions for improvements. In addition this kind of recommendation will undermine all the previous work done by the author and the work done by others that have contributed to this research. As a result one has to study the data material closer to give a more meaningful recommendation. Further it would not be meaningful to not answer all the research questions that were made in the beginning of this research. This means that the 2nd research question must be answered, that is, in what part of the value chain does the discrepancies originate from? That is the question that is being answered in this subchapter.

If one study the data material behind these calculations, it is clear that one can give a more specific recommendation to Spenncon with regards to the discrepancies encountered in this 1st category. Most of these mistakes registered in this 1st category are due to mistakes in Spenncon's activities in production or in the activities of making the production drawings i.e. most of the mistakes are in the process of making the elements or in the sketch that illustrates how the elements should be when the production process is finished. There were not reported many problems in relation to other activities in this 1st category such as the outbound logistical operations. This is the operations undertaken from the elements are put into the finished goods inventory (rail track) until the elements are delivered at the building site.

In addition there were not reported many discrepancies regarding Spenncon's own planning processes related to delivery, production and mounting in the building projects. Further none of the described environmental problems that had the potential to create havoc for Spenncon's entire value chain, did not transpire in any of the two projects. Please bear in mind the example with the sudden change in assembly direction as an example of the building project environment that was given earlier in chapter 3. This means that there was no evidence suggesting that there are many problems in the upstream or downstream processes relative to the two suggested problem areas regarding the creation of the concrete elements. This result was surprising to the author since the author would have expected that the environment described in relation to the building project and the outbound logistical operations would have the potential to produce most of the discrepancies. This is due to the fact that if changes in the building would occur, one would expect that it would be difficult to produce and deliver the elements to the building sites. It could also be difficult to deliver new and updated plans regarding these changes to the building site so that the assembly process could be done according to the new plans.

The author also believed that the outbound logistical operations could produce difficulties since the planning process had a relatively short planning horizon. The planning process begins with the notification of transport assignments between Spenncon and the transport provider Bolkan just 3 days before the transport assignment is planned to be conducted. This was described in chapter 1.3 The value chain for the delivery of elements to the building sites. Despite of what appears to be a relatively short planning horizon on the outbound logistical operations, it does not seem to cause any major problems in relation to the building projects. However, none of these expected problem areas arouse. This gives an indication that the relationships between the actors involved in the building projects seems to function in a good way i.e. it seems like the point 5 cooperative relationships from chapter 4.3 Lean construction is present in the building projects that Spenncon participates in.

As a result of the findings in this research, Spenncon should focus on improving the production process and the processes of making the production drawings considering that these two processes produce most of the discrepancies encountered at the building sites. This can also be seen in relation to point 6 in the chapter from lean construction (system perspective) since improving this specific problem area at this time, will increase the overall efficiency of the entire system and avoid sub optimization. These efforts should be aimed at reducing the errors that are occurring in these activities. Said using lean terms it is these two activities that create most of the waste for the assembly processes at the building sites. The answer to the 2nd research question is therefore that the production drawings and the production process is causing most of the discrepancies that are encountered at the building sites.

The author believes that efforts that will ensure quality in the operations that are the problem areas are the best solutions to solve these problems. This is due to the fact that these efforts will reduce the number of mistakes that are done in these activities and enhance the quality in these operations. These activities should be correct the first time they are done so that no rework at the building sites will be necessary. The problems that are encountered in the assembly process are occurring in relation to Spenncon's production processes. Either the input to the production process is incorrect (production drawings) or the outcome from the production process is incorrect (the elements). As a result of these findings lean production will be a better theory to improve the problems in the system relative to lean construction. As a result chapter 4.2 Lean production, lean manufacturing and "lean" will be utilized to come up with recommendations for Spenncon in this thesis. This means that chapter 4.3 Lean construction that have been used so far in this chapter will not be used to make recommendations since the problem areas uncovered did not belong to the construction environment or construction activities. This last point also gives a further indication that lean production is the correct theory to look for ways to improve the production process of the elements.

One can find good arguments for why the problems related to Spenncon are occurring in production theory. Bear in mind that the problems uncovered for Spenncon are in relation to the production stages of making the elements and production theory does therefore seem to be an appropriate area to look for evidence of these problems. It also seems like it would be useful to study the theory in order to see if Spenncon should do something about the problem areas that have been uncovered. Saying that this is a problem would not be enough to motivate change. It would probably be more motivating to try to say what these problems actually are causing for Spenncon. The outcome from these findings is that rework has to be done at the building sites in order to solve the mistakes that are done in the production processes. In relation to lean rework is seen as waste and should therefore be removed. This was presented in the chapter 4.5 Value and Waste under point 4 extra processing. However, looking somewhere else than just under the field of lean for why rework should be removed would also be meaningful. According to Yu and Efstathiou (2005) rework results in extra costs in form of money and time, but also in relation to extra efforts that must be taken to keep to the original schedule. Further they argue that these problems regarding rework goes especially for industries with mass-customized orders which they define as an industry where each product is made according to the specific customer order.

This description seems to fit well with the environment that Spenncon operates in since no building project or building is the same i.e. the products are made according to specific orders regarding that building project or that building. Yu and Efstathiou continue to argue that this type of industry produces a wide variety of products over small batch sizes. The outcome from this is that management over the production process turns out to be very complicated as the production department tries to uphold the quality and trace all the information for each product over the production processes (Yu and Efstathiou 2006). This indicates that there is not only Spenncon that is suffering from the problems uncovered in relation to this thesis. This also means that one can find good arguments and explanations in theory for why the discrepancies are occurring during the production processes at the factory at Hønefoss. However, this is not an excuse for letting these discrepancies to continue to occur. One can also see from these descriptions that Spenncon should have incentives for making these elements correct the first time. If the elements are not made correct the first time the result is extra costs in form of money and time to correct these mistakes at the building sites. In addition these mistakes mean that it is difficult to keep to the original schedule at the building sites. Said using other words not producing the elements correct the first time creates waste in from of money, time and extra efforts spent on getting the project back on schedule. This means that Spenncon should have economic incentives for reducing the errors in relation to the production process and the making of the production drawings hence reduce the discrepancies that are encountered at the building sites.

In relation to this thesis no calculations regarding the cost of these discrepancies have been made. Even if this is the case one can again look at what the theory suggests that the costs are in relation to rework at building sites. If one look at the theory regarding construction projects, one can see that rework can be a substantial part of costs in a construction project. According to Love and Sohal (2003) the cost of rework in construction can be above 10 % of the total project costs (Love and Sohal 2003). So Spenncon should have economic incentives for reducing the number of discrepancies that are encountered at the building sites thus the amount of rework that the assembly teams have to undertake at the different building sites. In addition Spenncon should have incentives for having an assembly process that goes as smoothly as possible since this will mean that various schedules will be easier to follow. This will again also probably mean that fewer resources have to be spent on getting the assembly process back on the schedule if problems arise somewhere in the value chain. This is due to the fact that if fewer resources have to be spent at the building sites at corrective actions or rework, more resources will be available to handle other disturbances in the value chain that can have an impact on the various building sites. If the assembly process goes more smoothly, the other plans will probably also be easier to follow since all the other plans are following or based on the assembly plan. This is taken from the introduction to the thesis where the assembly plans are described as “the mother of all plans” in relation to Spenncon value chain. So improving the assembly process will probably also yield a positive synergic effect on the other plans and the activities that these plans follows. This means that Spenncon should have economic incentives as well as other incentives for reducing the discrepancies encountered at the building sites due to the problems regarding the production process and the production drawings.

6.2 Recommendations for improving the problem areas for Spenncon

The scope of this thesis has been fairly wide even if this thesis has looked at one specific problem, that is, the discrepancies encountered during the assembly process under shell based construction projects. The reason for this wideness is that the discrepancies encountered in the assembly process could have their origin in most of the upstream processes that are undertaken in order to deliver the elements to the downstream assembly process. The outcome from this were that the thesis had to cover a wide area in order to look into all the possible problem areas that could be encountered in relation to the assembly process thus creating the need for understanding and describing a wide range of activities in Spenncon's value chain. This lead to that a wide theoretical framework were produced in order to try and cover all the activities that are undertaken to make and deliver the elements to the assembly processes. To come up with specific recommendations for how to improve a small part of the activities is therefore difficult. The reasons for describing most of the processes in Spenncon's value chain were that the problem areas were not known in advance. This means that the problems that Spenncon encounters in the assembly process at the building sites were not known before the data analysis were done. In addition the problem areas that was found in this research i.e. production process has not been studied by the author in great detail and the process of making the production drawings have not been studied at all. This makes this process of coming up with specific recommendations even more difficult. However, despite of this the discrepancies encountered at the building site are generating waste so lean should have a good tool set available to reduce the discrepancies that are encountered at the building sites.

The author believes that asking the workers at Spenncon for suggestion on how to reduce the discrepancies from these two activities would have been the best option to find solutions to these problems. This is due to the fact that the workers have the best knowledge about these two activities, and the fact that the involvement of workers is an essential part of lean both in relation to lean construction and lean production. However, the author does not have the possibility of doing so in relation to this thesis, since the timeframe will not allow for the involvement of the workers at this stage. At the moment there is also currently a lean project going on at the factory at Hønefoss. As a result the workers at the factory should have a potential for coming up with good suggestions on how to improve these activities since the workers already seem to have a good knowledge and understanding about lean. This makes the problem regarding the time frame even more disappointing. The outcome of this is that the author has to come up with these suggestions himself. This does nonetheless mean that Spenncon can produce their own suggestions in addition to those made by the author. This means that Spenncon has an extra unexploited potential for improving these processes after the research in thesis has been finished. It also means that one have a potential future topic for a master thesis next year i.e. seeking to improve the production processes and drawing processes so that these activities can be done correct the first time to avoid rework at the building sites. In addition this means that the workers can come up with good suggestions of how the proposed recommendations by the author can be implemented. This was the author's thoughts behind the recommendations that are about to be presented.

It is now time to present the suggestions for improving the problems uncovered by the research. It is also time to say something about how these suggestions can be implemented by Spenncon. Said in other words it is time to answer the 3rd and 4th research questions made in relation to this thesis. This will be done by stating the proposed solutions and subsequently making a suggestion how the specific solution can be implemented by Spenncon. In relation to these suggestions both theory presented earlier have been utilized in addition to additional theory. First the solutions based on the previous chapters are presented then solutions based on new theory are presented. As said earlier a wide theoretical framework was presented in relation to this thesis in order to cover all the operations done by Spenncon in their value chain. In addition the problem areas were not known in advance. As the problem areas now are uncovered, it will be natural to present some additional theory in order to be able to give more specific recommendations to the uncovered problem areas.

If one look at the lean theory presented earlier, two lean tools stands out as possible measures to reduce the problems in relation to the production process and the process of making the production drawings. The two tools that stands out from the theoretical chapters in order to reduce the problems encountered is the 5 whys analysis and quality assurance. Both of these tools were mentioned in chapter 4.2 Lean production, lean manufacturing and "lean". The 5 whys analysis were described in detail while quality assurance were just mentioned. As a result the 5 whys analysis is not presented again in great detail but the quality assurance point will be presented more thoroughly. Please look back at chapter 4.2 for further descriptions about the 5 whys analysis if anything is unclear during the descriptions about this tool.

- The theory behind the 5 whys analysis argues that it is impossible to foresee the problem that occurs during the production process before the problem actually occurs. In addition the workers normally blame each other for the mistakes that are done during the production process. This means that it may be difficult to find the problems and get to the root cause of the problems that are encountered. As a result the 5 whys analysis argues that best way to stop these problems from occurring is to oversee the production to observe what the problems actually are. When the problems are spotted, one should ask 5 why questions in order to get to the root cause of the observed problem. When the root cause is found by asking these 5 why questions, corrective actions have to be taken in order to eliminate the root cause of the problem and stop this problem from occurring again. This 5 why analysis can be implemented by Spenncon through having a person or persons with knowledge about the production process and/or production drawing process overlooking the activities related to these processes and find the mistakes that occurs. This person or persons could then locate the problems and use the 5 why analysis in order to get to the root cause of these problems. When the root cause is found, this person or persons can find a solution to the problem and elevate the problem from the system and stop this problem form occurring again. The workers should also be involved in this process since they can contribute to solving the problem. However, as the theory behind the 5 whys analysis points out workers do normally blame each other for the mistakes that are done. As a result the author believes that someone should overlook the processes so that the real problems can be pointed out. As a result the workers can be involved in fixing the problems but not in spotting the problems. However, the person or persons pointing out the problems must possess a wide knowledge about the operations but not participate in the production process itself. This has to be done to avoid a conflict of interest. The 5 whys analysis does then have to be used over and over again until most of the problems if not all of the problems are removed. Suggesting something about how many problems that have to be removed is difficult to say at this stage, but it have to be done until the bulk of the problems are removed from both processes. Saying something about how this can be done more specifically is difficult but it is seems clear that this tool definitely can be utilized by Spenncon in order to locate the problems and remove them from the production process and making of the production drawings. Some would probably argue that the making of the production drawings is not a production process, but the author believes that this is a process of producing drawings and as a result it is a process that produces something i.e. a production process.

- Quality assurance (QA). Quality assurance in japan is according to Monden (2012) defined as : “*The development, design, manufacture and service of products that will satisfy the customer’s needs at the lowest possible costs”* (Monden 2012, p. 219). In relation to the problems encountered for Spenncon in this thesis the term quality assurance could be done more specific. One can say that Spenncon should ensure that each process only supplies the subsequent process with products or services according to specifications set i.e. that different department’s only deliver products or services to the downstream departments without defects (Monden 2012). This specification can be done since the main problem found in relation to this thesis is that the design processes is not serving the production process with the correct information, that the production process is not serving the assembly process with a product according to specifications or a combination of both. As a result efforts should be made in assuring that the different departments only are serving the next department with correct services, products and information. Suggestions on how to improve the problem processes through lean tools are presented in the next suggestions from improvements. As a result tools on how to improve these specific processes are not presented under this quality assurance point. However, these lean tools are only saying how to improve the specific processes and nothing about uncovering problems that were uncovered in relation to this thesis. As a result this quality assurance point is instead presenting a management tool that can address quality issues and uncover these specific problems that were uncovered in relation to Spenncon in this thesis. However, before doing so some theoretical background for saying why one should implement this management tool is presented.

Monden (2012) argues that in order to assure product quality all departments must be involved. In relation to Spenncon this means that one should involve all the departments from the initial stages i.e. product planning stages and product design stages until the last stage i.e. the assembly stage. This has to be done so that the problems that may occur from the initial state of the products to the finished state of the products can be eliminated. One example that illustrates this problem is that it would be impossible to correct mistakes that are done in the planning or design stages when the product enters the manufacturing stages. In addition each department are also responsible for assuring that their specific area of responsibility is delivering the right quality to the next department e.g. if the planning and design departments is doing everything correctly and the production department is not producing the products correctly the outcome will still be of substandard to the assembly processes. As a result it is important that all processes are producing products that are according to the requirements. This means that one must have quality related functions and quality control activities in all departments. One way to uncover the problems between the departments is to have cross functional management. This means that one will have regular meetings that aims to address the problems that are encountered in companywide perspective i.e. problems encountered between the different departments such as planning, production, assembly etc. So that problems that spans out over the different departments can be addressed such as the problems uncovered in relation to this thesis (Monden 2012).

These cross functional meetings can be implemented by Spenncon trough having regular meetings between key employees. These key employees that normally are involved in cross functional management meetings are typically department managers from all of the different departments. The goal of having these meetings is to resolve the problems between the departments (companywide problems) and the participants are supposed to make suggestions on how these problems can be solved. The participants should also have the power to implement the solution to these companywide problems. In addition they should be given the responsibility to implement these solutions in their respective department (Monden 2012). Spenncon should have regular meetings between all the managers in the different departments. The goal of having these meetings should be to reduce the different problems that arise between the different departments such as production not delivering products to specifications to the assembly process. These meetings can then make the different departments aware of the different problems that are encountered between the different departments i.e. companywide problems. They can also address the problems that are occurring between the different departments so the problems can be solved. They can also work together to improve the problem areas by making suggestions on how to reduce and stop these problems from occur in the future. However, these meetings can probably not solve all the problems within the different departments. As a result the different department leaders may have to go back to their department and find solutions to the different problems that are occurring within their respective department. Then they can stop the respective uncovered problem from occurring. However, being specific about how to solve these problems would be difficult but as said many times before, the workers within the different departments will probably be able to come up with good suggestions on how to improve these specific problems that are found. This cross functional management will be a useful tool to both discover and solve problems for Spenncon. The meetings themselves may not solve all the problems but it can make clear what the problem is. When the problems are found the workers within that department can solve the specific problems that have been uncovered.

This was the solutions that were based on the theory review that have been done in relation to this thesis. In addition there are other possible solutions found in other lean tools. These other tools are now presented. These tools have been specifically added by the author after the data analysis was done so that the specific solutions to the problem areas uncovered could be made.

- Poka-yoke. Poka-yoke is the Japanese word for mistake proofing. The idea behind poka-yoke is to remove the problem that causes the mistakes. If it turns out that is impossible to remove the problem behind the mistakes the idea is that one shall have an inexpensive and simple inspection of each unit that is produced to assure that each unit is produced correctly. This means that poka-yoke is a tool that prevent mistakes or defects from happening in the first place. If it is not possible to prevent the mistake from occurring poka-yoke aims to make the defects or mistakes to stand out at the first glance. However, the ultimate goal of poka-yoke is to make sure that problems cannot occur. The inspection activities are just there to serve as a backdrop if it is not possible to design the processes in such a way that problems cannot occur (Fisher 1999). One should design the processes in such a way that it should be impossible to make mistakes. Saying how this can be implemented at Spenncon is difficult without the detailed knowledge about the production processes or the making of the production drawings. However, if one can prevent mistakes from being done in the first place or make the mistakes stand out immediately this will undoubtedly reduce the discrepancies encountered at the building sites. Maybe there are possibilities to for example make the cutting process of the elements in such a way that it is impossible to cut the elements at the wrong place and at a wrong angle. It may also be possible to make sure that drawings are made correctly before they are passed on to the production process e.g. through the use of 3D data modeling so that one can see if designed elements actually are made correctly. In addition it would also be advantageous to spot the mistakes as soon as possible after they are made. This is done so that it would be as easy as possible to correct mistakes if mistakes first happen. Maybe it would be possible to make a simple and easy inspection after each process is finished. In addition most of the elements have some idle time before they reach the building site and this idle time would be the best time to correct the mistakes that have occurred during the upstream processes. The same does probably also go for the production drawings as they also would have some idle time before they are used by production. If this idle time is used effectively this will allow the downstream processes to be carried out as effective as possible. So it would be advantageous to have a system that spots the mistakes as early as possible. These mistakes should at least be spotted before the elements enter the rail track and before the production drawings enter the production process. It would of course be most effective to stop the mistakes before they happen, but if this is not possible the next best option will be to correct the mistakes before they reach the subsequent process. If Spenncon is able to make the processes after the poka-yoke principle, it would definitely have the potential to reduce the discrepancies encountered at the building sites and reduce the discrepancies that are encountered between the different departments.

- Stop the line principle. The stop the line principle is a principle based upon that one shall stop the production/production line if abnormalities occur. This is due to the fact that it will be more difficult to spot the mistakes after they have been made relative to when the mistake is made. It will also become more difficult to sport the mistakes that are done after further work is carried out on the product or products. Doing more work on a product that contains an error would also be increasingly wasteful since this will mean more rework or more expensive scrapping at a later stage. As a result lean have devised a technique that shall stop the production immediately if any abnormalities occur during the production process either through human intervention or through automatic procedures. The idea is to enhance quality so that only units that are conforming to the requirements are produced. This does also mean that one must locate and correct the reason behind the defects to occur in the first place. This has to be done so that the next products are not produced with the same defects as the defect that stopped the line. In addition this stoppage presents an opportunity to improve the processes so that the same mistakes are not done again at a later stage. This means that the process of making the product or products can be improved further (Monden 2012). Saying how this principle can be implemented by Spenncon is difficult since the author knows so little about the production process or the process of making the construction drawings. In addition the production processes are different since the hollow core elements are made through an automated process while the other products are made through a more manually production process. This indicates that an automatic intervention seems more relevant for the making of the hollow core elements while manual intervention seems more appropriate for the other products. However, the workers should be encouraged to stop the production if they are not sure if the products are made correctly or if they believe that the production drawings contain errors. Further the workers should investigate what the problem is and how this problem can be prevented from occurring again later. As a result stop the line principle can stop both faulty products and drawings from reaching the subsequent processes, and it can also prevent the same mistake from occurring again later. In addition the stop the line principle can prevent the creation of waste at the current stage and in the future.

6.3 Additional recommendations to Spenncon

Based on the theory presented earlier in this thesis some additional recommendations can be given. The theory behind lean argues that continual improvement is an important aspect of lean and this is also one of the common elements in the perceptions under the field of lean. As a result Spenncon should not only focus on improving the activities in making the production drawings and producing the different elements in the long term. The goal should be to improve all processes so that the entire value chain is performing as well as it possibly can. It will not be enough to just improve some parts of the value chain one has to have overall view in the improvement efforts in the long term. This does also include the activities done at the building sites. This means that Spenncon also should look at the activities at the building sites and the problem areas in relation to the activities at the building sites. Because just studying the internal operations in their own value chain will have the potential to create sub optimization in the internal processes and not improve the totality of all the operations done by Spenncon. This is due to the fact that Spenncon is participating in a construction environment and delivering and assembling elements in this environment. This means that if the construction environment that Spenncon operates in does not work in a good way, Spenncon will not be able to get the maximum out of their internal operations or a good function in their value chain. As a result the totality of all operations has to be remembered when improving Spenncon's operations in the future.

In the literature view the author argued for that one should also look for ways to enhance value not just remove waste. The problems uncovered in relation to this thesis did not allow for improvements in relation to value creation. It does however not mean that this view cannot be utilized by Spenncon in the long term and as a way to achieve continual improvement. One argument that was pointed out in relation to lean construction was that buildings had a long life span compared to products made in relation to lean production. As a result Spenncon can look for ways to improve value for the customers over the lifetime of the buildings. It will of course be very difficult to foresee the future, but it can probably be possible to make the elements in such a way that the value for the customers in the future can be produced today. So enhanced value creation is also one way to improve in the future and ensure continually improvement for Spenncon.

7. Conclusion

The goal set for this thesis was to uncover why deviations did occur at the building sites. However, the company in this research Spenncon argued for that the author should answer some additional questions. The researcher agreed to this suggestion believing that this would increase the benefit for the company and also give the researcher additional challenges. As a result of this 4 research questions were made. These research questions were as presented on page 22. As one can see from these questions, the entire value chain for Spenncon had to be studied and described. In addition the building project environment that Spenncon operates also had to be described. The theory that was used in relation to improve these two areas was two disciplines of lean namely lean construction and lean production. Both of these theories were presented since Spenncon is producing elements i.e. carrying out production and subsequently delivering and assembling these elements in the construction project environment. In order to cover these two areas of Spenncon's operations, both of the lean theories had to be presented. The reasons behind the deviations at the building sites were not known before the data analysis was done. One only knew that the problems had to come from somewhere in Spenncon's value chain or in the construction environment around these construction projects. As a result one had not the option to exclude one of the topics to make the thesis more concise. The encompassment of both theories did however give the researcher a broader insight into Lean and a larger tool set to improve the operations.

In order to answer the 4 research questions which were the foundation for the entire research in this thesis a data analysis was done on a data set containing 2 building projects. Some will probably argue and say that this research has utilized a too small data set. The author agrees partially to this argument since the author undoubtedly would have liked to have a larger data set containing at least 1 or 2 additional building projects. However, due to the time frame and the problems related to agreeing on a topic for this thesis, there were no possibilities to increase the data set even if the author wanted to. In addition there were some problems in obtaining the data material that was utilized in the data analysis. As a result considerable time evaporated from the research time in this thesis. The outcome from this was that one had to make the best out of the situation that unfolded and utilize what was at hand in the best possible way. As a result the data analysis was done based on the 2 projects i.e. the AKA project and the Miele project. The answers to the 4 research questions were made using the data analysis and the two lean theories presented in this thesis.

The outcome from the data analysis showed that most of the problems were due to what was called category 1 mistakes. This means that most of the mistakes were done somewhere in Spenncon's own value chain. The data material behind these types of mistakes was studied closer and most of these problems belonged to mistakes done in the production process, in the process of making the construction drawings or both. The author argued for that these processes should be done correctly the first time they are done so that less rework had to be done at the building sites. The author also tried to find theoretical evidence supporting his findings and supporting the removal of these problem areas for Spenncon. The author made 4 recommendations on how to improve these processes. The theory that was used to make these recommendations were lean production since the problems uncovered in relation to this thesis belonged to the process of producing the elements. These 4 recommendations consisted of one question asking technique (5 why's analysis), one management tool (cross functional management) and 2 specific lean tools on how to improve these processes (Poka-yoke and Stop the line principle). These 2 first recommendations are suggestions on how to uncover problems and how these tools could be used to reduce the problems found. The two last suggestions are specific tools that could be utilized to improve the processes that are seen as the problem area. However, the author did not have the detail knowledge about these operations so stating how these suggestions could be implemented was impossible, but some suggestions were made. Then the author also gave some additional suggestions for Spenncon in the future. The first recommendation was that Spenncon should look at all operations when trying to improve so that sub optimization could be avoided. The second additional recommendation was that Spenncon should try to improve value creation for their customers in the future and not only focus on removing waste from the system. This is due to the fact that lean is not only about removing waste, it is also about creating value for the customers.

This thesis has therefore reached the conclusion that the main problems for Spenncon in relation to the assembly operations were done somewhere in Spenncon's value chain. The main problem areas were the production of the elements, the making of the construction drawings or both. In relation to these problem areas there were made 4 recommendations to improve these processes. These were: 5 why's analysis, cross functional management, Poka-yoke and Stop the line principle. Saying how Spenncon can implement these tools is difficult, but some suggestions have been presented.

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Appendixes:

Appendix 1 day report AKA project:

Spenncon
A Consolis Company

DAGSRAPPORT ID:10767

			Byggedag nr.
Prosjekt AKA, Nytt Hovedkontor	Prosjekt nr. 600710	Ukedag MAN	Uke 46
Ansvarlig arbeidsleder Gunnar Hovland	Arbeidsplass	År 2011	mnd. / dag 11 14

Vær: Skyet

Temp.: +3

Utført arbeide:
Montert bjelker, lagd ned hulldekker som lå lagret på dekke over kjeller. Montert søyler, sikring. Understøp søyler

Arbeidsstyrke:
3 mann

Kranfører:
Montører: 2
Flikkere: 1
Andre:

Avvik/Hindringer:
Kranoppstillingsplass ikke ferdig.
Ventetid på elementbil.

Besøk/Besikting:

- Byggeleder ☐
- Byggherre ☐
- Arkitekt ☐
- Konsulent ☐
- Arbeidstilsyn ☐
- Saksbehandler Spenncon ☐
- Andre ☐

Ekstraarbeider/Regningsarbeider

Timer regningsarbeider:

- Kran
- Bil
- Mont.
- Betong

Byggherre underskrift

Appendix 2 day report Miele project:

Spenncon

DAGRAPPORT			Dato: 24/10 -11
Prosjekt: **Miele Hovedkontor** **Prosjektnummer:600673** **Navn: Odd Ivar Nygård.**			
UTFØRT ARBEID: Tatt ut høyder for søyler + montert 5 stk søyler. Sveiset vinkler.	**Bemanning**	**Stk**	
	Egne	3	
	Innleid		
	Sum		
	Overtid		
	50 %		
	100 %		
	Kran		
Avvik/Hindringer (Husk å spesifiser timer på kran også)	**Antall mann og timer**		
Tilleggs-/Regningsarbeider (skal også føres på egen regning)	**Timer**		
Sign Montasjelag	**Sign Montasjeleder**	**Avvik registrert og behandlet?**	