RESEARCH REPORT

Value Stream Mapping

-a case study of an inner wall manufacturer

Jarkko Erikshammar, Louise Bildsten, Martin Haller

LULEÅ UNIVERSITY OF TECHNOLOGY

ISSN 1402-1528
ISBN 978-91-7439-840-3 (pdf)

Luleå 2014

www.ltu.se

TraIN

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

Value Stream Mapping
- a case study of an inner wall manufacturer

Jarkko Erikshammar, Louise Bildsten and Martin Haller

Institutionen för Samhällsbyggnad och Naturresurser
Luleå tekniska universitet
971 87 Luleå
HEMSIDA/WEBSITE: www.ltu.se

ABSTRACT

Value stream mapping has become a frequent used tool in implementing lean thinking at manufacturing companies. It is also an important tool for continuous improvement.

The successfulness as a tool is associated with the creation of a large-scale visual map of selected processes and interactions between these processes. In the process of making the value stream mapping, a more profound knowledge about the company's process is obtained by the employees, as its creation is carried out in collaboration with people performing the activities in the processes.

This case study was carried out at Moelven Eurowand, a manufacturer of interior wall systems for offices. The purpose of this study was to investigate the possibilities of shortening the lead-time of glass walls. The company was visited twice, the first visit was a value stream mapping workshop and the second a follow-up meeting. The improvement team members at Moelven Eurowand found the value stream mapping tool very useful.

SAMMANFATTNING

Kartläggning av värdeflöden har blivit ett av de mer använda verktygen inom Lean sammanhang. Dessutom är det ett viktigt verktyg för ständiga förbättringar.

Dess framgång är kopplat till skapandet av en stor visuell karta över hela företagets processer och samspelet mellan dessa processer. I arbetet med att göra kartan, fås en djupare kunskap om företaget genom att de som utför arbetet i processerna deltar i arbetet att rita upp värdeflödeskartan.

Denna rapport är en fallstudie av Moelven Eurowand, en tillverkare av innerväggssystem för kontor. Syftet med studien var att undersöka möjligheterna att förkorta ledtiden för glasväggar. Företaget besöktes två gånger. Vid det första besöket genomfördes kartläggning av värdeflödet och vid det andra besöket skedde uppföljningen av kartläggningen. Företagets representanter uttryckte att värdeflödesanalysen var givande.

ACKNOWLEDGEMENT

Writing this report has been a long process with company visits at Moelven Eurowand, discussion with our supervisor Anders Björnfot and searching for understanding.

We would like to thank Peter Lindberg, Kristina Nordvall and the rest of the process mapping team at Moelven Eurowand. We would also like to thank Anders Björnfot who has been supporting us during this process.

Finally we would also like to thank the "TräIn" (Träinnovationsnätverket) research program which is an EU financed collaboration project between IUC Norrbotten and Luleå University of Technology, which has made this research possible.

Jarkko, Louise and Martin
Luleå, January 2014

1 INTRODUCTION

1.1 Background

This report was part of the PhD-course "Värdeflöde från kartläggning till analys 7,5 hp". A case study was carried out in order to increase the understanding of the concept of value stream mapping (VSM) and its application at a manufacturer of inner wall systems. The data collection for the case study was performed within two workshops in November and December 2009 at Moelven Eurowand, a manufacturer of interior wall systems for offices, located in Hulån in Central Sweden.

Value stream mapping is a tool often applied in organizations working with Lean in order to model and analyze production processes. A study made by Erikshammar et al. (2010), in the same field, indicate that value stream mapping is a useful tool for visualizing the value stream.

Moelven Eurowand strived to double their production volume during the following five years by keeping the production without larger investments. One of the missions with this study was therefore to find managerial implications relevant for the company objective.

1.2 Purpose

The purpose of this work was to develop an understanding of the concept of value stream mapping and its application in the context of a manufacturer of inner wall systems. Moreover, the purpose was to demonstrate the possibilities of shortening the lead-time of glass walls with the value stream mapping application.

1.3 Delimitations

The study does not intend to be a fully developed extended approach of the value stream mapping tool nor does it give a formulism about how to deal with VSM in levels of machinery equipment.

2 METHOD

2.1 Single-case study approach and design

The case study approach was a suitable research strategy for the research in this report, since the objective was to develop an understanding of the concept of value stream mapping and its application. The case company was selected based on their explicit statement and willingness to develop their production process. The company's and its CEO's willingness to adopt a lean production perspective and systems building made this case also a good choice for the study.

2.2 Research Process

The research process began with literature studies in order to guide the case study design (Yin, 2003). The initial theoretical framework was used as a starting point to get an accurate picture of the theory before validation in practice. Thereafter planning and execution of company visits were conducted, including preparation of workshops and interviews.

2.3 Data Collection Methods

Value stream mapping was used as a method to structure the two workshops. The value stream mapping process was designed according to the method described by Rother and Shook (2003). The teams participating in the workshops consisted of the production plant manager, three operators from production, the purchasing manager and the CEO. The team members were selected by the company. The workshops were carried out at the case company's production site.

The workshop started with finding out the company's purpose of the value stream mapping sessions. The purpose became the aggressive goal to diminish the lead-time with 50 %. Thereafter the workshop began with an introduction of the lean concept and the value stream mapping approach. When the whole process was mapped, the process was analyzed and the future state map and the PDCA (Plan-Do-Check-Act) plan were created. The second workshop was a follow-up of the first one. This workshop began with a summary of the first workshop, then the PDCA was followed-up and discussed for adjustments.

All interviews were unstructured interviews, where the respondents afterward had the opportunity to verify a summary made by the interviewer. The team members were also given the opportunity to evaluate the process and the results. Participant observations were made at the work-shops.

2.4 Validity and Reliability

In order to strengthen the validity of the case study, the respondents were given the opportunity to verify the correctness of the interviews and workshops. In addition interviews were triangulated with archival documents and home pages. Participant observations gave the researchers a possibility to compare interviews with documents and action in the workshop.

3 VALUE STREAM MAPPING

Rother and Shook (2003) describe a method, "Learning to see", for mapping value streams. The method separates material and information flow. Rother and Shook (2003) discuss also the importance of having a process owner, a *value stream manager*, who will be responsible for the value stream, and the development of the value stream. The method is divided into mapping the current state, mapping the future state and implementation in what they define as Yearly Value Stream Plan. During the process of mapping the current state value added activities and non-value added activities are revealed. Rother and Shook (2003) state that the practitioner should start with an overall picture and later detail the process map where necessary. The future state or to-be scenario is then described, where the objective is to create value stream where every individual process is connected to a customer by preferably continuous flow and a pull system. Each process should strive for a single piece flow. The Yearly Value Stream Plan (Rother and Shook, 2003) is a break-down of the future state into goals, objectives, activities and responsibilities, which represents the implementation plan.

Wilson (2009) argues that value stream mapping can be applied to any business process including service, product development, manufacturing and office processes. When doing the value stream map, it is important to choose team members carefully. A common mistake is to choose the wrong members. Another critical aspect is that everyone must understand the purpose of the value stream mapping activity. It is important to have vision with customer-focus with a three-four year perspective. Lean includes both *kaizen* and *kaikaku*, where *kaizen* is small changes and *kaikaku* is a radical change. Value stream mapping is focused mainly on kaikaku. Takt time must be implemented to reach the vision to even out waste and overproduction. PDCA, as a follow-up plan, is a good tool to incorporate the vision. A vision without a plan is a dream according to Wilson (2009).

The value stream mapping application has been used and demonstrated in the construction context by Ballard et al. (2003), Arbulu et al. (2003), Álvarez et al. (2009), Serrano et al. (2008) and Khaswala et al. (2001).

Ballard et al. (2003) use the value stream mapping application for precast concrete fabrication. This case study of an engineer-to-order process came to the conclusion that a value stream map is a powerful tool to change the focus from machine and personnel utilization into focusing on lead-time reduction, throughput increase and improved productivity. By focusing on lead time reduction for engineered-to-order products the project emancipated that the production system itself would be more robust, i.e. less wasteful and give more rapid recovery. By using the value stream tool and "learning to see", the lead times were reduced and the production system became more robust in the sense that errors were caught earlier and the system itself could handle deviation without new planning.

"In short, they learned to look at the work-in-process to see if the production system was operating in accordance with its own rules" (Ballard et al., 2003)

Arbulu et al. (2003) have performed a case study of the supply chain of pipe supports that are used in power plants in the USA. Practitioners say that pipe supports often

arrive too late. In order to find out how to improve the process, it was necessary to find out how the supply chain of pipe supports were currently organized. One type of pipe support was therefore chosen for a value stream map that spans the whole supply chain both within the organization and the interface with company boundaries. Apart from improving the supply chain of pipe support the study also aimed to introduce value stream mapping as a general tool to model and analyze other kinds of supply chains in the construction industry. The study of pipe supports illustrates the complexity including dependency and variation that is characteristic for construction supply chains. The conclusion was that the value stream mapping tool is helpful to recognize opportunities of improvements in a supply chain. Moreover Arbulu et al. (2003) argue that there are three main points to be considered when reducing lead-time caused by waste. These are:

- Choosing suppliers early and involve them in design.
- Communication through standardized processes and limited variation of products.
- Integration of computer tools to facilitate design and product specification.

The study was of a very specific product, pipe supports, but Arbulu et al. (2003) argue that the fact of this study can be applied to any supply chain.

Álvarez et al. (2009) argue that lean makes the manufacturing process more robust, leading to operational excellence, continuous improvement and elimination of non-value-added activities. This means according to Álvarez et al. (2009) that lean practices increase factory performance as well as profits. Àlvarez et al. (2009) believe that the value stream mapping tool is effective and serves both a good communication tool for practitioners as well a reference model for theoretical analysis. Álvarez et al. (2009) have proven that an assembly line with a small space can achieve high levels of performance through redesign operative actions using the value stream mapping tool.

According to Serrano et al. (2008), value stream mapping is a graphic technique to redesign production systems. The aim of their article was to evaluate the applicability of the value stream mapping tool in redesigning the production lines of six industrial companies. Serrano et al. (2008) also conducted a thorough analysis of alternative methods, namely: flow diagram charts, structured systems, architectural systems and modeling and simulation software. The result of the study by Serrano et al. (2008) showed that value stream mapping is a useful, efficient and applicable tool.

Khaswala et al. (2001) explain the basic concepts of value stream mapping, as well as its advantages and disadvantages. Advantages of value stream mapping are according Khaswala et al. (2001):

- Value stream mapping relates the manufacturing process to supply chains, distribution channels and information flows.
- Value stream mapping integrates material and information flows
- Value stream mapping links production planning to demand forecasting and shop floor control in using takt time.
- Value stream mapping unifies methods like BPR, production flow analysis and process analysis that has previously been practiced in isolation.
- Value stream mapping is the base for implementing Lean in a company.
- Value stream mapping forms a company “blueprint” for strategic planning of the entire company.

Some disadvantages of VSM that Kwasala et al. (2001) mention are:

- Value stream mapping cannot map multiple products that do not have the same material flow.
- Value stream mapping lacks an economic measurement for “value”.
- Value stream mapping is mainly for high volume low variety (HVLV) products.
- Value stream mapping does not consider floor space for material handling.
- Value stream mapping cannot make a rapid change on a low budget.

4 RESEARCH FINDINGS

Moelven Eurowand AB manufactures and sells prefabricated inner wall systems for offices, see Figure 1. The wall system is called the “Eurowand method” which means that the walls arrive to the customer painted and ready for assembly.

Figure 1: Inner wall systems manufactured at Eurowand (the Eurowand system). The picture is reprinted with the permission of Moelven Eurowand AB

Moelven Eurowand AB was founded in 1973 and is Sweden’s largest supplier of inner system walls for offices. The company has a total responsibility in development, production and assemblage of the wall systems. The manufacturing is carried out in two factories situated at Hulån and at Kumla. The head office is in Örebro and the sales offices are in Örebro, Stockholm, Göteborg, Norrköping, Uppsala and Malmö. There are 160 people in total that work at Moelven Eurowand AB and the turnover in 2009 was 208 million SEK.

Our study was carried out at Moelven Eurowand AB’s factory at Hulån. The factory at Hulån has 40 employees. The wall system consists of solid walls, room separating walls, doorways and glass walls. The production floor is divided into three divisions: working, painting and sub-assembly of wall sections. Each of the wall parts has to pass these three divisions in order to be completed. The CEO asked us to follow the production flow of glass walls, see Figure 2.

Figure 2: Glass wall product. The picture is reprinted with the permission of Moelven Eurowand AB

4.1 The Workshop

4.1.1 The first step in workshop - mapping the current state

As earlier described in the methods section, the first workshop was initialized with a presentation about lean and value stream mapping and its purpose. It was explained that the lean concept is actually not a new invention, but is based on logical principles. These principles are to keep the factory clean and tidy (5S) and work in a logic way to increase efficiency, which are the objectives with value stream mapping.

When starting a value stream mapping process it is important to define the start and end point of the process that is to be studied. The task was to diminish the lead-time with 50 %, thus it is important to define what this lead time actually consist of. The value stream mapping illustrates the process from delivery of raw materials and ends with finished products, see Figure 3.

Figure 3: Studied process flow

The process is initialized by the input of raw materials i.e. wood products needed for the frame of the glass door and glass. The wood products consisted of different dimensions of timber bars and fiber boards i.e. MDF-boards. The production of glass doors consists of three steps. The first step is the processes in the machinery hall were all the pieces that constitute the framing are sawn and planed. The second step is the painting of the different wood parts and finally the third step is the assembly of the wooden parts with the glass part. After the assembly the glass doors are prepared for shipping. The current state map is visualized in Appendix 1.

The factory has a storage of MDF-boards and glass that has been delivered by their suppliers, see Figure 4.

Figure 4: MDF

The first operation is sawing of MDF boards in a format saw, which optimizes formatting in order to minimize material waste, see Figure 5.

Figure 5: Format Saw

The saw optimizes the orders from an order box, see Figure 6. The order box is the releasing point of production orders. Production orders are planned by the sequence of orders. The production orders are printed by the planning department and placed in the box.

Figure 6: Order Box

The interviews, value stream mapping analysis and production data collected by the company revealed that the flow in the factory was uneven. The unevenness was detected by the assembling division and the painting division when they had to wait for MDF bars that had not yet been planed or sawn because the machinery hall likes large batches to optimize machine efficiency, see Figure 7.

Figure 7: Large batches in machinery hall

The assembling team had to wait because the painting team wanted to paint as big batches as possible of the same color. The changeover-time of coloring was extensive. This is why large batches are preferred to avoid the often dirty and heavy work of doing a changeover. Through the analysis of intermediate stocks between activities with interviews, a bottleneck was detected at the assemblage station. This was seen by large quantities of painted bars was waiting for assembly, see Figure 8.

Figure 8: Painted bars waiting for assembly

So why are the assembly team waiting? The only problem was, it was not the right bars to enable assembly. The painting division has to chase missing parts, belonging to a specific series of yellow labels in order to paint it and enable assembly, see Figure 9.

Figure 9: Yellow labels marking bars belonging to different projects

Yellow labels were attached to bars of different projects in the machinery hall but when they are painted the labels disappear. This leads to confusion in finding the right pieces after the painting. After the painting, the next step is assembly; see Figure 10, whose problems have already been described about missing pieces. However other problems occur as well, it is sometimes hard to fit all the pieces together if they are not sawn with high precision. Moreover, there are quality issues discovered with the painting which leads to extra time for painting and drying.

Figure 10: Assembly station

After the assembly, the next step is packing for delivery, see Figure 11. Usually, there is no problem with the actual packing. However because the projects are not finished on-time there are many delays. The delays are due to that there are so many half-finished projects running at the same time, waiting for the last piece before shipping.

Figure 11: Packing of glass doors

When the walk in the factory was over, it was time to note down all the information in a value stream mapping diagram. This was carried out during the following day during the workshop. The whole writing down of the mapping was done interactively together with the participant group from the case company.

4.1.2 The second step in the workshop – finding the future state

In order to find the future state, it is of outermost importance to know the customer needs as it is the goal of lean and value stream mapping. Interviews were therefore conducted to pin-point customers' needs. The customers were grouped into on-site teams (i.e. the team that assembles the wall system at its location) and the end-customer (i.e. the people using the wall system). The customers' needs i.e. value that was found are listed in Table 1 (onsite-team) and Table 2 (end-customer.

Table 1: Customer's needs (onsite team)

Customer needs (on-site team)	**Can future state map solve this?**
On-time delivery	Yes
No damages	Yes
The right product	Yes
Complete delivery	Yes
Sufficient information about details of delivery	Yes
The right dimensions	Yes
Flexible delivery time	No

Table 2: Customer's needs (end-customer)

Customer needs (end-customer)	**Can future state map solve this?**
High quality finishing	No
High quality fitting of door in doorway	No
Acoustic (affected by precision in assembly)	No
Delivery precision	Yes

When all the customers' needs were detected, the goals were set to what the future map should achieve. To enable a pull-system instead of pushing to the market, it is essential to understand that the customer in fact is the pace maker of the factory. Thus the customer orders must be scheduled according to the factory capacity. To enable a

steady takt time for an even flow in the factory, the time schedule of finishing customer orders must be put into consideration. An arrow is therefore set with a label of even delivery of finished products in the future state map in Appendix 2. In order to even out the flow in the machinery hall, they must only produce what this demanded by the painting division. The takt time should be related to the pace maker process. The pace maker process in turn should be controlled by customer demand.

The machinery hall should limit their intermediate stocks with a maximum intermediate stock of one day. The projects should be grouped into batches and the highest priority parts should be manufactured first. An arrow of daily control is therefore put between the machinery hall and the painting.

The CNC-machine has a limit, which is the bottleneck (related to machine capacity) for the machinery hall. However, if the flow is more even and looking at the whole process, the NC-machine is not a bottle-neck. To spare man-hours in production, it is possible to invest in a sanding application for the NC-machine. Because this is the bottleneck this machine has to be controlled for daily output, see Appendix 2.

As the pace maker process is controlled by customer demand, the painting division should paint only what is needed for immediate subsequent activities. To know which pieces that should be painted, a whiteboard was found to be a good way of communicating this information between painting and assembly. No defect products should be passed over to assembly. Therefore daily control between those activities is illustrated with an arrow in the future state map, see Appendix 2.

The painting division is in need of more storage space and this can be reached by tidying up the shop floor. Another issue is that the painting machine needs regular service which is not maintained properly at the moment. There should be control of what and how much is to be painted each day, see Appendix 2.

As the assembly division often receive incomplete projects from the painting division. The assembly has to wait until they have all the pieces of a product. This leads to that the assembly becomes a bottleneck for the whole factory. The assembly should not tolerate any buffers in their production flow. The assembly must prioritize tasks that the shipping team needs to send. Decoupling of delivery from production takt time, and only deliver what the customer demands should be achieved. A two-bin system for semi-finished products was found to be a good way of organizing intermediate stocks, i.e. always have one finished and one semi-finished bin to keep the right takt time.

Just like the painting division, the assembly division also needs to free up space by tidying up the shop floor. This is because the finished goods need storage space before delivery. To achieve the goal of storage space a storage meeting should be held every week, with weekly planning of deliveries, see Appendix 2.

4.1.3 The third step of the workshop

The PDCA plan is a concrete list of actions that is decided should be done in order to reach the future state. A list of actions was noted down together with the participant team from the company. The list was the following:

- Visual planning for a more efficient information flow between the different divisions i.e. machinery hall, painting and assembly.
- Daily and weekly meetings between divisions in the factory.
- Remove unnecessary information on the yellow labels.
- Planning of customer orders for even flow.
- Make the change-over for the painting machine easier.
- More service on the painting-machine to make it running smoother.
- Find a solution to make the planer more efficient.
- Tidy up to facilitate movements (and flow) in the factory.
- The glue station should examine the products from the painting division. The defects products that are discovered by the glue station should be reported to be able to find the causes of defects.

4.1.4 The fourth step of the workshop- evaluation

The fourth step of evaluating the PDCA was done one month later. Some of the tasks were taken care of, others were in progress. The participating team showed enthusiasm and dedication to continue the value stream mapping process as it must be an always ongoing process.

5 ANALYSIS

In this section we will analyze our results in order to evaluate the method of value stream mapping. Wilson (2009) argues that value stream mapping can be carried out within any type of business. However, a case company with many repetitive operations with short cycle times is ideal (Yu, 2009). This case company had both short operation cycle times and many repetitive actions which made the company easy to measure and therefore suitable for the value stream mapping technique

According to Ballard et al. (2003), the value stream mapping process is a powerful tool in its focus on lead-time reduction, throughput increase and improved productivity. Moreover, Ballard et al. (2003) argue that low throughput i.e. bottlenecks is not necessarily caused by machine capacity, but wrongly use of people. This case study confirms with Ballard et al. (2003) that the right use of people is more important than machine capacity. It all has to do with people using the machines the right way. Womack et al. (1996) argue that value only can be determined by the customer, which in fact became the red thread throughout the whole value stream mapping process in our case study. The purpose of all changes into the future state was easily traced back to the customer needs. According to the enthusiasm and understanding created at the workshop in discussing causes of waste, value stream mapping seems to be an excellent communication tool for managers to improve company processes. Moreover it gives visualization of all processes, which enables a theoretical analysis. This both practical and theoretical usefulness was experienced by Alvarez et al. (2009).

In the mapping of the case company, the lack of changeovers showed to be the root cause for the uneven flow (the assemblage team received the final parts by the end of the week). This in turn, made high stress for the workers as the end of the week became very stressful. Moreover, there was a lot of waste in unnecessary movements and action in chasing missing parts. Furthermore it led to a crowded floor with lots of different parts not fitting together because of a missing piece. All this information was revealed for us as well as the participating team from the company because the value stream mapping process was carried out together with them on a large-scale map. Thus, the bottleneck (hindrance of flow) was revealed by the value stream mapping process to be the scarce changeovers. The basic idea of Lean Production given by Womack et al. (1990) argue that the basic idea of lean production is frequent machine-changeovers to strive towards as small batches as possible. Our case study does then in fact agree with the arguments of Womack et al. (1990) that the key to even out a flow with multiple projects is frequent changeovers. Thus the lack of changeovers becomes a bottleneck.

Finding the pieces was hard also because the shortage of space prevented the workers to move around and search for them. Many workers complained about the shortage of space. However, shortage of space often is related to tidiness rather than the area of the production hall (Höök and Stehn, 2008). One of the root causes were therefore not only batch size but also tidiness. The untidiness can thus be seen as a bottle-neck.

The value stream mapping revealed that there were many projects running at the same time, causing disorder on the shop floor, leading to further delays. One of the root causes to this was revealed during the process to be the customer orders coordination

with factory planning. It is better to keep cool and wait with some projects to not mix up the parts that will only cause further delays. The takt time should be related to the pace maker process and not to the bottleneck (search for missing pieces). The pace maker process in turn should be defined to customer demand. Wilson (2009) argues that takt is a tool with a good applicability also in complex production processes with high variation to even out the flow. Arbulu et al. (2003) argue that value stream mapping can be a helpful tool in recognizing opportunities of improvements in the supply chain, which seemed to agree with our case study. The supply chain in our case refers to in this particular argument the interaction between sales and production. Thus, the lack of coordination was revealed to be a bottleneck.

6 DISCUSSION AND CONCLUSIONS

Value stream mapping is not a tool to find bottlenecks in the meaning of machine effectiveness. The value stream mapping process sees he factory from a higher perspective to eliminate bottlenecks caused by coordination issues. Value stream mapping only works to analyze coordination between processes separated by buffers. In order to improve capacity on a more detailed level, simulation models are better.

Value stream mapping is only a tool, it is not a philosophy. The goal is to support the management team in collecting data about the current state of the factory to make the right decisions. The aim is to design a one-piece flow, with as high throughput as possible. ”Supermarkets” i.e. intermediate buffers should only apply where the flow is corrupted. To achieve one-piece flow, it is necessary with short change-over-times to facilitate frequent changeovers. Value stream mapping advocates pull instead of push. The key to this is to find out the decoupling point, i.e. where orders initialize production. A pulling system is thereby produced by prioritizing those products which first should be delivered, day by day, hour for hour.

6.1 Managerial Implications

In this chapter we will describe how value stream mapping should be carried out according to our experiences and studied literature.

6.1.1 Planning value stream mapping

The first step in planning value stream mapping is of course to find out the company’s needs. It is important to know the company’s expectations and desires to make them motivated. A team should be selected that includes all the divisions in the flow that is going to be studied. The company can select these team members themselves, but it is important that they are people that are open to change and improvements. The team members should be prepared with questions before the visit to the factory. It is good that they reflect before doing the actual analysis of the flow. The whole organization must be informed about the motives of the value flow analysis. Therefore it is important to persuade the team and the whole organization about the benefits of the method. The most important is of course the top management’s commitment as change is only possible top-down. A value stream analysis is preferable carried out at the company that is studied. This is because it is good to follow the flow in reality to get the most adequate picture of the current state in the flow. In lean there should be a process owner to obtain the perfect result of a value stream mapping. Therefore a process owner or “value stream leader” should be selected at the company. Demand the company to make queries about customer value. What does the customer want?

6.1.2 Starting the workshop at the company site

An understanding of the value stream mapping concept at the very beginning of the workshop is important to make all participants motivated and active. Therefore an introductory presentation of value stream mapping, in a pedagogic manner, is a good way to start the workshop.

After the brief introductory presentation of value stream mapping, it is time to set the goals, i.e. what exactly should be reached. An aggressive goal shows the team

members the powers of the value stream mapping tool. The goal should be measurable in order to see improvements clearly. Moreover the goal should be related to business goals. The goal should also connect to customer expectations. In order to find out customer value, queries should be made with customers or sales people.

Once the goal is set, the team members have to decide which product family and which product that should be analyzed. ABC-analysis supports the choosing of the product family. The product chosen should be the product that has the largest part of the company's turnover. Commodity products, i.e. standardized products with large volume are most suitable as standardized work is necessary to avoid exceptions. Moreover high volume has high impact on sales usually. When doing the first value stream mapping at a company it is important to not choose too complex products to begin with. Keep in mind that a value stream mapping is done on one product, so do not lose focus on this. When the product family and the product are chosen, the start and end points of the flow should be set clearly. Common start and end-points are the flow from trucks going in to the factory to trucks going out of the factory.

6.1.3 The mapping

After the limitations are set it is time to take pen and paper and follow the chosen product from end to start. If the end-point is chosen as the point when the truck leaves, it is here the walk with pen and paper starts. When following the flow "backwards" it becomes more obvious to see what the problems are as they often are revealed at the end of the flow. It is recommended to use basic tolls like pen and paper when walking in the factory as it is closer to production and focus is not on the tools but on the process. The whole team should participate in the walk around the factory so that maximum knowledge is contributed to the process mapping. Value stream mapping creates a simple picture, it is therefore not necessary to determine the lead-times too accurately. A rough value of average lead-times in the process is enough. The important thing is to capture the whole flow to know how activities interact with one another. Data connected to the goal should be collected e.g. lead-time, change-over-times and intermediate buffers. Buffers can be hard to estimate for actual sizes. Cycle time are collected through interviews during the walk. Look at cycle times, changeovers, personnel, available time, quality (scrap and/or rework), buffer and stock. Normally you will see large buffers in proximity before a bottleneck.

After the walk around the factory, it is time to sit down and organize the information. Machines that do not have buffered stock between one another should be grouped as one single activity. When the flow in the factory is written down, it is time to do the mapping of the information flow connected to the production flow. A problem when mapping the information flow is that it is hard to measure cycle times as administrative work is not the same as machinery work. However it is important to see the interactions to know exactly how the process flow goes. When value stream mapping is written down it is good to use a large-scale picture with simple symbols to make it visible and easy to understand for the whole team. A problem with pen and paper is that it is hard to erase and make changes, but that has to be overlooked as pen and paper is most understandable for everyone. When everything is written down, the bottleneck should be identified. We have not found a ready-to-use method to identify bottlenecks. There is no measurement for bottlenecks. We suggest that to find bottlenecks, interviews and walking around in the factory is the best way.

6.1.4 Remodeling the process

When starting to remodel the process it is important know already the level of abstraction. Furthermore it is important to focus on the whole process in order not to sub optimize. It is possible to use methods like the *Hejunka* box, FIFO, pacemaker controls, pull and supermarkets. Project team members can influence each other positively (common understanding) and negatively (focusing on wrong things. In particular subjective beliefs are often valued higher than facts. Bottlenecks can be eliminated through more people or parallel processing, reorganization, changing routines and policies, change or upgrade machines. It is important to evaluate after what changes that are doable. Discuss how to best handle the human side of change. If there is no support for fundamental rethinking, change must come step by step with *kaizen* (continuous improvements) in order to reach *keikaku* (leap in change). *Keikaku* is the future state map and the PDCA is the kaizen. Value stream mapping tries to accomplish the perfect factory. As it is not possible to estimate the efficiency of the future state with help of value stream mapping, simulations could be support to do so.

6.1.5 Follow up: PDCA (Plan-Do-Check-Act)

Remodeling must be followed by an action plan, PDCA (Plan-Do-Check-Act). We suggest training in bottleneck thinking. Focused on-site training on bottlenecks i.e. Hoshin could be helpful for improvement of flow. Also, SMED (Single- Minute - Exchange of Die), is recommended to improve changeover-times. Continuous value stream mapping analyses should be done to measure improvements and see the results of changes. It is also a way to know if the factory is on the right track. Value stream mapping does not include check against goal fulfillment. It is important to define what to measure. One person should be responsible for improvement activities. Customer satisfaction must be measured continuously in order to lead the company towards the right goals. A way of measuring customer satisfaction is to continuously write down complaints and act upon them; another way is to send out questionnaires. A long-term cooperation between buyer and supplier (this company) enables possibilities of customer adaption in order to make the buyer i.e. customer satisfied (Bildsten, 2013). Generally it is important not to lose the focus and to follow the plan. However the plan can change! Visual planning like for example whiteboards are helpful to inform the personnel about the progress of PDCA.

7 FURTHER RESEARCH

An issue with VSM is that it is not possible to measure in monetary terms. It makes it hard to motivate management if there is no connection to the final results in money.

REFERENCES

Álvarez, R., Calvo, R., Peña, M. and Domingo, R. (2009) Redesigning an assembly line through lean manufacturing Tools. *International Journal of Advanced Manufacturing Technology,* **43** (9-10), 949-958.

Arbulu, R., Tommelein, I., Walsh, K. and Hershauer, J. (2003) Value stream analysis of a re-engineered construction supply chain. *Building Research and Information*, **31** (2), 161-171.

Ballard, G., Harper, N. and Zabelle, T. (2003) Learning to see work flow: an application of lean concepts to precast concrete fabrication. *Engineering, Construction and Architectural Management,* **10** (1), 6-14.

Bildsten,L. (2013) Buyer-supplier relationships in industrialized building. *Construction Management and Economics*, Special Issue: Industrialized building.

Erikshammar, J., Engelmark, H. and Haller, M. (2010) *Värdeflödesanalys: en pilotstudie på Finsnickeriet AB.* Technical report. Luleå University of Technology.

Höök, M. and Stehn, L. (2008) Applicability of lean principles and practices in industrialized housing production. *Construction Management and Economics,* **26** (10), 1091-1100.

Khaswala, Z. and Irani, S. (2001) Value Network Mapping (VNM): Visualization and analysis of multiple flows in value stream maps. *Proceedings of the Lean Management Solutions Conference,* St. Louis, Montana, USA, 10-11 September.

Rother, M. and Shook, J. (2003) *Learning to see – value-stream mapping to create value and eliminate muda.* Lean enterprise Institute. Cambridge. Massachusetts.

Serrano, I., Ochoa, C. and De Castro, R. (2008) An evaluation of the value stream mapping Tool. *Business Process Management Journal* **14** (1), 39-52.

Wilson, J. (2009). Directions to discovery - value stream maps start and end at customer satisfaction. *Industrial Engineer*, **41** (4), 38-42.

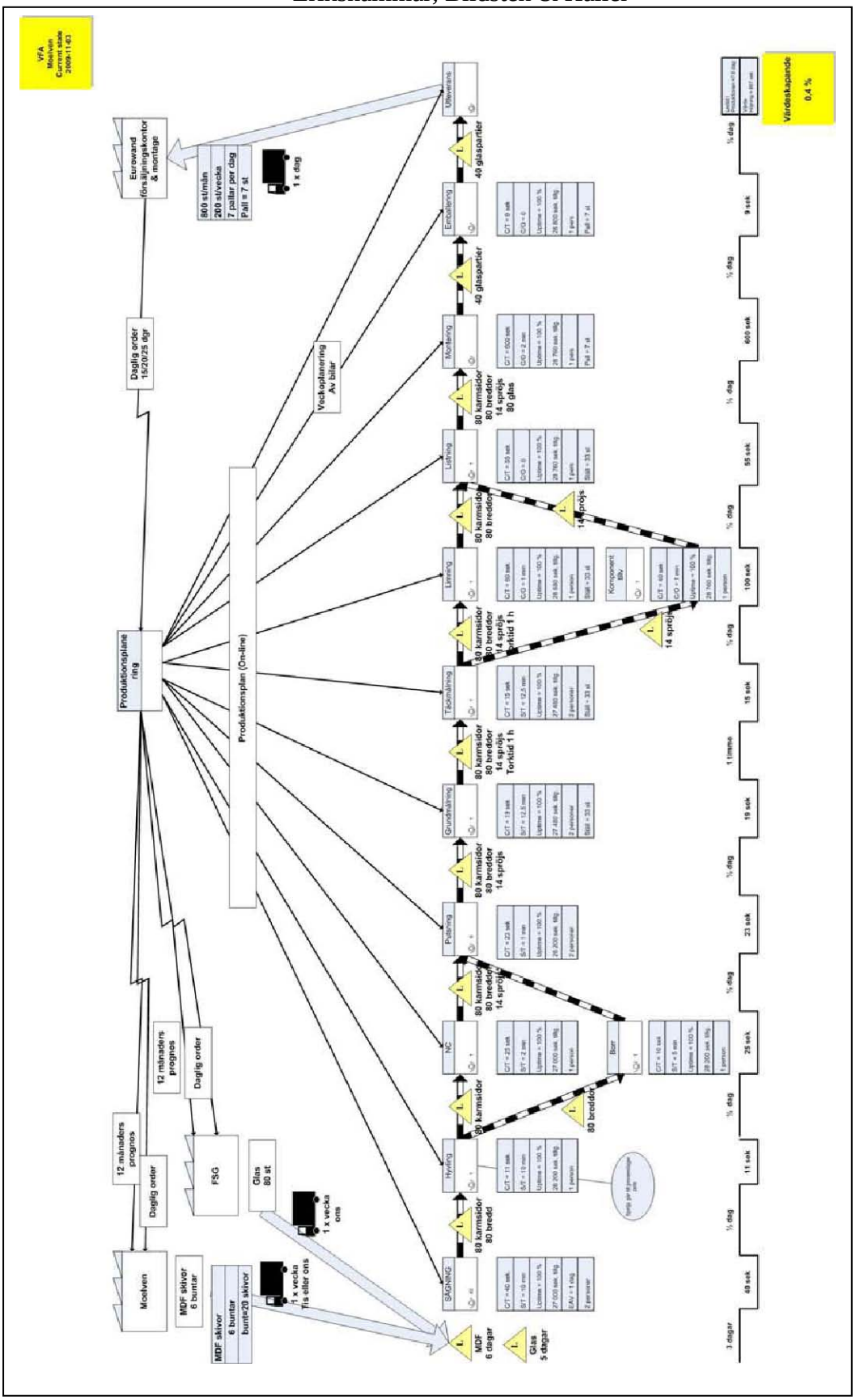
Womack, J. P., Jones D. T. and Roos, D (1990) *The machine that changed the world.* Free Press. New York.

Womack, J. P., Jones, D. T. and Roos, D (1996) *Lean thinking – banish waste and create wealth in your corporation.* Free Press. New York.

Yin, Robert K., (2003) *Case study research. Design and methods*, 3rd ed., Sage Publications. Thousand Oaks. California.

Yu, H., Tweed, T., Al-Hussein, M. and Nasseri, R. (2009) Development of lean model for house construction using value stream mapping. *Journal of Construction Engineering and Management,* **135** (8), 782-790.

Appendix 1: Current state of case company



Appendix 2: Future state of case company