The study of a kitchen assembly process in industrial housing

Bildsten, Louise; Guan, Wei

Published in:
Proceedings of the 6th Nordic Conference on Construction Economics and Organization

2011

Document Version:
Peer reviewed version (aka post-print)

THE STUDY OF A KITCHEN ASSEMBLY PROCESS IN INDUSTRIALIZED HOUSING

Louise Bildsten
Linköping Institute of Technology/Linköping University, Sweden
louise.bildsten@liu.se

Wei Guan
Linköping Institute of Technology/Linköping University, Sweden
wei.guan@liu.se

The kitchen is the heart of the house where people spend much of their time. It is, therefore, an important room that requires high quality. Because construction is argued to be unproductive and wasteful with low quality, studying a kitchen assemblage in detail is of particular interest due to its complexity with many details. In lean, the visualization and transparency of processes is the core for waste reduction and improvement. Low productivity levels are often argued to depend on a lack of information about the root causes of process problems. Thus, more information about the installation process of kitchens by studying the process is needed to target the sources of problems in terms of waste. The purpose of this paper is to gain a further understanding of how value stream mapping can be used to identify different types of waste that occur when acquiring and installing kitchens. Value stream mapping is carried out through observations and interviews at an industrialized timber house manufacturer. Data analysis resulted in information about inconsistencies in the kitchen installation process, i.e. the root causes of costs and delays for the entire housing project.

KEYWORDS: industrialized housing, waste, kitchen assembly, value stream mapping

INTRODUCTION

The housing construction industry in the West has long been accused of being wasteful and underperforming, where quality is often poor and the building times are long and costly with endless corrections to defects after completion (Latham, 1994; Egan, 1998; London & Kenley, 2001; Briscoe *et al*., 2004). Houses are "unique products of art" (Bertelsen, 2004, p.51) with an undocumented and complex production process (Gidado, 1996; Winch, 1998), considered as craft production (Barlow, 1999). This makes it hard to control the process and its outcome. In contrast, the manufacturing industry is more efficient. Therefore, the housing construction industry has been advised to learn from manufacturing and in particular lean production to become more efficient (Koskela, 1992; Ballard & Howell, 1994a, b; Gann, 1996; Koskela; 2000; Ballard *et al*. 2001; Bertelsen, 2004).

In industrialized timber housing constructed with volume elements, 80% are made inside a factory (Stehn et al., 2008). Thus, standardized industrial procedures replace much of the craftsmanship procedures. The volume elements are standardized parts made by industrial workers using automated production, though specialized craftsmen still make the interiors. The procedure of installing kitchen cabinets is a complex assemblage with many details. The purpose of this paper is to gain a further understanding of how value stream mapping can be used to identify different types of waste that occur when acquiring and installing kitchens.

THEORETICAL FRAMEWORK

Lean thinking

"Lean" has been frequently discussed in the Western construction industry during the last 15 years (Koskela, 1992; Ballard & Howell, 1994a, b; Gann, 1996; Koskela; 2000; Bertelsen, 2004). The reason is that house construction, as most other industries, is an industry in need of high variety and high efficiency to satisfy demand. Many writers, e.g. Koskela (2000), argue that lean is the "medicine" to make this come true through lean construction. Lean is a business system that originates from Japan (Womack *et al*., 1990). It all began when Taiichi Ohno, a Japanese businessman, visited a Ford factory in the USA and became impressed by its fast assembly. However, through studies of the Ford factory, Ohno saw waste, the worst of which was all the unfinished cars that required rework after leaving the expensive, non-stoppable production line of Ford (Womack *et al*., 1990). Therefore, Ohno created the Toyota Production System, known to the world as lean production.

The core of lean is to reduce all forms of waste in a process (Ohno, 1988; Womack *et al*., 1990). Ohno (1988) identified seven types of waste, described in Table 1 below.

Table 1: Seven wastes (Ohno, 1988)

Type of waste	Explanation
Overproduction	Producing products not demanded by customer
Defect products	Producing incomplete or faulty products
Unnecessary movements	Moving around of people
Waiting	People not working
Unnecessary transports	Moving around of material
Excessive stock	Raw materials, semi-finished or finished goods not in process
Unnecessary processes	Extra work on products not required by customer

This original classification from Table 1 has also been accepted by lean construction scholars (Mossman, 2009). In lean, value is determined by what the customer is willing to pay for, what Ohno (1988) defines as "real work", the rest is waste. Therefore, all waste must be banished to maximize value. Rother & Shook (2003) argue that value stream mapping (VSM) is an excellent tool to identify waste.

Value stream mapping (VSM)

A tool within lean, value stream mapping (VSM) is used to visualize a *value stream* on a large-scale map and measure value in relation to waste (Rother & Shook, 2003). The total value stream is a series of actions that are required to bring a product through the flow from raw materials to the customer (Abdulmalek and Rajgopal, 2007; Rother and Shook, 2003). Still, mapping the total value stream is an extensive task and Rother & Shook (2003) argue that the value stream from the incoming truck to the outgoing truck of a manufacturing company is the most critical to begin with. Therefore, it is the value stream from incoming to outgoing truck that will be treated in this paper.

How to carry out VSM

According to Tapping *et al*. (2002) and Rother & Shook (2003), the procedure of conducting VSM is basically, through the use of pen and paper, to draw all the materials and information flows of a product starting with outgoing truck and ending with incoming truck to immediately see the root cause of actions. The product chosen should be one in need of an improved flow. When value stream mapping is visualized on a large scale, it is possible to see where value is created and find sources of waste. This first map is called the current state map. The map is then changed into a future state map that represents the ideal production process. Rother & Shook (2003) also propose a definition of a working plan with a follow-up to reach the future state. In this paper, a product in need of an improved process flow is chosen (here kitchen cabinets) and the value stream of the product is drawn from incoming to outgoing truck. Waste is then identified through the mapping. However, the preceding steps from Tapping *et al*. (2002) or Rother & Shook (2003) concerning future state mapping, etc. are not treated.

Potentials in using VSM

Many writers see great potential in the use of VSM. Álvarez *et al*. (2009) and Rother & Shook (2003) believe that the value stream mapping (VSM) tool is effective and provides both a good communication tool for practitioners and a reference model for theoretical analysis. Pavnaskar *et al*. (2003) emphasis the advantage of analysing the current state through the visualization of the relationship between material and information flows. They argue moreover that systemic vision provided for a product’s flow reflects manufacturing system inefficiencies and can be the starting point of a strategic improvement plan.

Limitations with VSM

There are, nevertheless, also limitations with VSM. VSM requires a massive data collection that must be repetitive to be worth the effort. Construction steps are often lengthy with high variability, making it difficult to collect meaningful data. Braglia *et al.* (2006) comment that VSM is a suitable tool for mapping the production processes of ‘low variety-high volume’ type companies. However, many companies are actually rather of a ‘high variety-low volume’ type with complex processes, where a VSM application will fail because of the inherent multiple flows. Another problem, as Kawasala *et al*. (2001) note, is that VSM lacks an economic measurement for “value”. Moreover, it is a paper-and-pencil based technique, so its level of accuracy is limited (Braglia, 2006).

Still, house construction is regarded as repetitive enough to benefit from VSM (Yu *et al*., 2007). Previous research of VSM in house construction has been conducted in onsite construction (e.g. Yu *et al*., 2009), but not in factory-build houses. Hence, the use of VSM in factory-built houses is considered important and relevant.

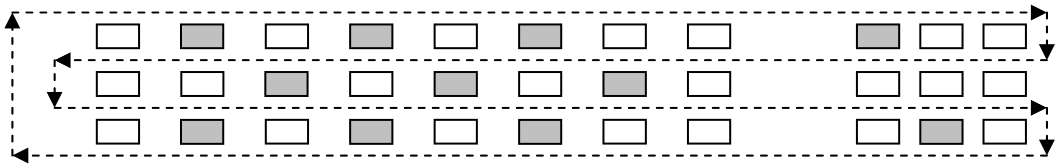
METHOD

A critical case study (Flyvbjerg, 2006) was chosen as an example of a housing factory that has emerged towards becoming a lean enterprise and thus a model for other house builders. The factory builds multi-storey timber houses through the construction of volume elements. Kitchen cabinets that are installed into the volume elements were chosen for the value stream mapping process (see Figure 1). The craftsmen installing the kitchen cabinets were observed for three months. During this time, all the steps in the kitchen assembly process, from delivery of the cabinets to assembled kitchens leaving the shop floor, were identified.

Figure 1: Kitchen installation in a volume element

The installation of the cabinets was rather complex and consisted of several steps that were observed in detail over several weeks. Thereafter, the cycle time for all of the different installation steps for 10 kitchens was measured. The operation times were measured by observing the kitchens for eight days during factory working hours 6.30-16. Each kitchen was observed every 15 minutes and how far the installation of the cabinets had proceeded was noted. Visiting the kitchens every 15 minutes was done systematically (see Figure 2).

Figure 2: Path of making observations in the three production lines

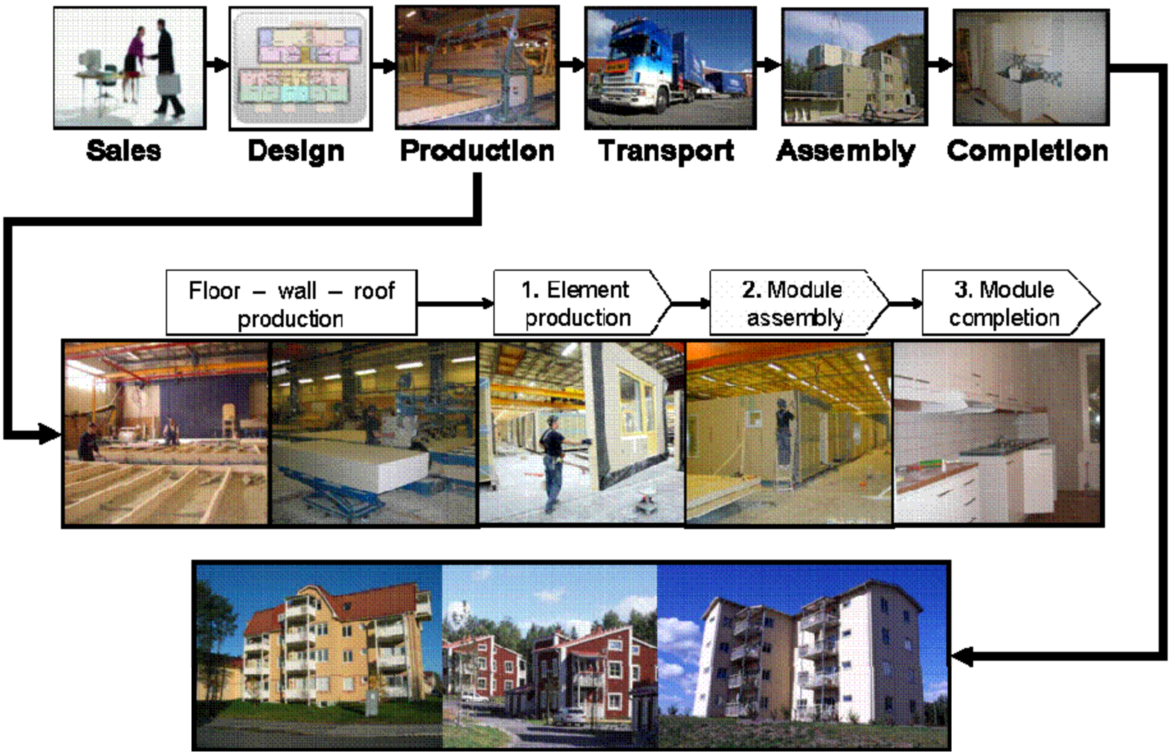


Three production lines of timber volume elements were observed where every second or third element contained a kitchen, shown as shadowed squares in Figure 2. Ten craftsmen were observed and interviewed, and asked the five whys to get to the bottom of problems. The five whys method means asking “why?” to someone five times about a cause to pin-point the source of problems (Ohno, 1988). The cycle times and waiting times were then plotted into a value stream mapping diagram (see Appendix).

CASE STUDY: INDUSTRIALIZED HOUSING FACTORY

The company studied is a housing factory in Sweden with a turnover of approximately 50 M€. The company produces multi-storey timber houses of two to six floors. At present, the company is in the process of implementing lean throughout the entire organisation.

Figure 3: The production of industrialized housing (our scope is in the module completion process)



The value stream mapping process started through the identification of the different kitchen installation steps and the start and end of the process. The different installation steps in production were identified as arrival, sorting, carpentry, tiling, electrical installations, plumbing, air check and preparation for transportation. Once identified, all the steps were studied in detail.

Arrival of cabinets

The cabinets arrived by truck every Tuesday morning, and the cabinets were placed outside the storage room. The time was measured for the unloading of the cabinets and estimated to an average of 15 minutes per truck load.

Sorting of cabinets

After the cabinets arrived, they were placed inside the storage room and sorted depending on which department they belonged to. All of the small pieces that fasten the cabinets to the wall and ceiling, belonging to each of the departments, were sorted according to type. The cabinets were then gradually moved down to be quickly accessible for transportation to the production line. The small pieces were sorted again according to their approximate usage for the specific kitchen. However, many of the small pieces were disposed of.

Carpentry

The process of installing the cabinets into the volume elements starts by measuring where the upper cabinets should be placed. A supportive board is placed to facilitate attachment of cabinets to the wall. The cabinets are then installed one-by-one and attached to each other where any accessible timber frame inside the wall is lacking. When installation of the upper cabinets is complete, it is time to install the lower cabinets. These cabinets have feet to create a space between them and the floor. The process of installing the lower cabinets begins by attaching the feet under the cabinets. A supportive board is attached to the side of the wall before putting the first cabinet in place, creating a space to open the cabinet door. The cabinets are installed one-by-one just as the upper cabinets. However, the cabinet under the sink is different, since holes must be drilled for the plumbing and electrical installations before installation. When all the cabinets properly installed, it is time to attach the sink. To attach the sink, glue is placed around the edges and the sink is pressed into place. Tools hold the sink in place as it is attached further with screws. The carpentry around the cabinets and the countertop are then put in place. This is the longest phase, since the pieces have to be cut to exactly fit the spaces. Running back and forth to the saw on numerous occasions is common here. One carpenter said, “Once I put a step counter in my pocket and it showed that I walked 3 km during one workday in the factory”. This shows many movements during the carpentry. All the edges are then sealed with silicon suture and tippex is used to cover the spots. After, the doors are attached and adjusted to the cabinets. The whole installation phase takes 11 hours.

Tiling

Tiles in the kitchens between the upper and lower cabinets are called the splashboard. A prerequisite before beginning the tiling is that the countertop, sink and upper cabinets are already installed. The process begins by applying mortar to the wall, and then applying the tiles to the mortar. Tiles lacking the appropriate size are cut to fit. A thread is placed underneath to create a space for the silicon suture. The tiling takes around 2.5 hours.

Electrical installations

A sub-contractor carries out the installation of electrical sockets. Drawings of where the electrical sockets should be placed guide the electrician. The electrician prepares a box of electrical sockets and installs them in the kitchen. Each kitchen has an average of 10 electrical sockets. If the placement of the electrical sockets is accessible, a socket installation takes approximately 5 minutes. However, the sockets are occasionally placed in hard-to-access areas, e.g. inside a narrow cabinet under the refrigerator, and installation then takes approximately 15 minutes. The electricians complete a form when the electrical installations have been made. However if the tiling has not already been made, all sockets cannot be installed. Depending on the number of sockets and their accessibility, the time for electrical installation varies from 30 minutes to 2 hours.

Plumbing

The plumbing is carried out by the house manufacturer’s own plumbers. The work of installing pipes below the sink does not vary greatly between kitchens. The only prerequisite before installing the plumbing is that the sink is installed. The plumber installs the tap and the pipes connecting the tap to the pipes, which penetrate the floor from below. Installation of the pipes and tap takes approximately 30 minutes.

Air check of pipes

The pipes are exposed to an air pressure of 1.5 bars for at least 30 minutes to ensure no leaks. Before exposure, all pipe-ends are sealed and the closures are removed after testing. A visual quality control of the pipes is made after the air test. The whole procedure of testing and controlling the pipes takes about 1 hour and 30 minutes.

Preparation for transportation

At the end of the production line, the volume elements including the kitchens are controlled before transport to the warehouse. At the quality control station, a check is conducted that all the cabinets are installed with no missing parts, that the electrical installations and plumbing have been made, and that there is no damage. Missing materials are documented in an online system connected to the purchasing department. Incomplete kitchens are often caused by customers not making choices on-time. Borders between volume elements can sometimes be a hindrance for some cabinets to be installed which prevents the execution of subsequent steps. This workstation also has the responsibility to sweep the floors and remove garbage that other workers have left behind and add some extra silicon suture where needed. The quality control takes approximately 45 minutes. The volume elements then exit the factory in a special order to facilitate assembly.

ANALYSIS

During the observations of the process of kitchen installations, different kinds of waste were found. The waste found in each of the installation steps will hereby be described.

The beginning of the process, as previously mentioned, is the arrival of the truck with cabinets. After the cabinets are discharged from the truck, they are not immediately put into their proper places, but aside, outside the warehouse. This causes unnecessary extra transport later when bringing them inside the warehouse, which is a form of waste.

The cabinets and adjoining pieces are then sorted. Here, the pieces are sorted twice, first according to type and thereafter to a specific kitchen. This is waste in terms of the unnecessary transport of materials. Moreover, the cabinets had to be moved around in the warehouse due to the lack of space, which also is a waste.

Carpentry is the most time-consuming step in the process of kitchen installation, accounting for approximately 40 per cent of the total production time. The calculation is based on data in the Appendix for cycle time of the processes. Carpentry is probably the most non-standardized and skill-intensive work compared to other steps in kitchen installation. The carpentry procedure of kitchen installations is not a standardized industrial process at present, it requires skilled carpenters. Therefore, the pace and quality of the work depends on the person's ability to structure the work and evaluate quality. Working independently can be a source of waste because of a lack of coordination, communication and motivation, which are necessary to drive up the pace of production. When observing the carpentry, many issues were discovered, such as half-finished kitchens that had to be further worked upon on-site. The causes were many, such as inadequate drawings, the customers' choices were not available and parts were missing, or the volume elements had borders that prevented complete cabinet installation. The carpenters moved around a great deal to saw the pieces, putting into questions the placement of the saw and the accuracy of measurements of the volume elements. After installation, the cabinets were constantly in need of finishing, such as silicon suture and tippex to hide defects.

Tiling, electrical installations, plumbing and the air check of pipes were all rather quick steps considering the total process time. In these processes, no waste was detected other than the lack of communication with upstream and downstream workers, which could cause interruptions of the production process. Although the activities themselves did not have any waste, if all the cabinets including the sink were not installed, most of these activities could not be executed. This caused half-finished kitchens without any activity for many hours, taking up space while waiting to be transported out of the factory.

The last step is the preparation for transport of the volume elements and ensuring that everything is included or backordered. Controlling this at the very end can be regarded as waste, because it is in fact rework of the previous quality checks. Everything should already have been completed! However, due to the inconsistencies in the process, it is necessary with this control.

In Table 2, different wastes detected in the process are categorized into the different kinds of waste that Ohno (1988) describes.

Table 2: Wastes detected in the process

Type of waste	**Where waste is found in the process**
Overproduction	There was no overproduction detected. Everything is make-to-order/engineer-to-order.
Defect products	The factory produces incomplete kitchens because the customers' choices were not available so parts were missing or the drawings were inadequate. The volume elements have borders that sometimes prevent complete installation of the cabinets. The cabinets need finishing, such as silicon suture and tippex to hide defects.
Unnecessary movements	There are a lot of movements to walk back and forth to saw new pieces and make the cabinets fit inside the volume element.
Waiting	As the carpenters are multi-skilled, they normally do not have to wait to assess a task. There are always different tasks ready for execution. However, when drawings are unclear, carpenters have to wait for instructions.
Unnecessary transports	The kitchen cabinets are moved around in the warehouse three times before reaching the assembly line.
Excessive stock	There are a lot of semi-finished kitchens waiting for the next step. A lack of communication between upstream and downstream workers can sometimes cause interruptions in the production process.
Unnecessary processes	Control of all previous craftsmen's work at the end of the line.

CONCLUSIONS

Value stream mapping with detailed observations of the product flow through the factory is valuable for detecting waste. By writing down the process on paper, the process is visual for discussion. Otherwise, undocumented processes can be interpreted differently by different people in the organisation. Hence, management may not be aware of the problems that cause waste and costs in a process on the shop floor might not be detected. To systematically follow a process is lengthy, though a deeper knowledge is obtained than assuming the character of the value stream through second-hand descriptions.

In this study, waste occurred mainly in terms of defect products, e.g. the products were unfinished when leaving the factory. Ohno (1988) saw this as the worst waste when studying Ford. It becomes rather expensive to fix all the completions afterwards. The roots of the problems were inadequate drawings and customers not making choices on-time. Through enforcing choices to be made on-time and avoiding cabinet being placed on borders between the volume elements, the kitchens can all be completed in the factory. This saves a lot of money in extra work and transports to the final location of the house.

The inaccurate sizes of the volume elements require an extensive amount of sawing when installing the kitchen cabinets. By placing the saw closer to the carpenter or working on improving the accurateness in size of the volume elements, the waste in form of unnecessary movements can be eliminated.

Since there is a problem with unclear drawings, standardizing and documentation of “best practise procedure” of installation with improved drawings and proper work instructions can make the installation process more efficient. Hence, instant comprehension in how to proceed with the next task can be achieved and waste in terms of waiting is eliminated.

There is waste in terms of unnecessary transports inside the factory. When the cabinets arrive, they should be placed at a given place until it is time for installation. This prevents damages and waste in terms of rework when moving them around the factory.

The semi-finished kitchens could be finished faster to prevent bottlenecks if a signal system is installed to signal downstream workers to prioritize the most critical work tasks. This prevents waste in terms of excessive stock and delays in the process.

If all the workers do self-check of their own tasks and report errors of their own work, the quality control could be eliminated and inconsistences in the process can be better visualized through everyone’s participation in improving the process and quality of the kitchens.

It can be concluded that a detailed study of the production process is important for process improvement. Without a close study of the value stream in progress, there is a lack of understanding regarding wastes that become hidden costs in the process.

ACKNOWLEDGEMENTS

We want to thank the Lean Wood Engineering programme for making this study possible. Additionally, we would like to thank all our reviewers and Jakob Rehme and Bozena Poksinska for their advice and support in reading the manuscript.

REFERENCES

Abdulmalek, F.A. & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study", *International Journal of Production Economics*, 107, 223-236.

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

Ballard, G. & Howell, G. (1994a). Implementing Lean Construction: Stabilizing Work Flow. *Proceedings of the 2nd Annual Conference of the International Group for Lean Construction*, Santiago, Chile.

Ballard, G. & Howell, G. (1994b). Implementing Lean Construction: Improving Performance Behind the Shield. *Proceedings of the 2nd Annual Conference of the International Group for Lean Construction*, Santiago, Chile.

Ballard, G., Koskela, L., Howell, G. & Zabelle, T. (2001). Production System Design in Construction. *Proceedings of the 9th Annual Conference of the International Group for Lean Construction*. Singapore.

Barlow, J. (1999). From Craft Production to Mass Customisation. Innovation Requirements for the UK Housebuilding Industry. *Housing Studies,* **14** (1), 23-42.

Bertelsen, S. (2004). Lean Construction: Where are we and how to proceed? Lean Construction Journal. **1**, October.

Braglia, M., Carmignani, G. & Zammori, F. (2006). A new value stream mapping approach for complex production systems. *International Journal of Production Research*, 44 (18-19), 3929-3952.

Briscoe, G.H., Dainty, A.R.J., Millett, S.J. & Neale, R.H. (2004). Client-led strategies for construction supply chain improvement. *Construction Management and Economics*, **22**, 193-201.

Egan, J. (1998). *Rethinking construction.* DETR, London.

Flyvberg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, **12** (2), 219-245.

Gann, D. (1996). Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan. *Construction Management and Economics*, 14, 437-450.

Gidado, K.I. (1996). Project complexity: The focal point of construction production planning. *Construction Management and Economics,* 14, 213-225.

Khaswala, Z. and Irani, S. (2001). Value Network Mapping (VNM): visualization and analysis of multiple flows Value Stream Maps. *Proceedings of the Lean Management Solutions Conference,* St. Louis, 2001.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Technical Report # 72, Center for Integrated Facility Engineering, Department of Civil Engineering, Stanford University, CA.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction*. VVT Technical Research Centre of Finland.

Latham, M. (1994). *Constructing the Team*. HMSO, London.

Lessing, J., Stehn, L. & Ekholm, A. (2005). Industrialised housing: definition and categorization of the concept. *Proceedings of the 13th Annual Conference of the International Group for Lean Construction,* Sydney, Australia.

London, K.A. & Kenley, R. (2001). An industrial organization economic supply chain approach for the construction industry: a review. *Construction Management and Economics,* **19** (8), 777-788.

Mossman, A. (2009). Creating value: a sufficient way to eliminate waste in lean design and lean production. *Lean Construction Journal*, **5**, 13-23.

Ohno, T. (1988). *Toyota Production System: Beyond Large-scale Production*. New York: Productivity Press.

Rother, M. & Shook, J. (2003). *Learning to See – Value-Stream Mapping to Create Value and Eliminate Muda*. Cambridge: Lean Enterprise Institute.

Stehn, S., L.-O. Rask, L., Nygren, I. & Östman, B. (2008). *Byggandet av flervåningshus i trä: Erfarenheter efter tre års observation av träbyggandets utveckling.* Technical report. Luleå University of Technology

Tapping, D., Luyster, T. and Shuker, T. (2002). *Value Stream Management*, Productivity Press: New York.

Winch, G. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research and Information*, **26** (5), 268-279.

Womack, J. P., Jones D. T. & Roos, D. (2007). *The Machine that changed the World.* Free Press.

Yu, H., Tweed, T., Al-Hussein, M. & Nasseri, R. (2007). Management variability in house production. *Proceedings of the 15th Annual Conference of the International Group for Lean Construction,* Lansing, Michigan.

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


Kitchen manufacturer
Construction site
Production control
Purchasing
House plans 10 weeks before delivery
Orderconfirmation 6 weeks before delivery
Delivery according to list
1 delivery per week
Cabinets (one by one)
Unloading
Sorting
Installation
Electricity
Tiling
VVS
Air check
Control
Truck 15 min
Intake 10min
1st sort 10 min
2nd sort 10 min
Control 2 H
To line 1 H
Upper c. 1,5H
Lower c. 2,5H
Small pieces 4,8H
Prepare 10 min
Sockets 50 min
Tiling 2,25H
Tap 5 min
Pipes 25 min
Seal 10 min
Measure 40 min
Unseal 10 min
Control 15 min
Control 20 min
Suture 20 min
Sweaping 15 min
Marking 10 min
Doc. 5 min
To storage 5 min
0,03 H
80 H
3,5 H
0,25 H
8,8 H
0 H
1 H
0,5 H
2,25 H
3 H
0,5 H
0,5 H
1,25 H
9 H
0,75 H
18,08 H
93,25 H
16%