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Problem finding in installation process

Thesis

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ABSTRACT

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<p>The Thesis was done to a local Company that delivers steel-framed halls as a turnkey solution. The topic of the thesis is to examine the installation process of PVC-covered steel-frame halls. The target set for the thesis was to find ways to increase profitability and customer satisfaction through improving installation process.</p> <p>Quality theories are examined and their link to increased profitability and customer satisfaction explained. The tools used were chosen based on the quality theories. Tools used are included in total quality management and Six Sigma. The data was collected by brainstorming and then set into cause and effect diagram. The data was then linked to process description and analyzed using process failure mode and effect analysis.</p> <p>Outcome of the analysis is presented in a Pareto-diagram allowing a clear presentation of results. The result is a list of problems in a prioritized order. These problems correspond to the wanted outcome well, and the Company should plan and carry out corrective actions and then repeat the process failure mode analysis to see if the corrective actions worked.</p>		

Key words FMEA, quality, Six Sigma

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1 INTRODUCTION

Before the start of the thesis work the Company had had some talks with members from the Centria-research faculty about installation process needing to be more easily controlled and more predictable. Better predictability would help the Company in making better projections about the project's completion times, which at the moment was very hard. The problem for the Company was that different installation teams had large deviation in installation times. This suggested, that there is variance in working methods, and that some steps in the installation process take too much time. Working motivation might factor to this also. The Company has their own installation teams, but they also outsource installation to trusted partners.

When I came into contact with the Company about the problems they are facing, they mentioned the need improve customer satisfaction and productivity by reducing installation times and fluctuations in installation times between different installation teams. In the beginning of the thesis project there was talk about using value stream mapping to map the process. This was quickly discarded as it would be too cumbersome for thesis work and would require much larger dedication. This is still something the company should consider to further improve and streamline the whole process chain. Thesis work began with initial meeting with the company, where the needs of the company were discussed and the basis for the scope of the thesis was presented. As I was not at all familiar with the installation of the PVC-covered steel-framed halls, it was decided on the spot, that on Monday I would go to an ongoing installation site, to get some idea about the process. There I spent 2 days observing the workers.

After getting to know the process and seeing it first hand, the planning of the thesis work began. Finding problems in installation process was chosen as the objective of

the thesis. The methods for acquiring data were decided in meetings with my instructor Tapio Malinen. The installation teams had the data and the quickest way to access it would be to map, what in their opinion takes up their time. This makes it possible to analyze where the time tends to go. This data would be linked to the process chart and a fishbone-diagram created from the answers. These answers would then be analyzed using failure mode and effect analysis (FMEA). FMEA produces a list of failure modes that are rated according to their criticality, so that the company can focus on the most critical failure modes and work their way down the list.

In this thesis I will first present some basic information of the Company in question. Second section of the thesis focuses on the theories used in this thesis containing quality theories linked to Six Sigma and total quality management and also presents the theories behind the tools that are used. Next I will briefly go through the process descriptions to give idea about the installation. Following the process description, I go through the work done for this research and present how I used the methods mentioned in practice. Finally, conclusion contains my thoughts about the project and the results and the future for the Company.

2 The Company

The Company has been founded in 1975. The idea for the company came from three colleagues' idea to offer a better and more lasting option to overpressure halls. In 1978 the Company moved to Kälviä where it is operating to this day. Production began in two halls that had been made by the Company themselves. Exporting started from Soviet Union as was normal in the 70s. Slowly exporting expanded to Sweden and Norway and slowly to central Europe. During the 1990s exporting started to more serious and it was towards former eastern bloc countries as well as Central-Europe. Nordic countries also have an important role. Exporting has slowly shifted towards France and Austria. (Best-hall, 2016.)

The Company is the leading steel-framed, PVC-covered hall manufacturer. It has been in business for over forty years and takes pride in the quality of the product itself as well as delivery. Whole supply chain is based on ISO-9001 certified quality system and is physically located in Kälviä. The Company is the only Nordic company that can offer everything from sales, design and production to installation. The Company's object is to fulfill the customers' needs in such a way, that every project works as a positive reference, guaranteeing long-term profitable operating and strengthening current markets as well as creating new ones. (Best-hall, 2016.)

The Company is product development and quality leader in steel frame halls and full service supplier. Product is delivered as a turnkey solution, according to the customer specifications. Employing roughly 120 personnel at the moment. Delivery times for the hall is estimated to be about 8 to 12 weeks. All of the production of the parts is done at the Kälviä production facilities. The Company has delivered about 4000 halls to date. Currently the Company has plans to expand the Kälviä facilities and increase workforce. (Best-hall, 2016.)

3 QUALITY

Quality as a term takes our mind to a product with high quality meaning that the product fulfills or exceeds our expectations. The expectations are usually based on the price of the product and the use that it is bought for. (Besterfield 2004, 1.) So according to this information, quality depends on the customer or the intended buyer. This makes it very difficult to make a good quality product and at the same time keep the cost of the product reasonable. This makes quality a very hard thing to control in manufacturing, so a better definition is needed for measuring quality in manufacturing. ISO 9001: 2015 [ISO 9001: 2015, 2015] defines quality as the degree to which a set inherent characteristics fulfills requirements. In this definition degree means that it can be described by adjectives, such as poor, good and excellent. (Besterfield 2004, 2.)

Quality is the responsibility of every worker in a company. The responsibility of quality starts with marketing finding out the customer's quality requirements and it continues on until the customer receives the final product. (Besterfield 2004, 5.) This means that quality is always in some part tied to customers' expectations of the product. The goal is to satisfy and exceed the needs of the customer. Difficulty will always be in knowing customers' expectations. Finding information about customers' expectations is essential for developing the product to a direction where the customers will be more satisfied. A study by Quality in manufacturing stated that 83.6% of the respondent said that they mainly measure quality by customer satisfaction. (Besterfield 2004, 35.) This connects quality very strongly with customer satisfaction and means that the company needs to think about the customer's whole experience of the transaction rather than mostly the properties of the product.

Quality consists of nine different aspects that are somewhat independent meaning that product can excel in some aspects and do poorly in other (Besterfield 2004, 2). Dimensions of quality are:

1. Conformance: Meeting the specifications of the customer.
2. Performance: Primary product functions such as clarity of voice received in mobile phone, radio.
3. Features: Added functions to a product such as recording system in a television set.
4. Durability: Lifetime of the products, which include repairs.
5. Reliability: The probability of a product performing its intended duty under stated conditions without failure for a given period of time.
6. Service: Ease of repair.
7. Response: Human interface, such as courtesy of the service personnel while registering a complaint from customer and while repairing at the customer's site.
8. Reputation: Customer's perception about the product which can be understood from a market research survey.
9. Aesthetics: The external finish given to a product to attract the customer.

(Besterfield 2004, 3.)

The product doesn't have to be excellent in every dimension, but the dimensions must be measured to find about the customer preferences and concentrate on the dimensions that the customer most values (Besterfield 2004, 2).

3.1 Lean

The most basic idea behind lean production is creating more value for customers with fewer resources. Focusing key processes to continuously increase customer value is the aim for a lean organization. The ultimate goal is to provide perfect value for the customer through a perfect value creation process that has zero waste. (Lean Enterprise Institute, 2016.) This means that the company can have increased profit margins and still have lower end price for the customer. Having zero waste is of course an

almost impossible goal, but when you aim toward it, every action you take takes you closer to it. Lean is applied through the whole value chain, not just some key parts. Lean companies are able to respond to changing customer needs with high quality, low cost and very fast throughput times. (Lean Enterprise Institute, 2016.) There are different types of waste, and waste can be put into seven categories:

1. Overproduction
2. Waiting, time in queue
3. Transportation
4. Non-value-adding processes
5. Inventory
6. Motion
7. Cost of quality, scrap, rework inspection

(American society of Quality, Overview, 2016.)

3.2 Six Sigma

Six Sigma is about organizing development and managing increase in knowledge. (Karjalainen & Karjalainen 2002, 14). The point is to have control of the whole organization from top to bottom, so that the intended changes and developments are understood in the same way by everybody and carried out in the correct way intended. At the core of applying the intended changes is DMAIC (Define, Measure, Analyze, Improve and Control) which progresses from managements expected result, to change in the process, to making the expected result a reality. (Karjalainen & Karjalainen 2002, 14.) By using a process like DMAIC for improvement, the process will eventually be widely understood in the company and the results accomplished faster and still in a controlled manner.

Six Sigma aims to make the product or service almost perfect for the customer. This entails more than just thorough quality checking of the finished product. The aim is to manufacture the product so that there are 0 defects ever. This of course is impossible in practice, but the aim is what keeps the manufacturing process improving in the right direction. Even the name Six Sigma refers to this, as sigma in statistical mathematics means standard deviation. Standard deviation is the value by which the measurements differ from the average. By reducing the standard deviation, the process becomes more and more predictable and controlled and the number of defects decreases. (Karjalainen & Karjalainen 2002, 17-18.)

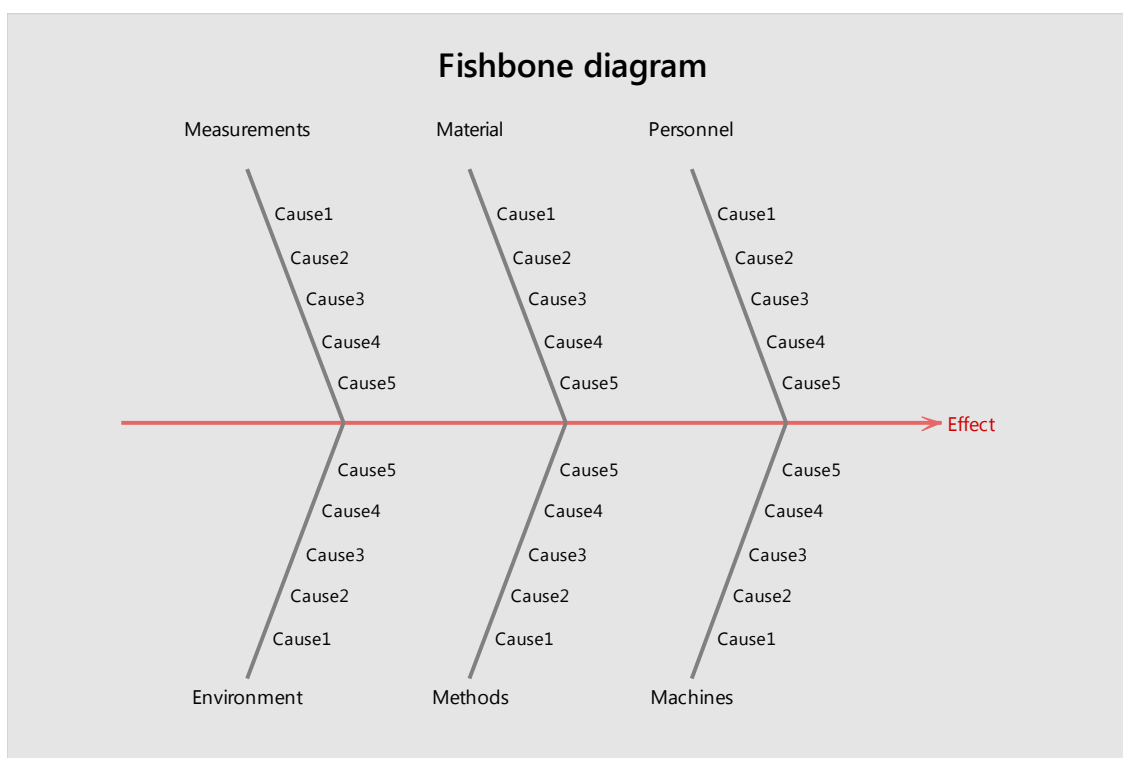
Six Sigma is not just a measure, but depending on the context can mean different things.

1. Six Sigma is a benchmark that can be used to compare the quality level of processes, services, products, features, equipment, machinery, departments or companies.
2. Six Sigma is performance (quality) target. Six sigma is very close to 0 defects meaning that there are 3.4 defects per million chance of defect.
3. Six Sigma is a new way to measure quality. Instead of using error rates or parts of million, we measure quality in sigmas or process capability index.
4. Six Sigma is a philosophy where the core message is continuous improvement in knowledge, quality and performance.
5. Six Sigma is statistics where a performance requirements are calculated for each critical feature in the product or service.
6. Six Sigma is a new strategy for sustainable development where corporate earnings are increased with less natural resources meaning better quality with less.
7. Six Sigma know-how based development strategy producing a new way of working on all organization levels. No more increased usage of resources for better quality, but an increased knowledge for whole organization. (Karjalainen & Karjalainen 2002, 18-24.)

3.3 Tools used in research

3.3.1 Cause and effect diagram

Cause & effect diagram is a graphical tool that identifies and organizes all possible causes that can influence output. Purpose is to identify, examine and give a more easily grasped presentation of the causes for the problem. (Karjalainen & Karjalainen 2002, 130.) Originally created by Kaoru Ishikawa in the 1960s, the cause- and effect diagram is also known as: Ishikawa-diagram, fishbone-diagram and root cause analysis. The diagram starts with the base problem on the right side in a box. From the box to the left starts the spine, which connects together the branches. Typically, four branches or categories are used. The branches are materials, machines, manpower(people) and methods. Sometimes a fifth category "environment" is used. The problems are collected through brainstorming and then set to join the corresponding category. This gives a clear graphical representation of the causes for the problem.



GRAPH 1. Generic cause and effect diagram made using Minitab 17

3.3.2 Process diagrams

Process diagrams or process flowcharts are used to get an idea about how a process is done. It is commonly used with process improvement as it allows pinpointing the targets for improvement making practical changes easier to plan. Process diagrams shows the order of operations within a process. There is no right way to make a flowchart as the most important thing is to give as much information as necessary for those who the diagram is made. The basic process of making a process flowchart, is to list first brainstorm the activities that take place within the process, then after all the activities are collected, start to put them in a sequential order. When everyone agrees, that the order is correct, add arrows pointing the direction where the process is moving. (American society of Quality, Process analysis tools, 2016.)

3.3.3 Pareto Diagram

Pareto analysis is a tool that is used when there are many different values and the object is to find the most significant ones. The analysis is constructed so, that the most significant factor is on left side and the bar continues with the second most significant factor to the right of that and so on. The graph is most useful when analyzing data that shows frequency, such as frequency of complaints for instance. (American society of Quality, Cause analysis tools, 2016.)

3.3.4 Failure mode and effect analysis (FMEA)

Failure mode and effect analysis is an analytical tool that uses the experience of people in finding possible failure modes in product, service, or process and helps in planning their removal. (Besterfield 2004, 91) FMEA is a central quality engineering tool in both product and process design. It is one of the relatively few pre-emptive quality tools. The purpose is to find problems in product or process in the design phase, so that it would be possible to remove possible failures before they happen. Product of FMEA is a list of failure modes in a prioritized order. By starting improvement from the first and working down the list, quality can be improved effectively and cost efficiently. The effects are most beneficial when the FMEA is done as early as possible in the design or the process. (Karjalainen & Karjalainen 2002, 168.)

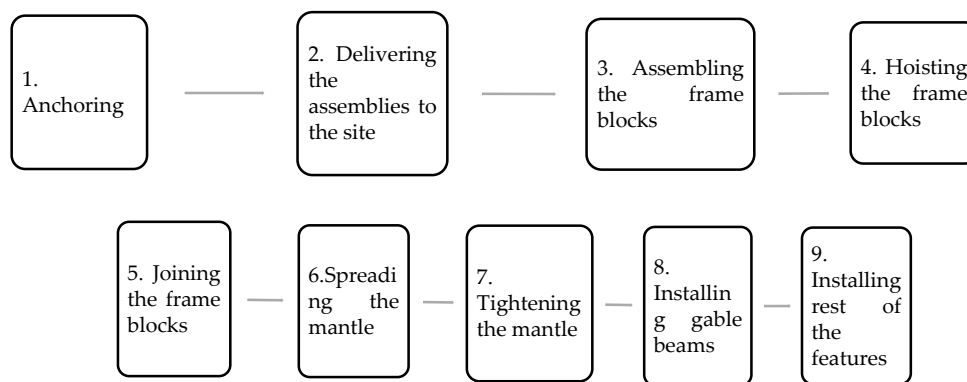
Benefits for FMEA are to improve quality, product safety and reliability. Quality, reliability and product safety are crucial aspects of a product or process, and they are almost certainly affected the most. A successful FMEA will also help in improving customer satisfaction levels and reduce the time it takes to develop a product. When the design is done well and FMEA has been utilized, the process will produce less scrap, and the product will need less rework and repairs. One crucial benefit is that the completed procedures will be well documented. This is one thing that is often lacking when improvements are made. (Karjalainen & Karjalainen 2002, 168-169.)

FMEA lists all the possible causes for failure. From this list it is possible to form a control plan. In this control plan the possible procedures be in a prioritized order, ready for the team to execute. One thing to remember is that FMEA must be updated and reviewed each time the process is changed or varied. Usually FMEA is done in the measuring phase, and it will be continued in the analysis and control phases of the DMAIC. This way it is made sure that the criteria is based on the actual current data, and will reflect the current situation. The three criteria that the analysis is based on are:

severity, probability and detection. These criteria will produce the risk priority number(RPN) which is the basis for prioritizing.

4 INSTALLATION PROCESS DESCRIPTION

Installation process takes weeks to complete. To have a better understanding of the structure of the process it needs to be broken into sections. This will also later help in linking the analysis to a correct phase. The installation process is divided into nine different sections as follows:



GRAPH 2. High-level process flowchart of installation process

4.1 Marking the anchor-lines

At the site, the first phase is marking the anchor-lines to the foundation. There are two basic types of foundation: asphalt and concrete. There is difference in marking the anchor-lines to the foundation between the two types. On asphalt foundation the customers mark the corner-points of the hall to the asphalt. Primary line is formed by nailing two anchors to the either end of the anchoring lines and then measuring the places of the anchors and marking them. For the concrete foundation, the anchors are usually installed during the casting of the concrete. Other options are either install

foundation bolts during the casting to attach the anchors to them, or chemically attach the anchors to the concrete. The anchors in either case have a tolerance of ± 30 mm. (BESTHALL PROCEDURE 2012, 4-5.)

4.2 Anchoring

The anchoring is done by using line wire to measure the position for the anchor. The outlines of the anchors are marked to the asphalt according to the distances of the departments. After careful measuring, the anchors are nailed to the asphalt. For concrete foundation, the process is the same, except that holes need to be drilled to the concrete before nailing. (BESTHALL PROCEDURE 2012, 6-7.)

4.3 Selection of the forklift and access platform

Marking the anchor-lines and the anchoring is basically outsourced so that when the installation team first come to the site, anchoring has been done and at least most of the parts required for the frame are delivered. Best-Hall will do quality checks so that the anchoring is done according to the quality standards. Also the working environment is checked by Best-Hall and the forklift and access platforms are leased according to the needs of the site. For instance, if the distances are great and the terrain soft, a forklift is not suitable and telescopic handlers or front-loader would be better suited for the environment. The amount of access platforms depends on the amount of workers. Basically there are two categories: 2-3 workers or 4-5 workers. If there are 2-3 workers, only one self-propelled boom is leased and one scissor lift. If there are 4-5 workers two self-propelled booms and one to two scissor lifts are leased. (BESTHALL PROCEDURE 2012, 8.)

4.4 Frame assembly

Frame assembly begins with preparations. The amount of working space dictates how the assembly and later the erection of the frame will be done. In a normal situation the frame is assembled on top of the foundations and there is enough room for the walls to be spread out over the foundations and there is enough room for the hoisting equipment. The size of the frame blocks must be decided beforehand and at the work site decide the best direction to start the assembly so that the parts are easiest to deliver. Hoisting plan states the size of the frame blocks and the hoisting spots. Typically, the roles for the installation team during frame assembly are as follows: one person is operating the forklift or telescopic handler. He is usually the most experienced, he sorts the elements. One or two people does the assembly of the frame. One person adjusts the frame and fastens the joints. (BESTHALL PROCEDURE 2012, 9.)

The actual assembly begins, as stated above, from one end of the building. The ridge element is the first piece that will be erected. The first element must be temporarily supported so that it will stay upright. The second element is joined to the first element by first installing ridge pipe, then buckling crossarms, purlins and lastly any possible additional binding pipes. The joints between pipes and beams connecting the ridge elements must be tightened as soon as a packet of three elements has been assembled or at the latest before installation of roof elements. To ensure that the distance between the departments stay correct during the fastening a so-called installation plank is used. The order for the tightening is as follows: first the buckling beams, then roof beams and lastly binding pipes. (BESTHALL PROCEDURE 2012, 9-10)

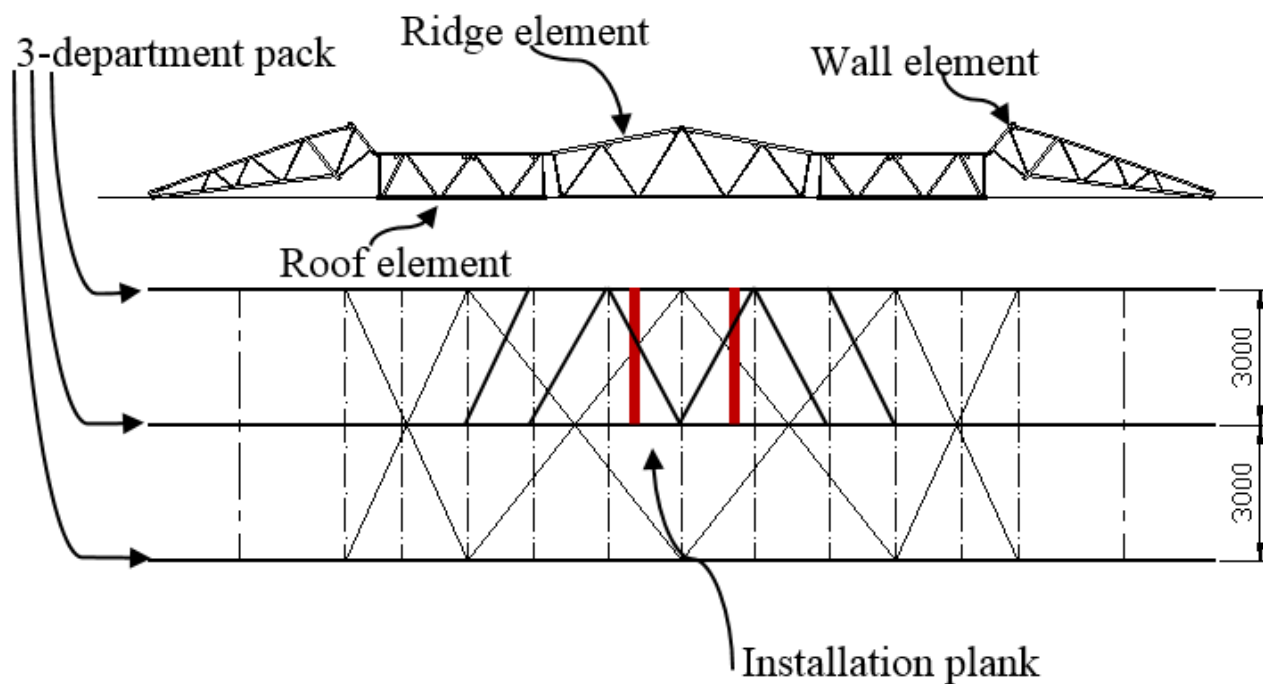


FIGURE 1. Side and aerial profile of a 3-department pack (adapted from BEST-HALL PROCEDURE 2012, 11)

Usually one element type at a time is installed completely before moving to the next type, as it is logistically most beneficial. It is also common to assemble one pack at a time. The installation of roof elements is done practically in the same way as the above described ridge element assembly. Lastly wind bindings are installed and preparations for hoisting are done. (BESTHALL PROCEDURE 2012, 11.)

4.5 Hoisting the frame

After the planning phase in the beginning of the project a hoisting plan is made based on the information at hand. The information may not be accurate in the beginning, and plan may need to be updated as the project moves along. Most likely the space available at the site does not match the hoisting plan, and the methods must be updated

accordingly. Large work sites should be visited before making the hoisting plan to make the original plan much more applicable (BESTHALL PROCEDURE 2012, 13.)

4.5.1 Hoisting techniques

Frame with ridge element:

Hoisting with one crane

Hoisting with one crane is the most common way to host the frame when the span of the hall is less than 35m, but also for larger halls if there is not enough room for two cranes. (BESTHALL PROCEDURE 2012, 13).

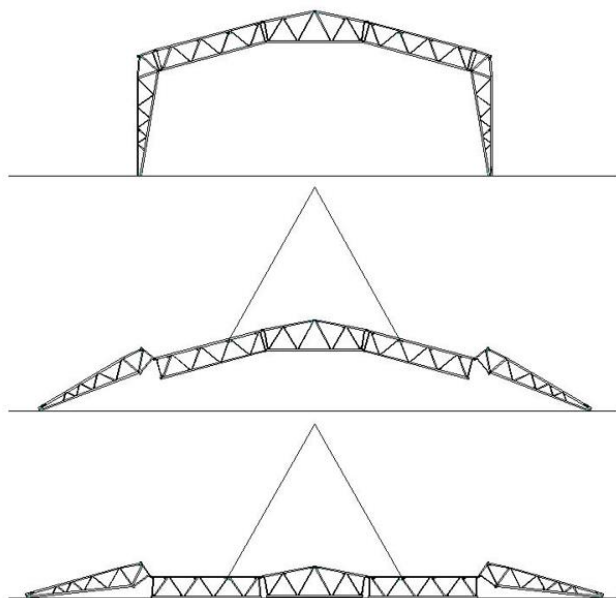


FIGURE 2. Hoisting a frame with ridge element with one crane (BESTHALL PROCEDURE 2012, 13)

Hoisting with two cranes

Hoisting the frame with two cranes should be done when the span of the hall is over 35m and there is enough room on both sides of the hall. Smaller frames can also be hoisted using two cranes if the frame is exceptionally heavy or a large enough crane is not available in the region. Also the lifting of the mantle will be easier with two cranes. (BESTHALL PROCEDURE 2012, 14.)

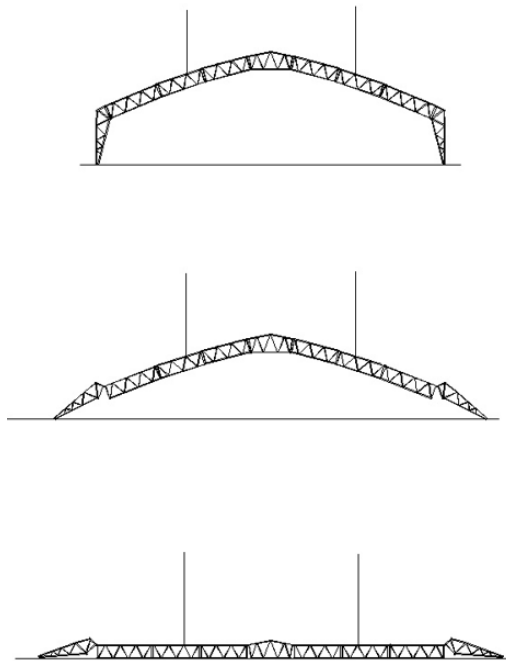


FIGURE 3. Hoisting a frame with ridge element with two cranes (BESTHALL PROCEDURE 2012, 14)

Frame without ridge element:

Hoisting with one crane

The first roof elements are assembled laying down and then set upright by forklift. Rest of the roof elements towards the wall, will only be joined from the joint and only during hoisting will be fastened from underside. This technique is very rare and almost only used when the building location is in hinterlands and no cranes are available making the transfer costs unreasonably high. (BESTHALL PROCEDURE 2012, 15.)

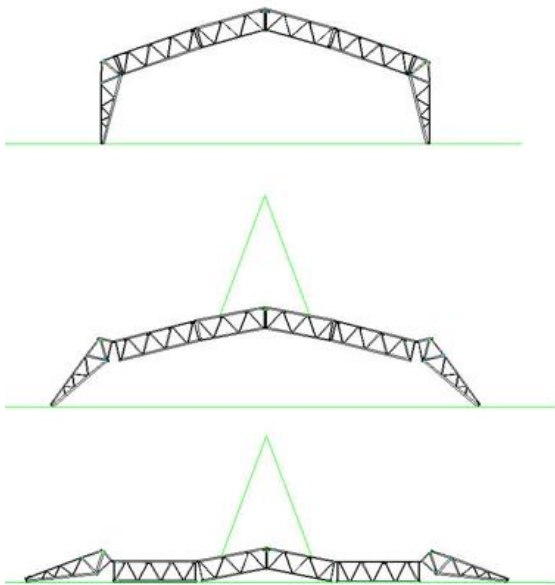


FIGURE 4. Hoisting a frame without ridge element with one crane (BESTHALL PROCEDURE 2012, 15)

Hoisting with two cranes

Frame is assembled with the roof elements in an upright position. The joint at the ridge is left open and the halves of the frame are attached to each other at the end of the hoisting. The goal during the planning of halls with span under 50m is to have ridge element, so that the installation will be easier. Special halls with span of over 50m there is no ridge element. (BESTHALL PROCEDURE 2012, 16.)

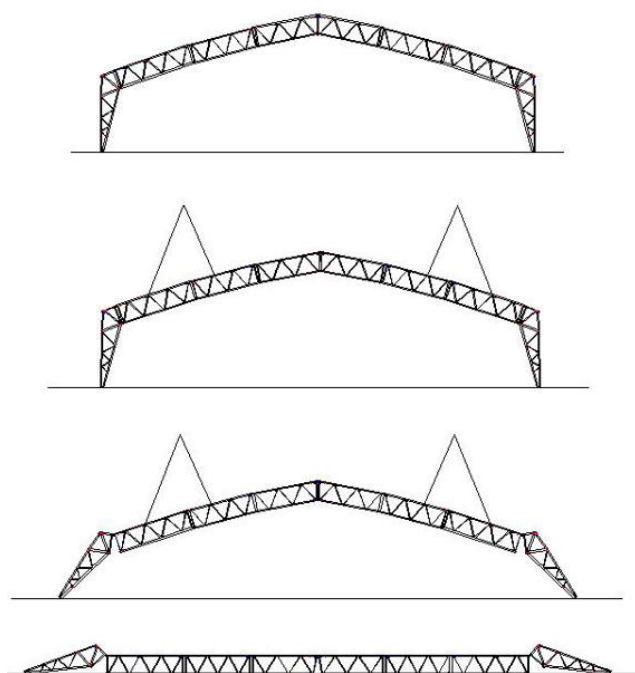


FIGURE 5. Hoisting a frame without ridge element with two cranes (BESTHALL PROCEDURE 2012, 16)

4.6 Joining the frame blocks

4.6.1 Preparation

During the hoisting the frame blocks are joined to each other. This phase must be taken into consideration during the frame assembly, so that the frames can be interlocked

correctly meaning that the frames have the necessary beams on the side where the frame next to it only has the slot for attachment. (BESTHALL PROCEDURE 2012, 21.)

4.6.2 Joining the frame blocks

While the frame has been lowered into its place, but the crane is still attached to the frame, the larger beams are set onto their place from corners to the ridge. Smaller beams can be bent by hand to fit their place. (BESTHALL PROCEDURE 2012, 21.)

4.6.3 Tightening the wind bindings

While tightening the bindings on the wall, it must be made sure that the end walls of the hall remain straight. This can be done by cross-measuring or by spirit level. The tightness of the bindings on the roof portion is achieved by measuring the average distance from the nut and reducing 15-20mm, which results in the target figure. (BESTHALL PROCEDURE 2012, 21.)

4.6.4 Installing the binding pipes

Binding pipes are only installed between the frames which belong to the same hoisting bundle, meaning that after the hoisting no more binding pipes are installed if not otherwise instructed. (BESTHALL PROCEDURE 2012, 21.)

4.6.5 Additional bindings

Any additional bindings are installed after the tightening of the wind bindings. All bindings mentioned in the installation plans must be installed on both ends of the buckling beam lines. (BESTHALL PROCEDURE 2012, 21.)

4.6.6 Installing the gable columns

Gable columns are installed by using a crane or, in small halls, a passenger hoist. The columns are set into upright position by using a pulley and a rope and then attached onto the truss from its upper head, the lower part is pushed into the ground and straightened to the alignment wire set between reinforcement pipes. Gable buckling crossarms are also installed during the column installation. Door columns are installed in the same manner. If the doorway has an upward acting door, special care must be paid to check the width, height and cross dimension of the doorway during the installation. (BESTHALL PROCEDURE 2012, 22.)

4.7 Spreading the mantle

4.7.1 Preparation

Spreading the mantle is the most critical phase of the installation and its importance cannot be overstated. Tools and equipment must be checked and serviced if necessary, machinery must have enough fuel. The assembly crew should also refresh their energy, so that they can work for a longer period without a break if necessary. Largest

single risk factor in spreading the fabric is the wind strength. The leader of the installation team has the responsibility to observe weather forecasts and he makes the ultimate decision to begin the work. (BESTHALL PROCEDURE 2012, 26.)

4.7.2 Spreading the mantle

When the weather forecast shows favorable weather and the preparations have been finished, spreading the mantle starts with attaching one traction bed to the frame and another to the forklift and by opening the mantle package. The package is opened by first pulling it about half way to over to the other side, and the switching sides to keep it in balance. The pulling is done using forklift. Immediately after the mantle has been spread all the way to the down the walls, all the pipes must be installed into their pockets, so that the mantle can be initially tightened. After the initial tightening and attaching all the pipes and fasteners and mantle is symmetrically on its place, the final cross-tightening can be done. (BESTHALL PROCEDURE 2012, 26.)

4.8 Hoisting the fabric to the end of the hall

4.8.1 Preparation

The fabrics are set on protective wrapping under the end. The fabric is marked from both ends as either red or blue, and are marked on drawings accordingly. This is the method to mark how the fabric is installed. (BESTHALL PROCEDURE 2012, 29.)

4.8.2 Installation

First, the lower end of the fabric is attached to the frame by pipes. After this the pipes for tightening are slipped into their pockets on the top part of the end fabric of the hall. Depending on the width of the hall 2-8 traction beds are attached to the top pipe and hoisted over the top boom. The lifting is done by pulling on the traction beds with a forklift. The fabric is finally tightened first vertically, and then horizontally. It is important to vertically tighten the fabric close to the eaves, so that the color difference is at the right height. (BESTHALL PROCEDURE 2012, 29.)

4.9 Installing inner fabric

4.9.1 Preparation

The inner fabric is delivered covered in plastic wrapping and tied onto a pallet. The ends of the fabric are again marked as either red or blue and one end is tied to the end pole of the hall, while the other one is attached to a forklift and carefully pulled straight on the ground. The package is opened so that the plastic wrapping stays under the fabric. (BESTHALL PROCEDURE 2012, 37.)

4.9.2 Installing the fabric

Pipes are pushed as far as possible from both ends to the pocket on the middle of the fabric. Rest of the pipes are pushed in through the cuts on the sides of the pocket. The pipes are pulled up by using a forklift and a pulley. After the middle line has been attached to the roof, the situation should look like the picture below:

(BESTHALL PROCEDURE 2012, 37.)



FIGURE 6. Installing inner fabric (BESTHALL PROCEDURE 2012, 38)

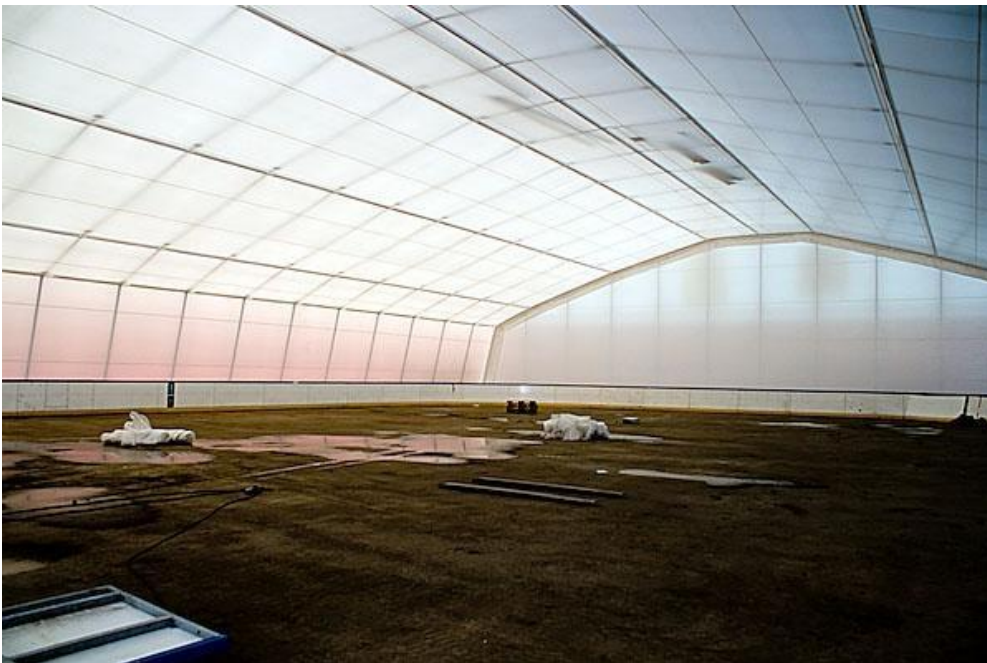


FIGURE 7. Installed inner fabric (BESTHALL PROCEDURE 2012, 39)

5 IMPLEMENTATION OF RESEARCH WORK

5.1 Visit to worksite

Thesis work started with a kick-off meeting on 5.2.2016 where the thesis' goal was set and some practical things agreed on. It was agreed that I would visit a work site in Teuva to get acquainted with the installation process. Next week after the meeting I went to visit a work site in Teuva. A customer had ordered hall to be used as production hall. This was a very good project to get acquainted with, because the hall was very large and was much heavier than Best-halls usual halls. Because of the size, the hall requires a lot more steel frames to support the weight. Also additional doors mean that the dimensions for the hall are: length 99.35m, width 50.00m ceiling 20.00m. One difference to their standard halls was that the walls of the hall were inside out compared to how they usually are. This is because normally the walls outside are vertically straight, and inside they are vertically a bit inclined so that the wall is thicker just under the roof and thinner at the base of the wall. In this case the outside walls were inclined and the inside walls were straight so that the customer could install their insulation inside the hall.

When I arrived to the work site, the workers had already started the assembly of the frame. What struck me the most was the amount of steel frame they needed to use. The customer had one building with manufacturing and the new hall was being built right next to it. This made it a bit harder to store the parts of the frame and to move around the site. The installation team had 3 members assembling the frame. One was operating the forklift and bringing the parts necessary to the other two, who did the assembly. Forklift operator had to use the forklift to set the frame parts so that the two could attach them as the parts are too heavy to lift without help.

The second time I went to visit the site at Teuva was about three weeks later, when the frame had been assembled on the ground and the hoisting was the next phase. The hoisting did not start in the best way possible, as one of the two cranes had too low hoisting capacity and a third one had to be called to come to help. As the cranes were hoisting one from each side, it was not taken into account that the wall containing the doorways would be heavier as the doorways required strengthening structures around them. The hoisting was delayed for about four hours because of this. When the third and smallest crane arrived, it was set up to help the side where the doorways were, so that two cranes were hoisting from one side and one from the other side.

When the frame was hoisted up, the wall was mounted onto its anchor in the concrete. It is very delicate work, as the crane still has to hold the weight and very gently lower it so that the workers can attach the wall on the anchor. When that is done, and the crane can safely be unattached from the frame, one worker starts to attach the buckling crossarms on the roof. Other three workers start to prepare the next piece of frame for hoisting. The process for the second frame and each after that is the same as for the first one, except that the frame must be attached to the previous with large braces along the height of the walls and width of the roof so that the blocks are attached. Rest of the braces are attached later, and can be bent by hand to fit. The hoisting continues in the same way block by block until the whole frame is erected. After the frame is erected and everything properly tightened, it is ready for the mantle.

5.2 Planning the research

After my two visits to work site to get acquainted with the installation process, I started planning the work with the help of my instructor Tapio Malinen. In the kick-off meeting with Best-hall we had talked about the need to improve customer satisfaction and productivity. Together with Tapio we made a plan to carry out the research. Basis was

that to improve customer satisfaction, I will focus on improving delivery time, as that was also one aspect mentioned by Best-hall. The task would be to get the data from the installation workers and with that data, create cause and effect diagram, which then would be used to perform failure mode and effect analysis.

5.3 Cause and effect analysis

To get the data for the cause and effect analysis I would have to get data from as many installation workers as possible. To use the cause and effect diagram, the effect is listed on the right side of the diagram, and then usually the causes are collected by brainstorming. In brainstorming the goal is to get as many causes as possible. Tapio had instructed me, that best way to carry out the brainstorming would be to get around ten installation workers to answer the question “where does your time go?” and collect the answers on post-it notes. I was in contact with Hanna Pakkala from Best-hall about the possibility of meeting installation workers as most of the workers only work at installation sites and a chance came up, when Best-hall organizes training for installation workers at the Kälviä facilities.

On the training day, the schedule was tightly packed but I got to collect my answers right after the meeting was opened. There were roughly ten installation workers and a couple of their supervisors. I introduced the purpose to the audience, and asked them to answer the question “where does your time go?” and put the answers on a post-it note one answer per note, so that I can later organize the diagram more easily. The brainstorming was a success and I received 62 separate answers. The next phase was to plan the categories for the diagram according to the answers. I ended up with 4 categories: materials, methods, machines and people. Out of the four categories methods proved to have the most and machines the least causes. After the initial 62 answers, the answers were sorted so that there is only one of each answer as there were few common answers. After sorting I still had 41 different answers which I then used to

form the fishbone diagram, by setting them under the corresponding category. This gave me a useful graphical representation of the causes leading to used time. Finally, I took a photograph of the fishbone diagram. The diagram can be found as the APPENDIX 2

5.4 Process failure mode and effect analysis

I wrote up the answers from the cause and effect diagram to an excel sheet so that I could manage them more easily. I now had the basis for the analysis, and the next step would be to evaluate each of the failure modes based on the three variables: severity, occurrence and detection. I planned to set the scale for each of the variables from 1 to 10. What became problem was that there is no data available for me to base the scale on. Also the failure modes were from many different fields, so no one set of data would set a good base. I decided that the best approach would be to get opinions from experts in the installation process. I managed to get a meeting where there were 3 experts on the installation process, and me instructing on the scale for the variables. The severity variable was loosely based on the cost of said failure mode happening, and the evaluation was carried out one failure mode at a time, comparing them all the time to similar previous failure modes. First every failure mode was evaluated in severity on a scale of one to ten. Next each of the 41 failure modes were evaluated based on the probability. In this case, the expert opinions and long history with installation helped very much as there are not much records of the failure modes, as many of them are fixed on the spot. Lastly, the failure modes were evaluated based on the chance of detecting said failure modes. Again expert opinions weighted heavily in this category. After the meeting I put the variables into the excel sheet and calculated the risk priority number(RPN). The document is available as APPENDIX 1.

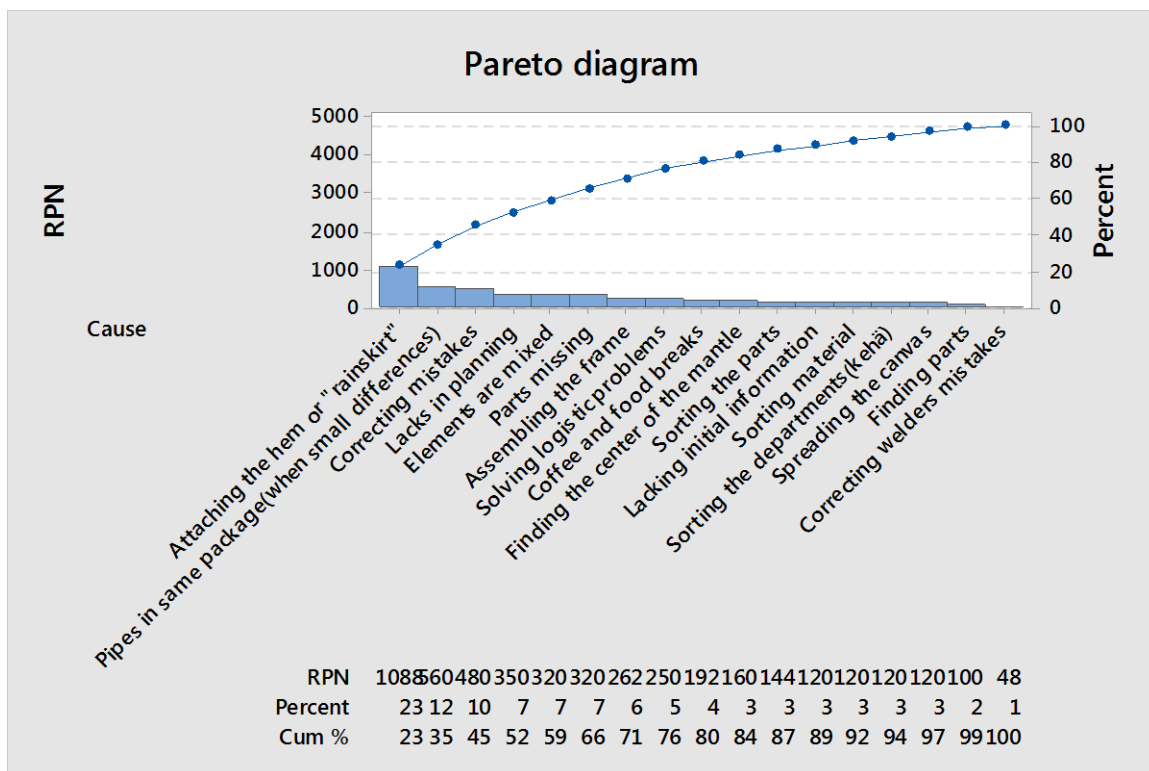
5.5 About the results of FMEA

The result as mentioned is a list of the cause with their risk priority numbers showing. As the name dictates, it shows the priority for the effect. Each effect derives from a cause and the next phase is to find corrective actions in order of priority to the effects. The cause is no longer of concern, as it is only used to find the effect that needs elimination. The results were not in any way unexpected, and many of the causes were well known before the start of the project. Hopefully, this concrete list gives the company a reason to take corrective action to at least the most prioritized ones. Most of the effects had so low RPN that they don't need any actions taken. Two of the effects had clearly higher RPN than the rest and should definitely be corrected as soon as possible. Following the two there are six more effects with relatively high RPN, which still should be taken corrective action on.

As the FMEA is an ongoing process, which needs to be done again each time the process changes, this analysis is no way over. The company should have a quality worker do the analysis in cycles, and most importantly this analysis is still lacking the corrective actions and analysis of those. The theoretical part of the work is mostly done, lacking only the planning of corrective actions. The implementation of corrective actions will require strict monitoring as the initial problem was that there is variance between installation crews. Different working methods cause variance between the crews, but also sometimes the project faces difficulties because the planning of the project is not perfect. The customer might have given wrong information about the room available at the site, and this can create a lot of logistical problems at the worksite and cause a lot of delay. Corrective actions on the most critical effects should definitely reduce the chance for large variance between installation crews.

5.6 Pareto chart

Last part of the research was to find a better way to present the findings. Tapio Malinen instructed me to use pareto diagram, which proved to fit the presenting perfectly. To make the data easier to read, all of the less significant failure modes with RPN lower than 100 was excluded from the diagram. I made the diagram with Minitab 17-program by inserting my FMEA into Minitab, then deleting the unwanted low significance cells, and then forming pareto from the RPN and Cause columns. The result is a good presentation of the causes in a clear order and data showing the percentages and cumulative percentage. From this diagram the problems can be easily chosen, and the improvements can begin.



GRAPH 3. Pareto diagram of the PFMEA results

6 CONCLUSION

Start of the project was successful in giving me a good idea about the installation process. The work was a bit complicated in the sense that the worksites are all over Finland, making the visitations limited and the installation workers not always at hand. In the beginning of the project I was a bit hesitant with the work, as I had not yet fully grasped the direction of the work and how to reach the results. As the work went on, the direction became clearer, and the theories started to make more sense in practice. The result in my opinion lead towards wanted outcome, and are definitely useful when implemented. With the goal being increased productivity and increased customer satisfaction, reducing the installation times will produce both. It will also help make the installation times more predictable, as most of the delays come from extra work and mistakes. By implementing better control, the chances for delays in the installation are reduced.

I really learned a lot from this project. In the beginning, the project seemed almost too large to tackle and I had doubts. With good guidance and determination, I noticed that I do have the ability to finish the project and I am able to find the solutions I was looking for. I also learned a lot about the Six Sigma ideology, as the tools used were part of that. I learned a lot more than just the tools used in this project. I learned about the approach to problems in quality and always having a systematic approach using the Six Sigma tools. I also learned a lot about the scientific reporting procedure as it was foreign to me in the beginning. If I were to do a similar project in the future I would definitely have more hands on approach. I noticed that doubts will just slow you down, and making mistakes is better than not doing anything. A mistake will make you realize what you should have done and steer you in the right direction.

REFERENCES

American society of quality, Failure Mode Effects Analysis (FMEA), <http://asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html>, referred 21.11.2016

American society of quality, Pareto Chart, <http://asq.org/learn-about-quality/cause-analysis-tools/overview/pareto.html>, referred 1.12.2016

American society of quality, What is a Process Flowchart?, <http://asq.org/learn-about-quality/process-analysis-tools/overview/flowchart.html>, referred 3.12.2016

American society of quality, What is lean?, <http://asq.org/learn-about-quality/lean/overview/overview.html>, referred 29.11.2016

Besterfield, D. Quality Control, 7th Edition, New Jersey: Prentice Hall publishing, 2004

Best-hall Oy, Procedure, rev-b, 2012

Best-hall OY, BEST-HALLIN HISTORIA KUVINA, <http://www.besthall.com/fi/yritys/best-hallin-historia-kuvina/#Tutustu-tarinaamme>, referred 20.11.2016

Ghosh, M. Process Failure Mode Effects Analysis (PFMEA), <http://www.processexcellencenetwork.com/business-process-management-bpm/articles/process-failure-mode-effects-analysis-pfmea>, read 26.11.2016

Karjalainen, T & Karjalainen, E. Six Sigma – Uuden sukupolven johtamis- ja laatumenetelmä. 5. painos, Lahti: Quality Knowhow Karjalainen Oy, 2008

Lean enterprise institute, What is lean?, <http://www.lean.org/WhatsLean/>, referred
26.11.2016

Process failure mode and effect analysis

PROCESS: Installation		Severity	Probability	Detection	action							
		1= No effect < 100€	1= Almost never									
		5= Rework >1000€	5= Monthly	5= Sometimes detected								
		10= Rejection (Over 20 000€)	10= Daily	10= No detection								
Process step	Failure mode	Effect	Severity	Probability	Detection	RPN	Corrective action	Responsibility / Time frame	Severity	Probability	Detection	RPN
Throughout the whole process	Time loss	Delays in installation	10	6	8	480						0
Throughout the whole process	Unclear or incorrect design	A lot of clarifying	7	4	1	8						0
Delivering assemblies/ Assembling frame	Not clear enough information from customer	Usually not enough room to work	8	3	5	120						0
Delivering assemblies	Information loss	Delays for workers	6	3	5	90						0
Throughout the whole process	Hard to reach location	Time used on travel	1	1	1	1						0
Assembling the frame	Unclear information for workers	Time used on clarifying	3	2	2	12						0
Throughout the whole process	Hourly workers	More time used on breaks	8	8	3	192						0
Throughout the whole process	Paid by piece workers	More efficient working	1	8	3	24						0
Assembling the frame	All necessary parts not at the site	Delay	4	3	2	24						0
Assembling the frame	All necessary parts not at the site	Delay	10	4	8	320						0
Assembling the frame	Fails in designs	Extra work at site	4	2	6	48						0
Installing rest of the features	Heavy work	A lot of time used	1	1	1	1						0
Throughout the whole process	Should be done along sidewalk, not at the end of the project	A lot of time used	3	2	3	18						0
Assembling the frame	Not clear enough information from customer	Time used for planning	2	2	2	8						0
Tightening the mantle	Not properly installed mantle	Rework	2	2	2	8						0
Tightening the mantle	Failures in tightening the mantle	Requires rework	7	2	2	8						0
Joining the frame blocks	Lots of work	Time consuming	2	2	2	8						0
Assembling the frame	Bad equipment	Time consuming	1	10	1	10						0
Spreading the mantle	Not always marked	Very time consuming	5	4	8	160						0
Assembling the frame	Lots of work	Time consuming	1	7	1	7						0
Assembling the frame	Ties at least one worker to that	Potentially other workers wait for the unloader	2	3	1	6						0
Installing rest of the features	Older models were problematic, not so much anymore	Extra work	1	7	6	42						0
Joining the frame blocks	Lots of work	Consumes time	1	3	2	6						0
Assembling the frame	Missing parts	Waiting for the parts to arrive	6	9	3	162						0
Assembling the frame	Searching parts	Time wasted searching	4	5	5	100						0
Joining the frame blocks	Requires a lot of know-how	Poor quality end product	1	8	2	16						0
Installing gable beams	Heavy work	Time consuming	1	6	2	12						0
Spreading the mantle	Poor weather	Delay starting	5	6	4	120						0
Spreading the mantle	Uneven spreading	Time consuming	2	4	3	24						0
Tightening the mantle	If the fabric is not correctly tightened, it will show on hem	Poor quality end product	8	6	8	384						0
Tightening the mantle	Inclination of the ground	Poor quality end product	8	6	8	384						0
Tightening the mantle	Behaviour of the fabric used not taken into account	Poor quality end product	8	5	8	320						0
Throughout the whole process	Fixes or returns	Time lost	5	3	6	90						0
Assembling the frame	Parts unclearly marked, extra work	Time lost	4	5	5	100						0
Assembling the frame	Calling around and finding the correct way	Time lost	10	5	7	350						0
Assembling the frame	Reorganizing and searching, extra work	Time consuming	4	3	4	48						0
Throughout the whole process	One has to unload the truck everytime	Time lost	10	6	1	60						0
Assembling the frame	Not in packed in any particular order	Time lost	8	5	3	120						0
Assembling the frame	Parts unclearly marked, extra work	Time lost	8	6	3	144						0
Assembling the frame	Not enough room, incorrect information from customer	Time lost	10	5	5	250						0
Assembling the frame	Parts unclearly marked, extra work	Time lost	8	5	3	120						0
Assembling the frame	Reorganizing and searching, extra work	Delays the work	8	5	5	320						0
Spreading and tightening the frame	Impossible to see differences with naked eye	A lot of time used	7	10	8	560						0
Assembling the frame	Bolts are not properly labeled in the boxes	Time lost	2	4	3	24						0
Throughout the whole process	Not failure, but a good thing	Acquire knowledge about the project	1	10	1	10						0
Throughout the whole process	Delays in bad weather	Delays the project	4	3	4	48						0

