Increasing Takt of Production

at SKANSKA Byggsystem

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Abstract

This project was carried out because of a need for increasing the production efficiency at SKANSKA Byggsystem. The current production takt is 20 modules per week which at first step should become 24 modules per week and in a second stage, 28 modules per week.

In this regard, the lean approach is applied to modify the procedures the production processes are based on. Value Stream Mapping is used as one of the lean tools to illustrate the total image of the operations and lead times. Although it is essential to consider both the production and administrative procedures in analysis and implementing Lean tools, in this project the focus is on production operations and material flow rather than the information flow.

In the empirical study, different production areas in the factory are considered and the material flow is described from storage of raw material until storage of finished modules. The empirical study has resulted in a description of the current situation of the factory and current value Stream Map is drawn based on that.

In the analysis part, different areas of waste in the production stages are defined and modifications for eliminating waste and increasing efficiency are suggested; having the main criterion of enabling the production to produce 28 modules per week, these changes have resulted in a future state Value Stream Map of the factory. In addition, modifications regarding the factory layout and outsourcing strategy are described as well.

Finally, it is discussed that with minor changes it is possible to produce 24 modules per week. It is shown that by keeping the same resources and production methods, it is impossible to have 28 modules per week, although, outsourcing the bathroom module results in a great improvement, however this is not enough for providing required extra capacity. The most applicable approach is to implement the changes and improve the production procedures to get to the maximum available capacity and add extra resources to provide the required capacity of 28 modules per week.
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1 INTRODUCTION

This document is the report of a master thesis project in the field of Logistics. The project is carried out by Hamed Yazdani, MSc student of Logistics at ‘Högskolan i Borås’ (HB), in response to efficiency improvement requirements at SKANSKA Byggsystem. Current average takt of the factory is 20 modules per week. The company intends to increase its takt to 24 modules per week in the first stage and 28 modules per week in the second stage. In this regard, Value Stream Mapping (VSM) will be introduced as an approach to provide a tool which makes it possible to visualize the whole flow of materials and information in the factory rather than just individual processes. By utilizing VSM, the current state of materials and information flows will be drawn and root causes of problems will appear and be easier to solve. With the help of other activities in the Lean concept such as 5S, TPM, Continuous flow, Pull system, Kanban etc. the whole flow will be improved and ideal future state map will be drawn. The future state map will be considered as a goal which all team members should strive for.

1.1 BACKGROUND

Traditionally companies set their prices according to the following formula:

\[ \text{Price} = \text{Costs} + \text{Profit margins} \]

The accounting department would determine the total cost and a profit margin typical for the industry would be added to the costs and the final price would be passed on to the customer. However, in today’s competitive market, price is considered as fixed or even falling and the following new equation applies to the new economical situation (Dennis, 2002):

\[ \text{Profit} = \text{Price (fixed)} - \text{Costs} \]

![Figure 1: Profit margins with fixed price](image)

In such an environment the only way to increase profit is to reduce costs. This can be done by utilizing the Lean approach and eliminating unnecessary activities known as ‘waste’. In this approach team members are involved in shared, standardized improvement activities. Lean production which is also known as the Toyota Production System (TPS), means doing more with less, while providing customers what they want.
The bases for the Lean system are Stability, Standardization, Just-in-time and Automation with Customer focus as its goal. In addition, involvement of flexible, motivated team members who continually seek a better way is the system’s heart and main tie which binds other activities together (Dennis, 2002).

Manufacturing companies stay in business because they transform raw materials into finished goods that their customers value. Processes transform material into products and operations are the actions (painting, cutting, grinding, plumbing, etc.) that bring about those transformations. Operations are considered the process elements that add value, but processes also include non-value-adding elements. However, a value stream consists of all elements; both value adding and non-value-adding activities that make the transformation possible (Tapping D. et al. 2002).

Required management actions to produce a specific product might be considered as managing following issues (Keyte B. et al. 2004):

1. Problem solving (e.g., design, production planning)
2. Information management (e.g., order processing and other nonproduction activities)
3. Physical transformation (e.g., converting raw materials to finished products)

As Keyte (2004) indicates management of these value streams involves a process for measuring, understanding, and improving the flow and interactions of all the associated tasks to keep the cost and quality of a company’s products as competitive as possible. More important, value stream management sets the stage to implement a lean transformation throughout the whole enterprise and keeps an organization from falling back into the traditional suboptimal approach of improving departmental-level efficiencies. A basic, but powerful, two-dimensional tool to help the management process is value stream mapping. It documents and directs a lean transformation from a ‘big picture’ perspective.

It is important to have the entire picture of the plant in mind, and not just individual processes. In this regard there are two main flows which might be considered: (1) the production flow from raw material into the arms of customers and (2) the design flow from concept to launch (Rother M., Shook J., 2003). However, having in mind the SKANSKA case our focus is on production flow. Taking the value stream perspective means working on the entire picture and improving the whole, not just optimizing the individual processes.

What is meant by Value Stream Mapping is simple: follow the product’s production path from customer to supplier and carefully draw a visual representation of every process in the material and information flow, which is called “current-state “map. Then ask a set of key questions and draw a “future state” map of how value should flow (Rother M., Shook J., 2003).

By implementing value stream mapping continued opportunities can be identified to enhance value, eliminate waste, and improve flow, this is not the end, but the beginning of the journey in value stream management (ibid).

In implementation of the Lean concept VSM is an essential tool because (Rother M., Shook J., 2003):
- It helps to visualize more than just the single-process level, i.e. painting, flooring, assembling, electricity, etc. in the production and one may see the whole flow.
- It helps to see more than waste. Mapping helps to find the sources of waste in the value stream.
- It provides a common language for talking about manufacturing processes.
- It ties together lean concepts and techniques, which helps to avoid “cherry picking”.
- Value stream maps function as blueprints for lean implementation; imagine trying to build a house without a blueprint!
- It shows the linkage between material and information flows, which is a very important function and no other tool does this.
- VSM is a qualitative tool by which one may define how a facility should work. Numbers are good for creating a sense of urgency or in comparison measures but VSM describes what should be done to affect the numbers.

SKANSKA Byggsystem is a factory building modular houses and requires improvements in its manufacturing operations and processes. The main issue is the requirements regarding increasing efficiency of production to increase takt of production. In this regard, Value Stream Mapping is a proper tool to implement for clarifying the whole situation of the factory and reveal improvement potentials.

Lean concepts and methods are applicable to SKANSKA’s situation, since the core competence of SKANSKA Byggsystem is its unique production system which makes it possible to cut costs and provide a final production with a very competitive price and in a very short time. By application of lean tools and eliminating wastes in the production processes it is possible to utilize the capacity of the plant in a more effective and efficient way. When the bottlenecks are revealed and pacemaker process in the factory determines the speed of production, decisions regarding the possible takt time will be more realistic and practical. As an expected result, takt time will be reduced and the continuous flow of material in a leveled production increases efficiency.

In addition, the project results might help the management to decide if the activities should be in- or out-sourced. Since the production volume is to become leveled in different processes and sources of wastes will be identified, it would be easier to make decisions about the activities which are directly related to plants core competence and those which are not might be outsourced.

1.2 COMPANY DESCRIPTION

SKANSKA Byggsystem is a part of the SKANSKA concern and manufactures modular houses. It is located in a small city called Gullringen in eastern part of Sweden. The company has 100 employees of which 90 ones are blue-collar. Working shifts considered in this project includes only one shift of 44 hours per week. SKANSKA Byggsystem has two main partners regarding the design and ownership of the modular house concept. These two partners are IKEA and Boklock.
Most of the parts are manufactured from raw materials. However, there are some items like, doors or windows which are prefabricated and purchased from outer suppliers. There are also items like, kitchen parts that are assembled in the factory before installation.

There are two main types of products, apartments and villas. Both villas and apartments are manufactured at the factory in the form of modules, for example each apartment is made up of 12 modules. These modules are built in the factory and sent to customer’s site for erection. The houses are sold to first tier customer who usually rent out the facilities to end user customer.

Regarding the volume of orders, SKANSKA Byggsystem has already filled its capacity for the next three years. Therefore, it is not the main concern of the company to find new markets neither is the obsolescence of the products. It is reasonable to assume the company is able to sale all of its manufactured products.

1.3 Purpose

The factory aims to increase its current takt of production from 20 modules per week to 24 modules per week in the first stage and to 28 modules per week in the second stage.

The purpose of this project is to propose modifications in the material flow and information flows in the production process in order to increase production takt. The method used for mapping the flows and proposing changes is Value Stream Mapping. However, it should be noted that mapping is just a technique. The important point is to implement a value-adding flow in which the value is defined by the customer. To create this flow a “vision” is necessary and mapping just helps to see and focus on flow with a vision of an ideal situation, or at least improved situation. The limitations considered in this project are described in the following part.

1.4 Scope and Delimitations

The scope of this project will be the “door-to-door” production flow inside the plant, including shipment to the customer’s field and delivery of supplied parts and materials.
As implied in the purpose, the main focus is on the production areas and operations to increase the efficiency and takt of production. The main limitation assumed in the project is the fixed number of working staff. The modifications are proposed to enable the factory to increase its takt having the same number of working hours and human resources. Since financial comparisons are not considered in the scope of this project, financial limitations are not defined explicitly and decision making regarding the modifications is up to the management team.

It is worth mentioning that amongst different value streams of design, information flow and physical transformation the focus is only on the last part. However some aspects in the information flow which directly affect the production process are considered as well.
2 Methodology

This chapter outlines the methodology that has been followed throughout the project. It includes research design, data collection and credibility of the project. Information about current state of the factory is gathered in the first stage and based on the purpose of the project the current state is analyzed by implementing the VSM tool. Afterwards, required changes and improvements are suggested in a so called ‘future state map’.

2.1 Research Design

There are many ways to design a study. Different approaches include experiments, surveys, archival analyses, history and case studies (Yin, 2006). However, the appropriate research design depends on a number of characteristics of the situation at hand. First of all, the type of research question is a dominant determinant. The more open and broad the question is, the less structured and closed should the research design be. In addition, the extent of control the investigator has over events play an important role in designing the study as well. For example, if the level of control is low, experimental study designs are hard to carry out. Finally the focus on contemporary phenomena as opposed to historical phenomena is an important factor in selecting a strategy (ibid).

As a general rule, case studies are the preferred strategy when the investigator has little control over events and when “why” or “how” questions are posed regarding contemporary phenomena.

The search for ways to improve the efficiency and effectiveness of the production procedure at SKANSKA Bygg system is certainly a broad and open question. The level of control is low in many aspects. Besides, the scope of the study changes as the interviews uncover new areas of investigation. The case study research design offers the best way to deal with these ongoing contemporary challenges and grasp the complexity of the task at hand.

Although the case study design is widely used, there are some traditional arguments against it. The most common one is that it leaves little room for generalization (Yin, 2006). This is however not a problem since the objective of this project is to identify and suggest solutions to the problem with production efficiency and effectiveness and its consequences on other aspects at the factory and not to provide general recommendations. Another problem is that case study design is often confused with case study teaching, where reality may be adjusted to emphasize a learning point. Finally, some argue that case studies are too time consuming and that the results are massive and unreadable. These problems can be referred to the methods used within the overall strategy, not to the case study design in itself. It is absolutely possible to conduct a case study that is neither time consuming nor incomprehensive (Yin, 2006). Within the case study, there are two fundamental means to combine empirical data with theory; induction and deduction. Induction refers to creating theory from actual knowledge. This means that the case study is used to come up with conclusions that lead to new theory. Deduction is the opposite, when theory is used to draw conclusions about the empirical data in the case study (Arbnor, 1994). This study is inductive in the beginning, since the problem definition stems from information received from SKANSKA and is not based on theory. After the planning phase, however, neither of the two approaches
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describes the intentions in the project in a satisfying manner. Dubois and Gadde (2002) provide a useful alternative. The abductive approach implies that theory and empirical data are used interchangeably and is especially useful for single case studies. This approach has therefore been applied in the main phase of the project. See Figure 3.

![Abductive approach diagram]

**FIGURE 3: THEORY VS. EMPIRICAL KNOWLEDGE (PATEL ET AL 2003)**

### 2.2 Data Collection

To achieve the purpose of the case study, qualitative along with quantitative data collection methods have been used. In this project, both primary and secondary data have been used. Primary information refers to collection of new data. There are three main methods to collect primary data; direct observation, interviews and experiments (Arbnor, 1994). Interviews and observation have been used in this case study. Experiment is not a suitable way to gather data in this project since there was not enough access to extra capacity of the factory to conduct experiments. The problem with ensuring repeatability of experiments is another valid reason not to choose this data collection method. Use of secondary data refers to already collected material (Arbnor, 1994). This method means huge savings in time and money but entail potential problems (Ghauri et al., 1995). Since the data have been collected for another purpose they may not cover all of the required aspects of the case study and they might not be directly related. Moreover, the accuracy of the data is harder to guarantee. It is therefore important to be critical and careful when using secondary information (Arbnor, 1994). In this project, internal electronic sources and internal documentation have been used as secondary data. The characteristics of the used data collection methods are outlined below.

#### 2.2.1 Direct Observation

Direct observation is a data collection method where the purpose is centered on learning by observing, as opposed to indirect observation where the learning mainly originates from another method and observing only serves as a complement (Arbnor 1994). Observation has been used for mapping material
flows and production operations. In addition to gathering lacking information regarding flows, the peripheral aim was to derive own perspectives and insights as a complement and verification to the information retrieved through interviews and existing documents. Moreover, observing the operations in the factory was a good way to increase the general understanding of the functions and activities of the factory.

Observation is a classical method of studying a problem which captures the social dynamics of a situation. This means that behavior and activities can be interpreted easily which would not be possible with other methods such as questionnaires and interviews (Ghauri et al., 1995). However, since observation covers events in real time it is a rather time consuming process and therefore they require extensive resources and time to represent correct results. Moreover, there is a risk of reflexivity, meaning that the studied event may proceed differently because it is observed (Yin, 2006). To reduce these disadvantages, all data gathered through observation are, if possible, supported by data from other data collection methods, such as cross-checking and interviews.

2.2.2 Interviews

Interviews are good in the sense that they are targeted and focused directly on the case study topic (Yin, 1994). They can be divided into personal, telephone, post and group interviews (Arbnor, 1994). For the purpose of this study, personal interviews have been used.

Interviews can be standardized, unstructured or semi-structured (Ghauri et al., 1995). Standardized interviews means that the same questions are asked in all interviews, preferably with closed questions meaning that there is a set of answer alternatives (Arbnor 1994). Although, these types of interviews are easy to analyze with high quality results they are not suitable in this project since the questions are of a type that require explanation and discussion. Instead, semi-structured interviews are more appropriate. This interview method means that topic and lead questions are decided on beforehand while the interviewee is given full freedom to discuss anything within these limits (Ghauri et al., 1995). This method provides different aspects in the answers that are needed to solve the problems which this project consists of.

Since the personal interview method involves contact between people, there are several possible risks and drawbacks that need to be considered for the method to reach its full potential. First of all, the answers are only as good as the questions asked. If the questions are poorly constructed there may be misunderstandings. Moreover, there is always some extent of response bias meaning that the answers given are subjective. Furthermore, the responses given are subject to interpretation which may be different depending on who is carrying out the interview. Finally, the interviewer influences the interviewee. The way in which questions are asked and the body language of the interviewer may reveal values and attitudes that affect the thoughts of the respondent. Also, reflexivity may occur meaning that the interviewee tells the interviewer what he thinks is expected from him, or lies because there is a lack of trust. (Yin, 2006)
2.2.3 Theory

Theory development prior to the data collection is essential in case studies, especially in the planning phase (Yin, 2006). It provides an overview of the studied area and can serve as guidance regarding what data is needed and how it should be analyzed. In this project, a literature review prior to framing the purpose of the study was not that important, since the problem and objective of the project were already defined. Theory was, however, important throughout the remainder of the project. It is important that all analysis, conclusions and recommendations are based on theory to be able to deliver a trustworthy result.

The supporting literature covers the following areas:

- Lean manufacturing
  - Value Stream Mapping
- Operations management

It should be noted that the theory from the literature study has been used in the analysis part to provide a proper link between related literature and existing data. In this way the results from the analyses are verified with literature and the reader can see the logic of results in a more clear way.
2.3 CREDIBILITY

To start with credibility of data one may consider three stages, data gathering, data processing in analysis part and output. In the data gathering stage most of the data are gathered either from current available files at the company or interviews. In case any data did not comply with the interviews or actual observations, it is assumed that interviews and direct observations provide the more accurate information. In addition, the data have always been cross checked with different sources to create a higher assurance regarding their accuracy.

In the second stage where the input data are processed, it is important to consider the required level of accuracy in analysis and reporting the output. In most cases the analysis is done to show the possibility of improvement in a specific operation. For instance, it is not really intended to calculate the exact capacity for an operation. The intention is to show there is an opportunity to improve the Overall Equipment efficiency (OEE) and general advices are provided to increase the efficiency of the operations, so the main effort has been put to reveal the problems and find out the potential improvement areas. However, the numbers are calculated as accurate as possible and it is attempted to have reasonable assumptions in the calculations.

The last part in analysis is creditability of outputs which directly depends on accuracy of input and precision of the analysis; correct input and correct processing should result in correct output. The output is structured in such a way to comply with the purpose of the project. Different suggestions are provided to increase the production efficiency and provide a smooth flow of materials. Besides, long-term effects and requirements of the suggestions are considered to solve the current problem.
3  THEORETICAL FRAME OF REFERENCES

There are different approaches to reduce the lead-time which results in an increasing takt of production. The one that is mainly discussed in this project is implementing lean tools to eliminate wastes. Therefore it is important to understand the lean philosophy and tools. In this regard, definition of waste and different kinds of waste is an important issue in lean thinking. To find areas of waste, it is helpful to map all processes in order to provide an overall view. Many different types of process mapping tools exist, however, each one is suitable for different purposes.

3.1  THEORETICAL FRAME WORK ON LEAN MANUFACTURING

The theoretical frame includes theories about both lean manufacturing and process mapping. In this section the history of lean manufacturing and the Toyota principles for implementing lean are discussed.

3.1.1  HISTORY OF LEAN PRODUCTION

Lean thinking and lean production is becoming more and more popular in western industry as a mean to improve productivity. One reason for this is that the Japanese industries during the last decades have far exceeded their western counterparts in productivity and quality (Womack, Jones 1996).

The most tangible product of Toyota’s pursuit for excellence is its manufacturing philosophy, called the Toyota Production System (TPS). TPS is the next major evolution in efficient business processes after the mass production system which was invented by Henry Ford. TPS has been documented, analyzed, and exported to companies across industries throughout the world. Outside of Toyota, TPS is often known as “lean” or “lean production,” (Jeffry L,2004).

After the Second World War, Toyota and other Japanese organizations suffered from the effects of the war. The resources were strained and Japan needed to rebuild its manufacturing industry (Akin & Goldberg, 2002). Many of the Japanese companies turned to the western industries to gain ideas and inspiration on how to build up their industry. In the United States, the need was for mass production to satisfy the needs of a large population. The Japanese market on the other hand was much smaller and investment assets were limited. Nevertheless, with smaller production volumes per part and limited resources, there was a need for developing a manufacturing system that was flexible and required fewer resources. The solution was the development of lean production system, and the production genius Taiichi Ohno at Toyota is said to be the man behind the development of lean production (Sohal & Egglestone, 1994).

In the beginning of 80's the western automotive industry began to realize that the Japanese way of manufacturing vehicles far exceeded the methods used in the European and American industries. Japanese companies achieved higher productivity and better quality using fewer resources. As a result, a major research project was initiated in the end of 1980 by Womack, Jones and Roos at Massachusetts Institute of Technology. The research showed that there was a significant gap in productivity and quality between the vehicle manufacturers in Japan and the rest of the vehicle manufacturers in the world. The
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The term “lean production” was used to describe the Japanese production philosophy (Sohal & Egglestone, 1994).

Lean production is not only limited to the activities that take place in manufacturing operations of a firm, it refers to activities ranging from product development, procurement and manufacturing over to distribution. The ultimate aim of implementing lean philosophy in an organization is to have the customer in focus when improving productivity, enhancing quality, shortening lead times, reducing costs etc.

3.1.2 Elimination of Waste

Lean production is about creating value for the customers with the minimum amount of waste and maximum degree of quality. Waste is defined as any activity that occupies the capacity of a resource and creates no value. Identification and elimination of waste makes it easier to focus on value adding activities and become more cost efficient. The Toyota production engineer Taiichi Ohno has described seven sources of waste commonly found in industry (Askin & Goldberg, 2002). The sources of waste include:

1. Overproduction
2. Defects
3. Unnecessary inventory
4. Unnecessary processing
5. Unnecessary transportation between work sites
6. Waiting
7. Unnecessary motion in the workplace

Nevertheless, a new category of waste has been recently defined as:

8. Unused creativity

The seven sources of waste will now be explained in detail together with tools to detect and reduce them.

Waste from Overproduction

The most significant source of waste is overproduction, which means producing more, sooner or faster than is required by the next process. Overproduction may be considered as the source all other types of wastes, not only excessive inventory and tied up capital in the inventory. Overproduction results in capacity shortage, because processes are busy producing the wrong things. Since the goal was to maximize the resource utilization, traditionally supervisors have been judged by the production volume resulting in the overproduction waste. All resources including machines and humans should be used only when they have useful tasks to accomplish (Womack, Jones 1996). Production according to customers’ demand is accentuated on Lean production because other wise products have to be stored and the risk of becoming obsolete would be high.
Overproduction is more common when products are made according to forecasts instead of direct customers’ order. Although it is more rational to produce according to customers’ order but this is not always possible since in most cases, customers requirements on delivery lead time are shorter than the production lead time. It means forecasting is inevitable, however the customer order point should be moved upstream in the production flow as far as possible.

**Waste from defects**

Lack of quality is another source of waste. When a product or a part is found defected it should be rebuilt or repaired and this means inefficient utilization of capacity and higher costs. An undetected defect has a negative impact on the customers’ perception as well. It is essential to find the root of the quality problem and remove the problem from its source. In manufacturing firms with batch production policy, the bigger the batch size, the more time it will take to notice a defect and this may cause the entire batch to be scraped. However, in manufacturing firms with smaller batch sizes and in the extreme case of one peace flow, defects are detected sooner and the station causing the defect can get instant feed back from its down stream operation (Womack, Jones 1996).

**Unnecessary inventory**

Keeping parts and products in inventory does not add them any value. Besides, keeping the inventory will hide problems and defers their discovery, in addition keeping inventory means a higher amount of tied up capital. However, it is not reasonable to eliminate inventory mindlessly since inventory solves problems regarding variation in demands or production. Instead of eliminating the inventory, the reason for the existence of inventory must be removed (Karlsson & Åhlström, 1996).

Mainly two types of inventory exist: work in process (WIP) and parts storage. WIP are the parts stored between each process and parts storage are the raw material which was brought from the main warehouse to the production area to be processed (ibid).

Lean manufacturing always emphasizes on reducing inventory. This can be either reduction of buffer inventory or reduction of batch sizes or both. Buffer inventory is reduced by eliminating unwanted variations. The positive points of reducing inventory are listed below (Womack, Jones 1996):

- Shortening throughput time
- Reduction of tied up capital
- Smoothing production flow
- Lowering space utilization costs
- Reducing risk of obsolete material
- Accelerating detection of quality problems

The list above shows that reducing inventory is related to other sources of waste such as waste of time, defective products and transportation. It means reducing inventory helps saving other wastes too.
UNNECESSARY PROCESSING

An incorrectly designed process can be a source of waste. Activities in a process in organizations can be divided into 3 categories (Askin & Goldberg, 2002):

1. Value adding
2. Non value adding but necessary
3. Non value adding and unnecessary process

Lean production emphasizes on reducing this non value adding and unnecessary process steps. Changing design of parts, limiting functionally, unnecessary tolerances and rethinking process plans can often eliminate and simplify process activities in the manufacturing process (ibid).

A tool for determining non value adding activities is process mapping. All steps in a process are indicated by graphical symbols and different activities are linked with arrows. A detailed map of a process often reveals unnecessary stages and sequences, and can be used to improve the process design (Brassard & Ritter, 1994).

UNNECESSARY TRANSPORTATION

Transportation waste includes all type of unnecessary transportation of material, work in process and components, which do not add value to the products. Most unnecessary transportation is due to the inappropriate layout of the factory and at the same time it is hard to find a way to optimize the layout of a factory. A traditional perspective is based on the mass production principle. In the mass production, machines and equipments are often grouped on a functional basis that maximizes transportation between functional areas. However, lean manufacturing layout is based on product families which use the same operations and dedicates equipments to each product family. This approach results in less transportation (Brassard & Ritter, 1994).

A tool that can be used for analyzing transportation waste is the spaghetti map which indicates the physical flow of material, products and humans. Basically all the movements are drawn on a current layout map, in order to reveal unnecessary transportation. The map often looks like a pile of spaghetti before the layout is improved and that is the reason it is called spaghetti map.
WAITING

Waiting adds no value so it is considered as a source of waste and might be caused due to different reasons. It can be waiting for correct information, products waiting to be processed, machines waiting for their operators and waiting for material to arrive. One common type of waste is waiting for inventories which might be a large part of the total production lead time (Womack, Jones 1996).

UNNECESSARY MOTION IN WORK PLACE

Motion consumes time and energy so it is necessary to eliminate motions that do not add value, such as stretching for tools and moving materials within stations, etc. This objective should be considered when designing workplaces, processes, operation procedures etc. Reducing waste of motion includes everything from considering detailed hand motions during the assembling process to selection of machines and design of fixtures to reduce the setup times and material handling (Askin & Goldberg, 2002).

3.1.3 TOYOTA PRODUCTION SYSTEM

![Toyota Production System Diagram](image)

FIGURE 4: TOYOTA TEMPLE DIAGRAM (SOURCE: THE TOYOTA WAY)

To implement Toyota production system it is important to understand what is knows as “Toyota Temple”. First comes the foundation which is built by, heijunka representing smooth production flow in
both volume and mix; stable and standardized processes which build up a system; visual steering to make everything as clear and simple as possible and Toyota philosophy which provides a special perspective in every aspect of production. People, who make continuous improvement possible by reducing wastes in the operations, are in the center of the temple. Each part of the temple is important by itself but at the same time they should work in a way that they reinforce each other. Its main goals are best quality, lowest cost and shortest lead time, the roof. The outer pillars are Just in time, which is probably the most famous aspect of Toyota production system, and Jidoka which emphasizes on the visibility of problem.

3.1.4 14 PRINCIPLES OF TOYOTA PRODUCTION SYSTEM

Every company in the world might claim that they are lean, but what exactly is a lean enterprise? It is the result of applying the Toyota Production System (TPS). The TPS is Toyota’s unique approach to manufacturing. Lean manufacturing is defined by James Womack and Daniel Jones as a five step process:

1. Defining customer value
2. Defining the value stream
3. Making it “flow”
4. “Pulling” from the customer back
5. Striving for excellence

Likert has a different approach and describes the 14 principles that constitute the “Toyota way”. The principles are divided into four different categories (Jeffry K., 2004):

1. Long term philosophy
2. The right process will produce the right result
3. Add value to your organization by developing your people
4. Continuously solving problems results in organizational learning

SECTION 1: LONG TERM PHILOSOPHY

Principle 1: It is essential to make basic management decisions according to a long-term philosophy, even at the expense of short-term financial goals (Jeffery K., 2004).

Staff must work, grow and align the whole organization towards a common purpose that is bigger than making money. They should understand their place in the history of the company and work to bring the company to the next level. The next level is considered in the philosophical purpose that influences and guides any short term decision making. In this regard, the starting point is to generate value for the customer, society and the company, therefore every attempt is made to achieve these goals. However, it is crucial to be responsible and strive to decide the company’s fate. Actions must be made with self-reliance and be trustworthy.
**SECTION 2: THE RIGHT PROCESS WILL PRODUCE THE RIGHT RESULTS**

**Principle 2:** Create continuous process flow to bring problems to the surface (ibid).

In order to achieve continuous flow, work processes should be designed in a way that the amount of time in which any operation is idle or waiting should be reduced to zero. Besides, the flows should be able to move materials and information as fast as possible to make it possible to detect faults as soon as possible. Nevertheless, the key to a true continuous improvement process is common, evident perception of the flow throughout the organization culture.

**Principle 3:** Use “Pull” systems to avoid overproduction (ibid).

The production process should be designed in such a way that customers become provided with what they want, in the amount they want and at the time they want. Material replenishment initiated by consumption is the basic principle of the Just-In-Time approach. As a result, work in process and warehousing of inventory must be minimized by stocking of small amounts of each product and frequently restocking based on what the customer has actually taken away. However, to enable this method to work, it is necessary to become responsive to the day-by-day shifts in customer demand instead of relying on computer schedules and systems tracking inventory.

**Principle 4:** The work load has to be leveled out (heijunka). (ibid)

Eliminating waste is just one third of the equation of making lean successful. Eliminating unevenness in the production schedule is just as important, however, generally this point is often not understood at companies attempting to implement lean principles. Therefore, all manufacturing and service processes should be leveled out.

**Principle 5:** To get quality right at the first time, a culture of stopping to fix problems should be built (ibid).

Quality for customers derives the company’s value scheme. Therefore modern quality assurance should be used and the capability of detecting the problems must be built into equipments, so that they stop when a problem occurs. Besides, to simplify the procedure, a visual system must be developed to alert the team or project leader that a machine or process needs assistance. In addition, the organization should be working in a way that its support system quickly solves problems. At the same time, the culture of stopping the production should be built in to get the quality right at the first place and first time to enhance productivity in the long run.

**Principle 6:** The foundation for continuous improvement and employee empowerment are standardized tasks (ibid).

To maintain predictability in production, regular timing, regular output of a process, stable and repeatable methods should be used. Nevertheless, creativity and individual experiments should be made in a way that standards are improved and modified into new ones. This can be a guarantee for the case when a person moves on, the learning can be transferred to other newcomers.
Principle 7: Visual control will reveal hidden problems (ibid).

With the help of simple visual signs people can determine whether they work in the correct, standard condition or deviate from it. However this might also cause some problems, for example, using a computer screen may move the worker’s focus away from the work place. It is very helpful to reduce the report to one piece of paper, even for the most important financial decisions.

Principle 8: Only dependable, thoroughly tested technology that serves workers and processes should be used (ibid).

Technology must be used in a way that it supports workers and not as a means to replace them. It is better to work out the processes manually before adding any supporting technology. Usually new technology is often unreliable and difficult to standardize. In this regard, it is preferable to use a proven process that works generally than to use a new, untested technology. Actual tests must be conducted before adopting new technologies, business processes, manufacturing systems or products. It is essential to reject or modify technologies that conflict with the company’s culture, or might disrupt stability, reliability and predictability. However, it is good to encourage people to consider new technologies when looking into new approaches to work.

SECTION 3: VALUES ARE ADDED TO THE ORGANIZATION BY DEVELOPING PEOPLE AND PARTNERS

Principle 9: Leaders should be grown in a way to understand the work, settle the philosophy, and teach it to others (ibid).

It is more effective to develop potential leaders from within, rather than bringing them from outside the organization. To be most effective, leaders must be the symbols of the company’s philosophy and way of doing business. Besides, good leaders must understand the daily work in great detail so they can implement the company’s philosophy in the best way.

Principle 10: People and teams who follow the company’s philosophy have to be developed (ibid).

A developed, stable and strong culture in which company values and beliefs are widely shared is an essential key for a successful company. People should understand the importance of team working and they should learn how to work in a team to achieve a common goal.

Principle 11: It is essential to respect the extended network of partners and suppliers by challenging them and helping them improve (ibid).

It is vital to respect partners and suppliers and treat them as an extension of the business because their dependability is crucial for business developments and critical situations.

SECTION 4: ORGANIZATIONAL LEARNING IS GAINED BY CONTINUOUSLY SOLVING PROBLEMS.

Principle 12: Thorough understanding of the situation is possible only when leaders go and see for themselves (Genchi Genbutsu).
The most effective way to solve problems and improve processes is that managers go to the place of problem occurrence and personally observe the situation rather than drawing conclusions from words of mouth or computer screens. Therefore, managers should think and speak based on personally verified data.

**Principle 13:** It is important to make decisions slowly and thoughtfully and implement them rapidly (ibid).

Managers should not pick only a single choice and work on it unless all alternatives have been thoroughly considered. However, when one option is picked they should act quickly and cautiously. It is important that all the people affected in the decision should be asked for their ideas and opinions before moving on. Although this process is time consuming, it helps to develop the potential solutions, but once the decision is made, the result should be set for quick implementation.

**Principle 14:** To become a learning organization, the most essential aspect is continuous improvement (Kaizen).

All processes should be designed in a way that they run without requiring inventory. In this way wasted time and resources become easy to see for all. Once a stable process is developed, continuous improvement tools should be used to reveal and eliminate the sources of waste. Standardizing the best practices is an important way of learning, instead of reinventing the wheel with each new project and each new manager.

### 3.2 THEORETICAL FRAME WORK ON PROCESS MAPPING

Process mapping simply involves illustrating processes in terms of how activities and operations within the process relate to each other. It is important to understand the definition and importance of the process concept. Ron Anjard (1998) defined a process as “a series of activities (tasks, steps, events, operations) that takes an input, adds value to it and produces an output (products, service, or information) for a customer. Customers are all those who receive the process output.” Therefore one may conclude that the purpose of each process is to satisfy its customer with the least resource consumption. In order to understand, document, analyze, develop and improve a process, its mapping is vital. A process map is a visualized means for picturing all the work stages and how inputs, outputs and tasks are linked. (ibid)

Although there are different techniques for mapping processes they all identify different types of activities that take place during the process and show the flow of materials or people or information through the process steps. A process map can be drawn at various levels of detail. However, all process maps should be developed from the top-down approach. One should begin mapping at the macro level of the process which determines the scope of the system. Then the process should be “peeled” down to its lower levels. A single process may be broken down into 5-15 sub-processes. (Ron Anjard, 1998)
According to Aguiar and Waston (1993), the process mapping tool is useful in improving the customer focus of the process, assisting in eliminating the non-value added activities and reducing the process complexity.

**3.2.1 HOW TO CONDUCT PROCESS MAPPING**

Different steps in process mapping were introduced by Aguiar and Waston (1993), as follows:

1. Define the purpose for developing a process map
2. Establish the team
3. Map “As Is” process
4. Establish measures for improvement
5. Propose changes
6. Map the “should be” process

**Step 1:** Define the purpose for developing a process map

It is essential to know the goal and aim of creating the process map. It determines the depth and breadth at which process details should be analyzed (ibid).

**Step 2:** Establish the team

The team should be consisted of representatives from different levels of the organization and should have a cross-functional impact. Based on the scope of the process mapping it might be helpful to engage some key suppliers and customers.

**Step 3:** Map “As Is” process

To get started with mapping, the team should collect information regarding how the process actually works at the moment. This might be done by interviewing key personnel involved in that process. Some examples of questions which might be considered are given below (ibid):

- How and where the process starts, what the different stages are
- Who files the paperwork at each stage
- Who makes the decisions at each stage
- What the operations at each point are, etc.

It is necessary to remark that a mapping procedure is an iterative approach and the initial map is never 100 percent correct by first trial, however it will give some idea about opportunities for modifications in the future.

**Step 4:** Establish measures for improvement

Providing the “As Is” map is not a solution by itself and it is only the start for improvements. Besides, before identification of the changes a target should be defined for measuring the improvements. A
direct link has to be between the target for improvement effort, the organization’s strategy and competitive position.

**Step 5: Propose modifications**

After preparing the “As Is” map and developing improvement goals, the potential improvement areas should be identified. Some of the common improvement areas which contribute to wasted time, or incorrectly executed operations are described by Savory and Olson (2001):

- Eliminate duplicate activities
- Combine related activities
- Eliminate multiple reviews and approvals
- Eliminate inspections
- Simplify processes
- Perform activities in parallel
- Outsource inefficient processes
- Recognize worker teams

**Step 6: Map the “To Be” process**

The “To Be” map presents the ideal future situation. It describes the process after all non value adding activities are eliminated. It shows a new or improved process that meets the goals established and eliminates deficiencies. After implementing changes, the “To Be” map becomes another “As Is” map with new possibilities for improvements. Continuous improvements are possible by iterating the cycle between the “As Is” and “To Be” maps.

### 3.2.2 Value Stream Mapping

It is said, “One picture is worth a thousand words”. Among existing mapping tools VSM (Value Stream Mapping) is taken into consideration. VSM is a tool which was developed by TOYOTA and is supporting means for Lean manufacturing. It helps to understand the material and information flows, a product or service makes during its way through the value stream. VSM is focused on continuously minimizing waste or to maximize flow efficiency. According to Jones and Womak (2003) VSM is the simple process of direct observing the flows of materials and information as they occur now and then envisioning a future state with more efficient performance. The map summarizes the performance of the process stages, shows the inventory currently accumulating between the operations, compares value adding time with total throughput time and helps to envision possible modifications in initial flow to reduce the total throughput time. Results expected from the VSM are: eliminated waste, improved quality and increased flexibility and availability. A VSM takes into account not only the activity of production, but the management and information systems that support the basic process. This feature is especially useful when working on reducing the cycle time, because one may gain a deeper understanding about
Increasing Takt of Production at SKANSKA Byggsystem

May, 2008
Hamed Yazdani

information flow in addition to the material flow. The basic idea is to first map the current production processes, then above it map the information flow that enables the operations to work together (ibid).

The value stream map implements different measures such as cycle time, batch sizes, set-up time, lead time, number of operators, value adding time, type and number of products, shipment volume and frequency and working hours. Several different steps exist in VSM, see figure 5. First the current state map is created which shows the current actual situation. Business and manufacturing waste that occurs in processes can easily be identified by creating a current VSM. Once the current state map is created it becomes the baseline for improvement and for the creation of a future state value stream map. After all VSM is only a tool, unless the future state was achieved in reality (Rother and Shook, 2003).

![Diagram of Value Stream Map](image)

FIGURE 5: INITIAL VSM STEPS, (ROTHER AND SHOOK, 2003)

The goal of VSM is to identify, reveal and remove waste in the operations. Waste is defined as any activity that consumes capacity or resource but creates no value for the customer. VSM is basically a tool for communication, but it can also be used as a strategic planning tool, and as a tool used in change management (ibid).
4 EMPIRICAL STUDY

According to the defined purpose, the empirical work has been focused on production processes. In the first stage data regarding the current situation of the factory is gathered. Quantity and type of data are identified based on value stream mapping requirements. These initial data have been used in an analysis of the current situation and for proposing potential improvement areas.

In this section the overall view of the factory operations are illustrated. There are mainly two areas defined. The first area covers the physical process of production which deals with material flow and the second area is related to administrative processes which deals more with the information flow. It is worth mentioning, the data regarding the design stage are not looked into.

4.1 FACTORY LAYOUT

The general factory layout is shown in Figure 6. The area hatched with red color is used for production activities and the blue hatched areas are basically used for storage. The production area is around 12000 m² plus an extension area around 2500 m² which is used for assembling kitchen parts and painting outer walls. A layout with more details including the operations in the main production area is shown in Figure 7.

FIGURE 6: GENERAL FACTORY LAYOUT
The storage area is totally around 9000 m². However, the storage area attached to the production area is around 4000 m². This area is used for storing plasters, pre-manufactured windows, recycling materials containers, cut wood, and a temporary place for storing finished modules. The other separated storage area is mainly used for other raw materials such as woods, insulation materials, etc.

More details about material flows and the sequence of operations are described in the next part, materials flow.

4.2 Material Flow

The main production area is consisting of the so called Hall 16, Hall 17 and Hall 22. The order and detail operations done in each station is shown in Figure 7. General operations done in each production hall is described in the following part.

4.2.1 Different Production Areas

Hall 22

Hall 22 is the place in which plaster plates are cut into proper pieces by means of a CNC machine. Other preparatory activities such as cutting woods, assembling of the ventilation module, cutting pipes, wet module floor cutting and building of the outer roof is done in Hall 22 as well. Cut plaster plates required in the wall production line are kept in buffer shelves for later use in Hall 16. As mentioned before, plaster plates are kept in Hall 25 before being cut. Cut wood parts in Hall 22 are sent to a buffer shelf in Hall 25 and are moved to Hall 16 when required.

Hall 16

Hall 16 is the manufacturing area of the factory. Cut wood, plaster and other construction materials come to this hall for producing floors, walls and inner roofs. The assembling procedure is more or less the same for all of these parts. First the frame is built, and then it is filled with insulation material and depending on the part, the outer part is covered. For example, in the case of inner walls it is covered by plaster, in the case of the floor it is covered by wood and parkets and in the case of roofs it is covered by special plasters.

Hall 17

Hall 17 is the station where assembling of the floor, walls and inner roof takes place in 4 different lines. Lines 1 and 2 include wet modules and line 3 and 4 are assigned for modules without any wet sections. At the first station parts are assembled, then in a specific sequence electrical work, plumbing, carpentry, painting, tile work, kitchen installation and quality control are done. Details might be seen in Figure 7.
Chapter 3: Empirical Study

FIGURE 7: FACTORY LAYOUT
4.2.2 PRODUCTION PROCESSES

The production process is a combination of several sub-processes. Different lines work separately to build up sections. Afterwards these sections are assembled together and move on for further operations. The final product of each line is a module which along with other modules builds up a complete house. For example, an apartment is made of 12 modules. Separate modules are manufactured in the factory and they are assembled together in place to produce an apartment or a villa house.

As shown in figure 8, there are three main production flows before the assembly point. Wall production which includes both inside and outside walls, floor production and inner roof production are these three processes. A synchronized production planning helps all flows to arrive at the assembly point at the same time. After the assembly station, a module which is structurally stable and complete is erected. Afterwards interior work is done in 4 different lines. However, currently only two modules can be assembled at the same time, because there are only one traverse for lines 1 and 2 and one traverse for lines 3 and 4. Figure 7, illustrates the situation of lines more clearly.

The most important enablers of production are infrastructure, information flow and logistics. These enablers are not directly involved in production but are of great importance. Managing these enablers is essential because they are vital in keeping a smooth synchronized production flow without delays and machinery breakdowns.

4.2.3 WALL PRODUCTION

The wall production line has totally 11 stations and both interior and exterior walls are made in Hall 16. There are totally 17 operators working in the wall production line. The first station is automatic frame montage. According to interviews, the first station in wall production can be considered as a bottleneck in the whole production process. There are several short parts which should be measured
and fixed before assembling of the frame and this procedure is time consuming. The short pieces are already cut and brought from Hall 25 where they are kept in. At the second and third station single and double plasters are installed. In the fourth station preparations for piping and electrical works are made. After this station, the inner wall goes a different way compared to outer wall. The reason is requirement of a lifting facility for outer wall sections. In the remaining stations mineral wool for insulation purposes and other plaster installation steps take place. When the walls are produced they become erected in a vertical situation and go through a line in which additional operations are done. For example installation of windows and filling are done while the walls are driven in the lines before the assembling station in Hall 17.

4.2.4 Floor Production

The steps for producing the floor are similar to wall production. There are 5 stations in floor production and 10 operators work in the floor line. At the first station, the main frame of the floor is assembled and passages for pipes are provided. Then plaster slabs are put on the frame and the floor is turned for filling insulation material. At the fourth station parkets are put on the floor and the fifth station is used as a buffer station to complete the floor operations. In the floor line, 2 operators start the production and follow each floor to the subsequent stations until the end of line. This is done because it is appreciated to know the responsible person in case there is a fault.

4.2.5 Inner Roof Production

The steps for producing the inner roof are similar to the wall and floor production. As well as for the floor line, the inner roof has 5 stations and 10 operators are assigned in the line. The procedure is exactly like floor production except for the parkets which are replaced with plaster.

4.2.6 Interior Work

After producing different sections of outer and inner walls, floor and inner roof they are moved to Hall 17 for assembling and interior work. There are four separate lines for interior work. Figure 8 provides a visual illustration regarding the location and different stations in the lines. Lines 1 and 2 have the facilities to prepare modules including wet sections of bathroom and shower. Lines 3 and 4 build up the modules without wet sections. In the very first station of assembling there are two traverses operating for lifting the sections. This limitation implies that it is not possible to assemble more than 2 modules at the same time. When the module is assembled complementary operations are done in each module. In the second station installation of electrical wires and facilities are done. Afterwards in the third station montage of ventilation system, door frames, locks etc. are done. In these stations primer filling is done as well, since it takes time for it to be dried. The fourth and fifth stations are for tile work, installation of bathroom slab and paintings or putting wall papers. Performing carpentry work and final installations are done in the last stations, for example Installation of kitchen stuff and radiators. Quality control and piping pressure tests are done in the last station as well.

After finishing the interior work, the modules are covered and prepared for transportation. They are stored temporarily in the storage area until all modules required for a complete building are ready to ship. It is worth mentioning that excessive movements and transportation of modules sometimes results in deflections and quality problems.
4.3 INFORMATION FLOW

The bond that ties different production flows and synchronizes them is the information flow. Each section of the production knows what to make and when to make it based on the schedule provided by production control part. Everybody knows at what time each part should be produced and knows when he is supposed to be finished. Nevertheless, sometimes it happens that something out of schedule becomes necessary. For example, deviations in size forces the cutting machines to do some reworking and cut correct pieces. These deviations in production result in schedule deviations. Besides, unforeseen breakdowns in machinery can be considered as other sources of becoming off schedule.

4.3.1 PRODUCTION PLANNING

Production planning is done on a daily basis. Each operator receives a schedule showing the activities he should take care of during the day. However, for operations done in the CNC machine or the cutters, in practice it is pretty common that activities are performed off-schedule. The reason might be deviations or mistakes in production which require immediate action.

The Figure 9 summarizes the current situation and operations of the factory in a Value Stream Map.
4.4 **Current State Value Stream Map**

![Current State Value Stream Map](image)

**FIGURE 9: CURRENT STATE VSM**
5 ANALYSIS AND DISCUSSION

In this section required modifications are discussed according to the purpose of the project and summarized in the future state Value Stream Map.

5.1 PROBLEM PERCEPTION

The following diagram (figure 10) shows how different aspects affecting the speed of production takt have been considered. At the highest level, there are two main issues influencing the takt: production process and administrative procedures. However, the analysis is mostly focused on production. It is worth mentioning that all of the aspects are not considered in the analysis since modifications in some parts will satisfy the requirements for purpose of the project. This brainstorming diagram might be helpful in future improvements; it gives a clue of possible areas for modifications.

For the analysis of the current situation, revealing the wastes in different operations helps to point out the potential possibilities to increase the efficiency. The criterion is to satisfy the requirements for 28 modules per week as the production takt.

FIGURE 10: PROBLEM PERCEPTION
5.2 TAKT ANALYSIS

At the time of study, takt of production had an average of 21 modules per week. However, numbers like 17 modules per week and a maximum of 24 modules per week can be seen in the production logs as well.

Each module requires 139.3 man-hours for its direct manufacturing. In addition, regardless of production takt 21 man-hours are required for indirect operations done in the assembly of kitchen shelves, logistics, quality control, etc. Around 70 workers out of total 90 blue collar workers are active in manufacturing lines. Table 22 shows required man-hours for different operations.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Required hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>12.5</td>
</tr>
<tr>
<td>Bathroom</td>
<td>12.5</td>
</tr>
<tr>
<td>Painting</td>
<td>13.3</td>
</tr>
<tr>
<td>Hall22</td>
<td>13.33</td>
</tr>
<tr>
<td>Wall</td>
<td>28.33</td>
</tr>
<tr>
<td>Floor</td>
<td>16.67</td>
</tr>
<tr>
<td>Roof</td>
<td>16.67</td>
</tr>
<tr>
<td>Carpentry</td>
<td>13.33</td>
</tr>
<tr>
<td>Plumbing</td>
<td>6.67</td>
</tr>
<tr>
<td>Electricity</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total direct</strong></td>
<td><strong>139.3</strong></td>
</tr>
</tbody>
</table>

**TABLE 1: REQUIRED DIRECT MAN-HOURS FOR EACH MODULE AND OPERATION**

Assuming 73 blue collar workers during each week (number of operators at the time of study) and only in production lines, provides 3212 Man-hours available. Simply, dividing the number of available Man-hours by 139 becomes 23 which is the highest theoretical number of modules that can be manufactured by the current capacity of the factory. However, this is not often the case because all of the operators are not always present in the factory and unplanned break-downs reduce the speed of production. As previous estimations show, the takt of production has been usually below or equal to 24 modules per week and more than 73 persons have been working in the production lines as well.

To make it more practical, a reverse calculation is done for calculating the takt. The main goal is to achieve 28 modules per week. Assuming the same number of resources available, the required man-hours for modules should be reduced to increase the takt. In this regard changes in the production procedure are suggested to increase the speed of manufacturing.

To become able to produce 24 modules per week, the required man-hours should be reduced by 6 hours which comes to 133.3 man-hours for each module. Nevertheless, if it is required to produce 28 modules per week and there are 3212 man-hours available each module should not take more than 115 man-hours to be built. Obviously, around 25 hours should be reduced from the
manufacturing time or more than 73 persons should be employed for manufacturing the modules with the takt of 28.

In the following parts, based on the Lean approach, different suggestions are provided to increase the efficiency and reduce the production lead time. The trivial solution would be employing new workers, to increase the available man-hours. However, this point is not discussed as a solution and only modifications of the production procedures are considered.
5.3 MAKE IT LEAN

In this part different areas of waste at the production lines of the factory are discussed.

5.3.1 OVER-PRODUCTION

As mentioned above, the company has enough demand in the market to fill its capacity for the next three years. In this regard, over-production is not a problem for the current situation of the factory and in practice; the factory sells what it produces.

Nevertheless, over-production might be considered in sub-processes where parts are pre-manufactured and stored as Work-In-Process (WIP) buffer. This buffer is inevitable since it is required to adapt the speed of production for different processes and to provide a steady production flow. However, it might be possible to reduce the WIP volume by creating a continuous flow of material and reduce the waiting time of buffers.

5.3.2 DEFECTS

Quality problems and defects cause rework and occupation of resources. Although quality is checked during the production and there are some check lists for quality control, some of the defects are not clear until the last station. Besides, some of the defects originate from the transportation. One of the solutions to reduce the quality problems is to update the check lists as often as possible and try to trace back the problem to its source. In addition, it is worthwhile to show the workers their performance. Installing an information table, visible to all workers, can provide a good measure for different operations on how they are performing. Concepts like Overall Equipment Efficiency (OEE) might be helpful in measuring performance of operations. Figure 11 shows how OEE is calculated.

As shown in the diagram, OEE is calculated mainly for machinery, but in the case of SKANSKA Byggsystem production process, availability can be considered as the availability of assigned personnel. Performance can be measured according to planned takt and actual takt for each production line and quality can be measured by number of defects per module. Reporting these numbers to everybody can make a clear image of performance to different operations as well as revealing the processes which require more resources or quality controls.
5.3.3 UNNECESSARY INVENTORY

Currently, the company sells what it manufactures, so there is only a temporary inventory for finished modules, and as soon as that they are complete to build up the whole apartment they are shipped to the construction site. Regarding the incoming materials, the factory holds an inventory for them and due to delivery lead times, it is not possible to omit these inventories in practice. However, it is possible to implement a systematic approach for ordering new materials. The factory does not use a MRP system to keep track of orders and volumes of materials in the factory. The method for ordering and handling materials can be improved in the factory reducing the waiting times for materials to arrive. Besides, problems regarding the poor quality of raw materials generated from suppliers might be revealed by a proper procedure for receiving and handling materials.

5.3.4 UNNECESSARY PROCESS

The waste of unnecessary processing is not mentioned in the list of wastes because any major unnecessary processes were not found in the production operations.

5.3.5 UNNECESSARY TRANSPORT

Parts of the unnecessary transportations in the factory are due to the factory layout. For example, some of the incoming raw materials are unloaded at a place which is not their final storage area, and they require to be transferred to another hall or place for use or storage. In addition, the production sequence is another source causing extra transportation. The most proper sequence for production should be First-In-Last-Out, because if the last module which should be transported to construction site is produced first then it goes to the end of storage area, and the last manufactured module will be the first one to be transported. However, this is not the case and usually the lifting truck spends quite a lot of time to organize and replace the modules. These extra, unnecessary transportations, not only occupy resources and impose unnecessary costs, but also result in defects in the modules. As visits show, for lifting the modules, the truck uses a fork that provides the most flexibility for the truck to handle other things meanwhile. This fork puts a small support in the middle part of the module, causing the whole module to be under strain and the module deflects like a curve. Although, the deflection is small, it is big enough to result in fractures and imposing extra work in the plant. In this regard, manufacturing the modules in a sequence that FILO logic applies the defects will be fewer and transportation will be less as well.

In addition, to provide a smooth flow of material Figure 12 suggests the required changes to have a continuous material flow. As it is shown in the figure, the gap between the storage area and the hall 16 should be filled with a new building and production facilities in hall 22 moved to this new building. In addition, raw materials which are partly stored in hall 25 can be moved to the main storage area, and freed space here can be used for storing modules which are waiting for transportation. Besides, making hall 22 empty makes it possible for expanding production lines and having more than 4 lines after the assembly station.
The continuous flow reduces the transportation and provides a smooth flow of materials. However, it requires an essential financing which is the only limitation for implementing this layout.

5.3.6 WAITING
Decreasing the waiting time is one of the main approaches to increase the production takt. The largest time spent during production, is waiting for the paint and filling to be dried. More than 12 hours which is around 10% of the direct production time is required for paints and fillings to dry. Although, other activities might be done during the waiting time, postponing the waiting time, shifting it or omitting it can increase the production speed dramatically. There are two suggestions for reducing the waiting time assigned for paintings and fillings. The first is to shift the painting activities towards the end of the working time as much as possible, where no manufacturing takes place. Paints and fillings might get dried during night, but this approach is hard to be standardized because not all of the modules are in the condition at which they should be painted in the end of working day. The second solution is to postpone the painting to the last station and let the painting dry during storage. This step might be postponed even until the last stage in construction, when the last quality checks are done before handing in the project to the customer. In this way unforeseen quality problems and in-site repairs might be carried out as well.
The other areas of waste which are related to waiting are those related to change-over times and set-up times, when the production line switches the modules. The main solution to reduce these waiting times is to increase the production line flexibility and adjust the production plan. As mentioned above, each apartment is built in two levels and each 12 modules result in one level. So from each module there should be at least two similar modules which are put on top of each other. A trivial solution to reduce the set-up and change-over times is to manufacture two similar modules in a row. This change also facilitates the production, because producing similar things in a row increases similarity scale and repetitive activities are done in a shorter time.

To increase the production line flexibility there are two main modifications required. If the production plan is supposed to change into manufacturing two modules in a row the production lines for the wall and assembly station should be modified. The wall production line should be adapted to produce inner and outer walls in its both branches. Currently outer and inner walls are separated after the fourth station.

The second modification is the requirements in the assembly station. There are four lines, and potential for assembling four modules at the same time, but only current two traverses are able to serve two lines at the same time. Therefore, producing two modules in a row requires increased flexibility in the assembly station as well.

5.3.7 UNNECESSARY MOTION

Currently at wall, floor and ceiling production lines workers who start to build a module come along with the module in different stations to build it up. The positive point of this approach is that the responsible persons for manufacturing of each module are known, so in case a defect occurs, the responsible person can fix the problem. Besides, the workers perform different activities and do not do the same job every day. However, this approach’s worst effect is losing the takt image. In this way teams that are more efficient and skilled, finish their job faster and it is possible to see stations that are more progressed compared to the proceeding station. In this regard, and to increase the speed because of learning it is suggested to keep the workers in the same station at least during each working day. In this way first of all, a clear takt image is created; each station knows if they are before or after scheduled time. Stations at which operators have finished their job can go back one station and help their colleagues.

Another area to reduce the unnecessary motion is the bottleneck of the factory, or first station of wall production. Usually wall frames are built of parts with a large variety in size. These parts are cut into proper sizes and kept in shelves in hall 22 as a buffer. When required they are moved to hall 16 for production. To omit this transportation, and increase the production speed by reducing the search time for the proper part size, it is suggested that an exclusive cutter be put at this station. The cutter should cut required pieces with some time lag to reduce the risk of running out of required pieces. However, this time lag should be kept as short as possible to reduce the mistake possibility as much as possible and have a pull system as well. A small buffer creates a proper reliability to this approach.
5.3.8 Unused Creativity

It should be possible to ask the people who have direct hands on production to suggest the most practical solutions for production modifications. They are the ones who can see the real problems and can confirm if a solution is practical or not. However, it is an important point that people from outside often can see things which are not easily visible for those who work with it every day.

5.4 Outsourcing and Insourcing

It is important to adapt capacity of the factory regarding the strategic requirements and company goals. Figure 13 shows the decision process concerning outsourcing or keeping an operation insourced.

```
Is activity of strategic importance?  
No → Does company have specialized knowledge?  
  No → Is company's operations performance superior?  
    No → Is significant operations performance improvement likely?  
      No → Explore outsourcing this activity  

Yes → Explore keeping this activity in-house
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**FIGURE 13: OUTSOURCING STRATEGY (SLACK 2007)**

Considering the unique approach of the factory in manufacturing houses anything that helps to deliver finished houses sooner, is desired and any obstacle that results in an increased lead time should be removed. It is important to consider the total lead time, because increasing the takt of production is a positive point in case the modules are sold. Producing modules and storing them or waiting for other problems to be solved hides the positive effects of an increased production takt.

Regarding the goal of increasing takt, it is possible to outsource the bathroom module. The answer for all of the questions mentioned in the figure is No. This change reduces around 12 hours from the total required man-hours for each module. However, the main obstacle of this decision is lack of transparency in financial information which makes it hard to calculate the potential benefits.

The important point about outsourcing is the reliability of the supplier. An unreliable supplier might result in even worse situations compared to the time that capacity is kept inside. To reduce the risk of an unreliable supplier, it is always helpful to have at least two suppliers in parallel. In this way the risk is reduced and a constructive competition between suppliers can take place of which the factory can be beneficiary. In case of a single unreliable supplier, it is reasonable to have a reserved capacity inside. At the moment, only the production of the outer roof of the houses is outsourced.

Outsourcing might be a good solution for the current situation of the factory, since this can free some of their resources by outsourcing the activities and assign the freed resources to requiring operations.

Figure 14 shows a summary of the different modifications in the factory.
5.5 FUTURE STATE VALUE STREAM MAP

FIGURE 14: FUTURE STATE VSM
6 CONCLUSION

The main purpose of this project has been to increase the takt of production from 20 to 28 modules in two stages. It must however be mentioned that even with fixed resources the production takt varies, because there are always unforeseen situations and incidents that makes it complex to have precise figures and calculations.

Minor improvements facilitate the production of 24 modules per week as a steady takt. Increasing the flexibility of the production line and deferring the paintings might be enough to achieve this.

Keeping the same resources and achieving a takt of 28 is not practical with the current production method and designs. A big change and help might be outsourcing the bathroom module, but due to the fact that the pre-manufactured bathroom module is relatively expensive and lack of transparency in financial gains makes it difficult for the managerial board to make a decision.

Totally, for each module around 25 hours should be reduced from the number of required man-hours. In practice by postponing the second painting and outsourcing the bathroom module more than 16 hours might be gained. It is not possible to calculate the real effects from the modifications in the production lines, but extra required capacity might be gained by employing new resources or shifting the resources to different areas where the requirements are higher. However, easily shifting the posts requires common knowledge and flexibility of the workers.

The current situation and possible changes are shown in two Value Stream Maps referring to the current and future states of the factory. This tool can be used to see the whole flow of materials in the factory and thus have a deeper understanding of the production process.
7 REFERENCES


Arbnor I., Bjerke B. (1994), Företagsekonomisk metodlära, Studentlitteratur, Lund


Liker, Jeffrey K, 2004,“The Toyota way: 14 management principles from the world’s greatest manufacturer, McGraw-Hill


Rother M., Shook J., 2003, “Learning to see”, Version 1.3, Lean Enterprise Institute, One Cambridge Center, Cambridge, MA


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