PARAMETRIC VALUE STREAM MAPPING FRAMEWORK: A CASE STUDY OF A SMALL SWEDISH INDUSTRIALIZED HOUSE-BUILDING SUPPLIER

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ABSTRACT

Industrialized house-building is based on repetitive processes used in the supply, design, manufacturing and erection of pre-configured houses. Industrialized house-building contractors are dependent on many small suppliers and sub-contractors in their supply chain. These small suppliers, with limited resources and capabilities, need to be able to develop products and processes in order to deliver future customer value without wasting development resources on non-viable products. Our question is whether product development by small and medium-sized (SME) industrialized house-building suppliers could be supported by parametric Value Stream Mapping.

The objective is to explore a process design framework in which Value stream Mapping (VSM) is used to identify improvements and to generate product development suggestions, based on a set of parameters defined as P_1, P_2..., P_n.

The testing was carried out at a Swedish SME supplier to the industrialized house-building sector, using a newly-developed roofing board with an integrated membrane, with the parameters (P_1) customer needs, (P_2) waste on construction site and (P_3) construction worker safety. Data were collected using interviews and video-recorded participant observations on two construction sites.

Findings indicate that VSM cannot describe attributes of a product other than those associated with production flow. However, parametric VSM helped the case study company to stop current development and instead suggest valuable product attributes. The implications are that parametric VSM enhances the application of VSM. Parametric VSM can be used by SME suppliers as an input to product development in order to validate product attributes before launch. However, this is based on a single case study and further research is needed.

KEYWORDS

Value Stream Map, Product Development, Industrialized House-building, Small Business, Process Design

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INTRODUCTION

The house-building industry in Sweden has been criticized as being inefficient, under-developed and corrupt. However, this is a criticism that continues to be leveled at most house-builders around the world (Josephson and Saukkoriipi 2003).

Industrialized house-building contractors are dependent on many small suppliers and sub-contractors in their supply chain. These small suppliers, with limited resources and capabilities, need to be able to develop products and processes in order to deliver future customer value without wasting development resources on non-viable products (Erikshammar et al., 2013).

Industrialized house-building methods (Koskela and Vrijhoef 2001) that use prefabrication and modularization (Lennartsson and Björnfot 2012) have been suggested as one approach to reduce process variation through standardization (Alves et al. 2006, Höök and Stehn 2008) and product development (Björnfot 2004). Several methods have been suggested to support industrialization, one of which is value stream mapping (VSM).

A value stream contains all activities be they value-adding, non-value-adding or necessary but not always adding value, according to Rother and Shook (1999). When identifying a value stream, value stream mapping and analysis is suggested (Womack and Jones 2003). The method is hands-on and helps to create more value with fewer resources (Rother and Shook 1999). Our question is whether product development by small and medium-sized (SME) suppliers of industrialized house-building could be supported by parametric Value Stream Mapping (pVSM).

The objective of this study is to explore a process design framework in which VSM is used to identify improvements and to generate product development suggestions based on a set of parameters defined as P_1, P_2..., P_n. A test of it was carried out at a Swedish SME industrialized house-building component manufacturer.

VALUE STREAM MAPPING

VSM is described as an iterative method for mapping and analyzing value streams (Rother and Shook 2003). Its purpose is to quantify and communicate production process characteristics such as material and information flows as well as non-value-adding activities (Lasa et al. 2008). It is mainly used for process improvements such as lead time reduction, increasing throughput and reduction of work in progress (Alvarez et al. 2009). Björnfot et al. (2011) showed from three cases studies (a patio-door manufacturer, a door manufacturer, and a kitchen cabinet assembly) studies that VSM can work as a change-agent within industrialized house-building in convincing all actors of the positive effects of working with continuous improvements. Further is has been demonstrated by Simonsson et al. (2012) that VSM can be used by on-site practitioners to see the day-to-day flow of work, to understand the effect of straight-forward improvements to workflow, and to see the effect of applying industrialized working methods.

VSM consists of the elements “mapping the current state gap”, the “future state design” and a “yearly value stream plan”. The current state gap presents a visual representation of the value-adding and non-value-adding activities in a process. The future state design is a value stream where the identified problems of the current state have been remedied. The yearly value stream plan forms the implementation plan, which closes the gap between the current and the future state, as well as determining the schedule of necessary changes needed to improve the production process as defined by the future state design (Rother and Shook 2003).

A PARAMETRIC VALUE STREAM MAPPING FRAMEWORK

Product development with parametric design shows that there are several parameters to take into account when developing a new product or modifying a pre-existing product. Each parameter is corresponding to a customer value, which is an important transformation discussed by Erikshammar et al. (2010) were all actors in a house-building project will value different parameters. Value can also be other parameters than cost, time and quality as discussed by Salvatierra-Garrido et al (2009). The value can be even extended to a wider perspective in which the return of value from the construction industry to society as whole (Pasquire and Salvatierra-Garrido 2011). The design of the production and supply chain processes could be supported by VSM. This approach may be especially important for SMEs that have limited resources and where implementation of unsuitable solutions can be detrimental to the company.

The proposed process design framework (Figure 1), based on the literature review, presents a systematic description of how SMEs may use the approach to reduce the risks when developing new products. The objective is to generate a customer-unique product development proposal which improves the product using a defined set of parameters (P_1, P_2..., P_n).

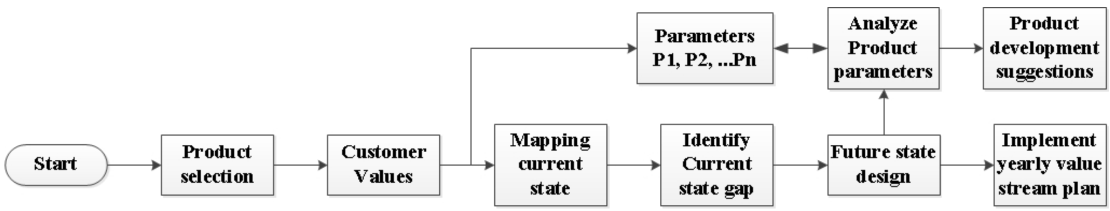

Figure 1: Process design framework based on (Rother and Shook 2003)

The initial step is the selection of the product or product family to be developed. When selecting the product, the customer's requirements are also captured. Important questions to answer are "who are our clients?" and "whom do we create value for?". After choosing the customer or customer groups, a suitable method for collecting customer requirements is selected. Interviews are a good way of collecting qualitative data from a range of roles such as those responsible for purchasing or the product itself as well as team leaders and operations staff at the construction site.

The following step is to map the current state by describing customer requirements and the value flow on the construction site. In order to be able to process data after site visits, video-recording is recommended for capturing on-site observations. After the identification of gaps and analysis of the current value stream, the flow is divided into a yearly value stream plan and an evaluation of the selected parameters for the product. Data can be collected through observations, interviews, workshops or archival documentation. Analysis is needed to examine the fulfillment of goals in respect of the parameters P_1, P_2..., P_n. The analysis concludes with product development suggestions.

CASE STUDY

The supply chain for industrialized house-building companies in Sweden is made up of many small companies that have fewer than 250 employees and a turnover below € 50 million. To validate the proposed process design framework, a qualitative case study of a construction component manufacturer was chosen, because of the company's position within the industrialized house-building supply chain. The case study company produces components such as tongue boards, façade panels, pre-cut beams and other components for industrialized builders of detached family houses. The data collected in relation to the proposed framework are shown in Table 1.

VSM is difficult when following a house-building project that occurs only once and where the process is not repetitive. Back-tracking of the process flow from finished product to goods received is not possible, so a method had to be developed. The two products were video-recorded on two different sites. The video-recording was then played back and the researchers made notes on value-adding and non-value-adding activities. The interpretation of value-adding and non-value-adding activities could then be verified by the on-site construction team.

Table 1: Data Collection Methods

Data Collection Method	Details	Purpose
Interviews	Six (6) recorded, transcribed interviews with three persons with purchasing roles, and three persons from on-site production	Create understanding of customer values and compare with participant observations
Participant observations	Two (2) on-site video-recorded participant observations i.e. on each product (Product A and Product B)	Isolate non-value-adding activities from value-adding activities, based on interviews

SELECTED PRODUCTS

Two products were selected for testing the method. Product A is a mature product, chosen in order to validate known issues with the product and see if they are picked up using this method. Product B is a new product to test with the developed framework.

Product A: Roofing with tongue board

This product is manufactured by using tongued panels, glued and pressed together into a board of a standardized format and then fastened with nails. The usual measurements are either 3600 x 540 mm or 2400 x 540 mm. One board weighs about 23 kg, depending on the type of wood (spruce or pine) and the moisture content in wood. On the construction site, the boards are attached to the trusses (Figure 2) with nails or screws on each panel. When the whole roof is finished with the boards, a membrane is rolled out. The membrane is about 1000 mm in width and overlaps adjacent membranes by 150 – 200 mm in order to create a waterproof layer. After that, an outer roofing material, such as roof tiles, is fitted.

Product B: Roofing with tongue board with an integrated membrane

The case company had, together with a membrane supplier, developed tongue board with a waterproof membrane applied to it at an off-site production facility. This way it would not be necessary to attach the membrane on-site. The assembly activities on-site only differ in the actual membrane assembly. The boards are fastened in a similar way, but the construction worker has to lift the membrane before attaching the board to the truss. Product B has the same dimensions as product A, which means that a 3600 x 540 mm board weighs 24.6 kg, depending on wood type and moisture content in wood.

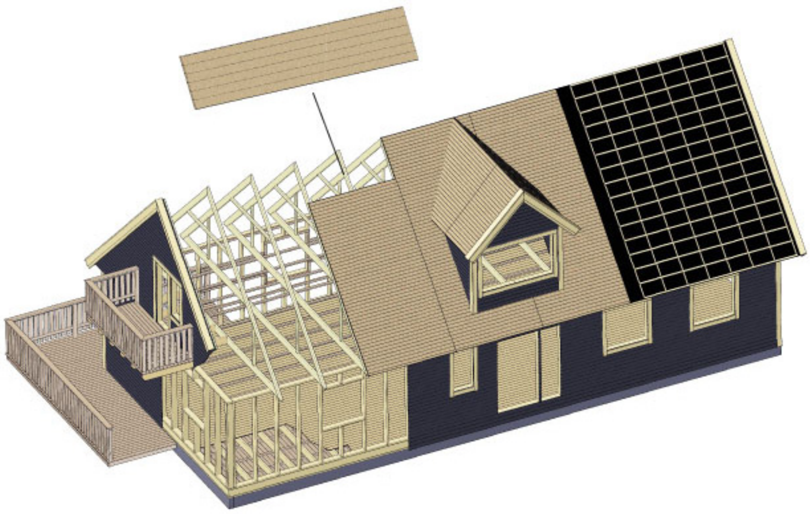

Figure 2: Tongue board

Horizontally, the construction is waterproofed by 100 mm of membrane overlapping the next board (Figure 3).Vertically, there is a seam and no overlapping membrane, but it is waterproofed by lifting up the membrane and adding a 250 mm strip (top-down). The strip has glue on its upper side, with a paper-cover that is removed, after the strip has been attached on the seam. The membrane is then put back on the strip, covering the seam (Figure 4).

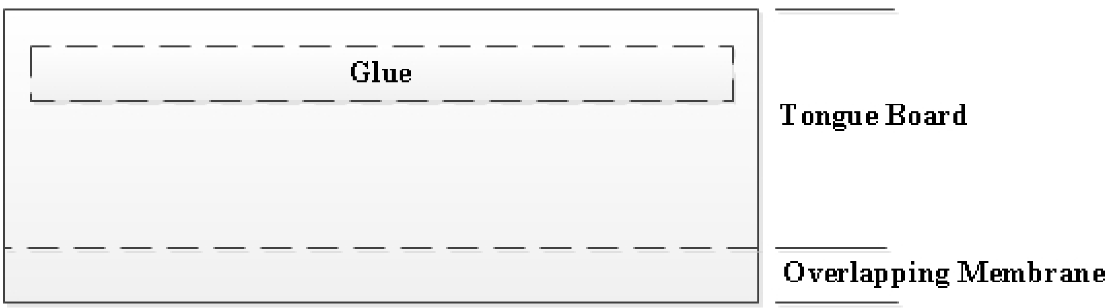

Figure 3: Tongue board

In this study, the parameters selected were: (P_1) customer needs, (P_2) waste on construction site and (P_3) worker safety during construction. *Customer needs* are analyzed to find to what extent customer needs are fulfilled. Depending on the level of fulfillment, it can generate product improvements. It is also important to evaluate whether the future value stream can deliver these needs. *Waste on construction site* focuses on what activities are performed at the construction site, whether they are value-adding or non-value-adding and what behaviors are generated by current product parameters. By analyzing process time, method and quality defects, an idea of the process and product attributes can be formed. *Worker safety* is the third parameter, analyzing the behavior and what possible risks the product might generate. This parameter can help in the development of more safety-oriented products.

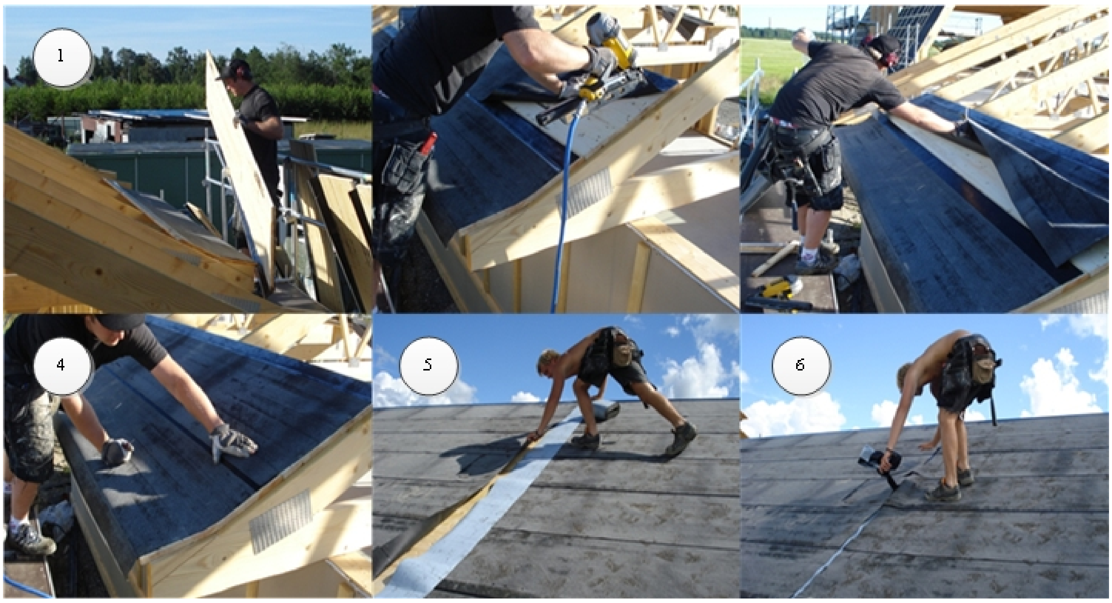

Figure 4: On-site assembly of product B

CASE FINDINGS

This section describes the research findings from the interviews and the participant observations. The participant observations are transformed into a VSM.

INTERVIEWS

The findings from interviews are summarized in Table 2. Other findings include the fact that customers are currently using product A because they think it is more stable than competitors' products. People from on-site production that had used the product previously stated that "it is faster than assembly of tongue panels". People from on-site production that had not used the product were less positive towards the product. The value parameters are that respondents wish to reduce further the on-site assembly time and to reduce the risk of on-site accidents.

Table 2: Summary of the customer needs based on interviews: respondents A – C are people with purchasing roles; respondents D – F are people from on-site production

Value parameter	From respondent
1. Board should be adopted to truss interval	A
2.The board should stabilize the construction	A,B
3.Construction workers should be able to walk on the board after assembly	A, B
4.Assembly time should be reduced on-site	A, B, C, D, E, F
5.The boards must have a good fit (board to board connection)	F
6. Better quality wood to visible parts	A,B
7. Visual numbering on boards to simply assembly	B
8. Boards should individually adjusted to the project, not standard dimensions	A, B, C, F
9. Make larger boards that can be lifted with a crane	B
10. Project based packaging from factory (i.e. number of boards)	C
11. Reduce time on roof to minimize risk exposure	A, B
12. Reduce Weight	A

VALUE STREAM MAP

A VSM is visualized as described by Rother and Shook (1999). The observations are divided into observation 1 (product A) and observation 2 (product B). Observation 1 was made on-site, at a single family house (Figure 4) with two dormer windows, a roof sloped 34 degrees, 127 m^2 area and 1200 mm between trusses.

Figure 5: Observation object 1 and object 2

Observation 2 was made on-site, at a single family house with a garage (Figure 5). The house has a mansard roof, with dormer windows, (63° gradient, 179 m^2, 27° gradient, 126 m^2) and 1200 mm and 768 mm between trusses. The garage has a saddle roof with a roof slope of 27 degrees, 52.5 m^2 area, and 1200 mm or 900 mm between trusses.

The value stream map (Figure 6) shows that the house-building company gives the case study company an annual forecast of the total number of houses and a detailed report with a rolling 3 month horizon of the actual number of products sold.

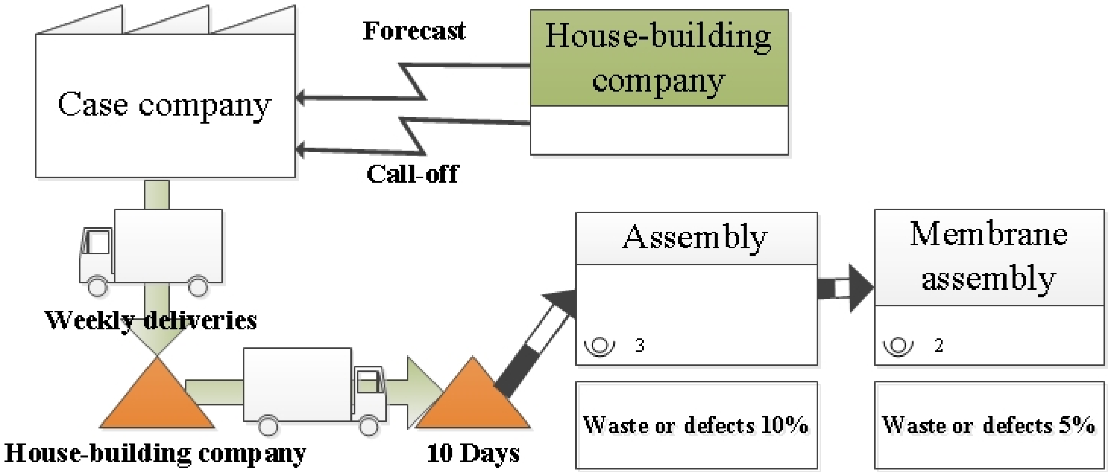

Figure 6: VSM

The house-building company makes a call-off, every week, which is delivered from the case company to the house-building central warehouse. The house-building company has a team that carries out project-specific picking, packing and deliveries to their construction site. On the construction site, the roofing process is either with (A) or without (B) membrane assembly. Cycle time (C/T) was calculated based on the total assembly time divided by the number of square meters covered so that both observations could be meaningfully compared. A summary of the value-adding and non-value-adding times is given in Table 3.

Table 3: Summary of activity type time and proportion of total time

Activity type	Product A Total time (min/m^2)	Product A (%)	Product B Total time (min/m^2)	Product B (%)
Value-adding time	0.69	18	1.04	28
Waiting	1.22	32	1.17	31
Moving	0.57	15	0.37	10
Movements	0.66	17	0.52	14
Re-work	0.53	14	0.39	10
Planning	0.16	4	0.25	7
Total	**3.84**	**100**	**3.74**	**100**

The observations revealed that there was a distinct learning curve for product B assembly, which caused a delay because none of the workers had worked with that type of product before. Another observation was that there were some quality issues with the delivery from the factory (membrane attached the wrong way on the tongue board and damage from transport) but also damages caused by handling on the construction site.

ANALYZING THE FRAMEWORK

Table 2 shows that customer needs dictate that the board should be easy to assembly and that it should stabilize the construction. The analysis also shows that fulfillment of customer needs 8 and 9 would also satisfy customer needs 1, 7, 10, 11 and 12. Hence, project-specific configuration of boards might meet all those requirements, although none of the respondents commented on this.

Waste on the construction site can be analyzed from the perspectives of value-adding and waste. Value-adding time is increased with the integrated membrane compared to assembly of the membrane at the construction site. In this study, waste, in the form of waiting time, is often caused by waiting for material or tools, or the construction workers waiting for each other. Material handling and unnecessary movements are other types of waste that can be reduced using product B. However, both products required unnecessary movement on the construction site, related to the movement and adjustment of the boards. Another observation was that product quality defects in the boards generated a lot of unnecessary movement and handling.

Worker safety is increased by the reduction of time on the roof, and thereby the risk of accidental falling, with product B. However, the increased weight of the integrated membrane (product B) increases the risk of strain injury.

If we were to analyze the VSM results alone, the conclusion might be that product B is a solution to the on-site requirements, but applying more value parameters to the analysis (*customer needs*, *worker safety*) makes the choice of product B as a solution less obvious. Since the small change in time per square meter cannot satisfy the other parameters (P_1 and P_3), the product is probably not a viable solution for single family houses. The case company also came to this conclusion and stopped further marketing of product B until these other parameters had been thoroughly investigated.

DISCUSSION AND CONCLUSION

We have developed and tested a framework for integrating VSM with the evaluation of other parametric values, which makes it possible to improve the production and the product development process performance in industrialized house-building. By the use of a case study, we tested the use of parametric VSM: the case company stopped selling product B until further investigations had been carried out. This framework gave the manager at a small company the opportunity to verify product parameters before proceeding with further production process development and marketing of product B. An additional benefit of the integrated framework is that the manager had time to understand the problem description and the suggested solution from a customer perspective.

The position taken is that VSM can be enhanced to support product development (Figure 1) by analyzing the relationship between the production process, product attributes and a number of defined parameters (P_1, P_2..., P_n). Customer requirements should always be P_1, but the others, P_2..., P_n, can be decided on by the investigator. However, the results do not conclusively prove or disprove this position and are based on a single case study.

The framework makes it possible to validate VSM solutions towards product parameters and compare current state designs with future state designs in respect of production efficiency. The framework needs to be further developed to define interfaces and the interrelationships between the different framework steps.

Our framework also made use of a method of collecting data for VSM for a project-unique product: video-recording. The video-recording helped us to categorize data, but also to verify findings with workers, which would not have been possible through discussions and field notes alone.

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