Designing an assembly line for modular house manufacturing

Increased efficiency of the manufacturing process
This exam work has been carried out at the School of Engineering in Jönköping in the subject area Production Development and Management. The work is a part of the Master of Science programme Manufacturing system. The authors take full responsibility for opinions, conclusions and findings presented.

Examiner: Vanajah Siva

Supervisor: Per Hilletofth and Tomas Wigerfelt

Scope: 30 credits (D-level)

Date: 2018-06-09
Abstract
Having an efficient production is vital for companies that are facing highly demanding customers along with tough competition. In addition, the production layout has a significant impact on the production efficiency hence it the choice of production layout is an important question to consider. A common production layout is the assembly line whereas companies with products that are not adequate for assembly line production; are seeing advantages of working with assembly lines. An example is the modular house manufacturing industry. Therefore, the purpose of the study was to investigate how an assembly line for modular house manufacturing and the related material supply may be designed in order to increase the overall efficiency of the manufacturing process.

A single case study has been conducted at Zenergy AB, Skillingaryd. Empirical data has been collected through various sources; interviews, observations and document studies. In addition, a literature review has been conducted. The theoretical framework and empirical data has been established by the means of pattern matching and further on data analysis was done thus the results of the study were acquired.

To conclude, it is shown in the results that implementation of an assembly line for modular house manufacturing can be beneficial despite the fact that its products are not adequate for assembly line production. Further on, there are three main critical factors to consider during the assembly line design process for modular house manufacturing. The critical factors are; line balancing, dry time and bulky materials. The critical factors will in turn have a significant impact on the choice of the assembly line production layout and the related material supply.

Keywords
Modular house manufacturing, Assembly line, Material supply
Acknowledgements

We would like to express our appreciation for the support and encouragement given to us during this thesis project. We would like to thank Robert Gurbin at Zenergy AB for giving us the great opportunity along with guidance and support that has been vital for the accomplishment of this study. Furthermore, we want to thank our supervisor Staffan Ivarsson at Zenergy AB along with all the people involved in the assembly line project group and Zenergy AB for the hospitality and support that has been given during this study. The results would have not been obtained without the insightful discussions that has taken place during the collaboration. We also want to thank our supervisors Per Hilletofth and Tomas Wigerfelt for the guidance and support they have provided us with along this thesis. Their comments have inspired and enriched this thesis.

/Matea Cosic and Viktor Rochowiak

Jönköping, May 2018
# Table of contents

## 1 Introduction ................................................................. 7

1.1 BACKGROUND .................................................................. 7

1.2 PROBLEM FORMULATION .................................................. 8

1.3 PURPOSE AND RESEARCH QUESTIONS .................................. 9

1.4 SCOPE AND DELIMITATIONS ............................................. 10

1.5 OUTLINE ....................................................................... 10

## 2 Frame of reference ............................................................ 11

2.1 COMPONENTS OF THE FRAME OF REFERENCE ....................... 11

2.2 BENEFITS AND DRAWBACKS ............................................. 12

2.2.1 Assembly lines ................................................................ 12

2.2.2 Modular house manufacturing ........................................ 12

2.3 CRITICAL FACTORS ......................................................... 13

2.3.1 Line balancing ............................................................ 13

2.3.2 Dry time ..................................................................... 13

2.3.3 Bulky materials .......................................................... 13

2.4 DESIGN OF ASSEMBLY LINE ............................................ 14

2.4.1 Tact and tact time ....................................................... 14

2.4.2 Cycle time ................................................................... 14

2.4.3 Material supply .......................................................... 14

2.4.4 Exploitation of resources .............................................. 15

2.4.5 Quality and productivity .............................................. 15

## 3 Method and implementation ............................................... 16

3.1 RESEARCH APPROACH ..................................................... 16

3.2 RESEARCH STRATEGY ...................................................... 17

3.2.1 Case study ............................................................... 17

3.3 DATA COLLECTION .......................................................... 18

3.3.1 Primary data collection ................................................ 18

3.3.2 Secondary data collection ............................................ 20

3.4 DATA ANALYSIS ............................................................. 20

3.5 TRUSTWORTHINESS ......................................................... 21

3.5.1 Credibility ................................................................. 22

3.5.2 Transferability ........................................................... 23
Table of contents

3.5.3 Dependability ................................................................. 23
3.5.4 Confirmability ............................................................... 23

4 Findings and analysis .......................................................... 24
4.1 CASE COMPANY DESCRIPTION ........................................... 24
4.2 EXISTING MANUFACTURING PROCESS .................................. 24
  4.2.1 Pre-assembly ............................................................... 25
  4.2.2 Main assembly ............................................................ 25
  4.2.3 Materials and resources .................................................. 29
  4.2.4 Quality ................................................................. 30
4.3 BENEFITS AND DRAWBACKS FOR HAVING AN ASSEMBLY LINE FOR MODULAR HOUSE MANUFACTURING ......................... 31
  4.4 CRITICAL FACTORS TO CONSIDER WHEN DESIGNING AN ASSEMBLY LINE FOR MODULAR HOUSE MANUFACTURING ................. 32
    4.4.1 Line balancing ........................................................... 32
    4.4.2 Dry time ..................................................................... 33
    4.4.3 Bulky materials ........................................................... 33
4.5 POSSIBLE FUTURE MANUFACTURING PROCESS ....................... 33
  4.5.1 Production layout .......................................................... 34
  4.5.2 Line balancing .............................................................. 36
  4.5.3 Material supply ............................................................ 39

5 Concluding discussion ........................................................... 42
5.1 CONCLUSION ...................................................................... 42
5.2 THEORETICAL AND PRACTICAL IMPLICATIONS ......................... 43
5.3 LIMITATIONS AND FURTHER RESEARCH ................................ 44

References ................................................................. 45
Search terms ................................................................. 49
Appendices ................................................................. 50
List of figures

Figure 1. Fixed position. ................................................................. 7
Figure 2. Assembly line. ................................................................. 7
Figure 3. Scope and delimitations of the study. ................................ 10
Figure 4. Relation between research questions and theoretical frame of reference. .............. 11
Figure 5. Types of assembly line layouts (Kara et al. 2010). ........................................ 12
Figure 6. The abductive research approach. ........................................... 16
Figure 7. Case study designs (Yin, 2013). ............................................ 17
Figure 8. The process of data analysis of the study. ..................................... 21
Figure 9. Present state of the production layout. ....................................... 24
Figure 10. Present state of placement of materials ....................................... 30
Figure 11. Assembly line for modular house manufacturing .......................... 35
Figure 12. Workstations of an assembly line for modular house manufacturing ............... 36
Figure 13. Assembly line for modular house manufacturing and the related material supply. 40
List of tables

Table 1. Overview of the completed interviews. ................................................................. 18
Table 2. Overview of the completed observations. ............................................................. 19
Table 3. Overview of the completed document studies. ...................................................... 19
Table 4. Summary of trustworthiness evaluation for the study. ........................................... 22
Table 5. Working procedure – Day 1. .................................................................................. 25
Table 6. Working procedure – Day 2. .................................................................................. 26
Table 7. Working procedure – Day 3. .................................................................................. 26
Table 8. Working procedure – Day 4. .................................................................................. 27
Table 9. Working procedure – Day 5. .................................................................................. 27
Table 10. Working procedure – Day 6. ............................................................................... 27
Table 11. Working procedure – Day 7. ................................................................................ 27
Table 12. Working procedure – Day 8. ............................................................................... 28
Table 13. Working procedure – Day 9. ............................................................................... 28
Table 14. Working procedure – Day 10. .......................................................................... 28
Table 15. Working procedure – Day 11. .......................................................................... 29
Table 16. Assembly line working procedure. .................................................................. 38
1 Introduction

This chapter presents the background and problem formulation of the study followed by purpose and research questions. At last, delimitations and outline of the thesis are presented.

1.1 Background

An efficient production has a large impact on the competitiveness of a company (Sansone et al. 2017). Companies that are facing highly demanding customers along with tough competition; needs to adapt their manufacturing system in order to achieve competitive advantage (Hilletofth, 2011). An important question when it comes to manufacturing system design is the choice of production layout. The production layout has a significant impact on the overall efficiency of the manufacturing system, for example in terms of productivity and profitability (Limère et al. 2012).

There are different types of production layouts that could be considered (Kara et al. 2010). One of the more traditional production layout is the fixed position layout (Corominas et al. 2011). This layout means that the assembly takes place at a fixed position (Figure 1). Value is being added to the product at the site of assembly by bringing personnel along with materials and equipment to the site.

![Figure 1. Fixed position.](image1)

Another common production layout is the assembly line (Corominas et al. 2011). This layout means that the products are being transported between different value adding stations (Figure 2). An article (input) arrives to the first station where an assembly operation takes place. Further on, the product is being transferred to the next station for another assembly operation. For each assembly operation, material is being added. This process continues until the product has passed all stations thus the product is finished (output).

![Figure 2. Assembly line.](image2)
Assembly lines imply a need for a well-planned process for material supply. Thus, it is essential to feed the line at the right place in the right time with the right parts (Limère et al. 2012; Ikuma et al. 2010). An assembly line in combination with an efficient system for material supply can enhance the flow efficiency in the production (Limère et al. 2012).

The assembly line is today rather common and the number of companies using this type of production layout is increasing, even though their products are not adequate for assembly line production (Emde et al. 2010). To continue, assembly lines are mainly adequate for products with a constant flow of high frequency. Despite this, companies that produces low volume products that are large, bulky and with variation sees advantages of working with assembly lines. An example of companies that produce these types of products are companies in the modular house manufacturing industry (Nasereddin et al. 2007).

Modular house manufacturing imply that the working operations are performed in a factory environment. The 95% finished products leaves the factory and are being transported to the construction site; in order to be attached onto the foundation (Ikuma et al. 2010). The products of modular house manufacturing industries imply a challenge for assembly lines due to their short production series and low product volumes, hence it is hard to have a constant utilization of resources.

The aforesaid indicates that the right choice of production layout can enhance the competitiveness of a company due to an increased efficiency of the manufacturing process. It is also indicated that an assembly line production layout can enhance the production flow efficiency; but may not be adequate for all types of products. This can be seen as an obstacle when designing an assembly line. Further on, assembly lines have been widely studied and it is not new to the literature that design of assembly lines is a problematic process. Due to complexity in working operations and industrial constraints; problems occur during the design along with balancing of assembly lines (Corominas et al. 2011). Despite this, there is a gap in knowledge of assembly lines associated to modular house manufacturing.

1.2 Problem formulation

The housing shortage in Sweden is the highest since National Board of Housing started its statistical analyses in 1983. A total of 88 percent of 290 municipalities suffer from housing shortage in Sweden. Sweden has a population that consists of a large group of young adults, but also a high immigration, which has a significant effect of the increase in demand for housing (Hyresgästföreningen, 2017). In addition to this, it is crucial for the modular house manufacturing industry to be able to meet this demand; which implies that there is a need for efficient manufacturing systems where implementation of assembly lines is an alternative in order to increase the efficiency in the manufacturing process.

As mentioned previously, the products of modular house manufacturing are not adequate for assembly line production (Emde et al. 2010). On the other hand, it has the privilege to have a positive impact on the efficiency of the manufacturing process. The complexity and need of producing high quality products within modular house manufacturing implies a challenge for the design of an assembly line. This is due to the need of assuring high efficiency and profitability at the same time as the quality of the products does not decrease (Corominas et al. 2011). The modular house manufacturing industry needs to reflect upon the benefits and drawbacks when considering an assembly line; in order to assure that the benefits overvalue the drawbacks before drastic changes are being made.
In order for an assembly line to be successful, the planning and design phase are central to develop an assembly line that is purposeful and aligned with the goals of the company. If the design of the assembly line, including its work stations and materials supply, is well planned and designed; it provides opportunity for enhancing production performance objectives such as less cost, space and time along with higher quality levels (Gonçalves and Salonitis, 2017). The modular house manufacturing industry needs to define what critical factors to consider during the design process of an assembly line along with how the assembly line can be designed to assure that the desired results will be obtained.

The aforesaid indicates that there is an interest in analyzing benefits and drawbacks for implementing an assembly line for modular house manufacturing. There is also an interest in discovering critical factors for designing an assembly line for modular house manufacturing along with how an assembly line with the related materials supply can be designed for modular house manufacturing in order to provide greater efficiency in the manufacturing process.

1.3 Purpose and research questions

It is stated in the problem description that there is a constant increase in the demand for housing which in turn puts pressure on the modular house manufacturing industry. Further on, it is stated that implementation of assembly lines can have a significant effect on the production efficiency; but can imply disadvantages if it is implemented for large and bulky products with variation. It is also stated that the process of the design of an assembly line with the related materials supply for modular house manufacturing is challenging. Therefore, the purpose of the study is:

To investigate how an assembly line for modular house manufacturing and the related material supply may be designed in order to increase the overall efficiency of the manufacturing process.

In order to fulfil the purpose, three research questions have been formulated. The modular house manufacturing industry is seeing advantages such as shorter throughput time and a consistent flow which in turn has a positive effect on the efficiency of the manufacturing process. Further, this can increase the competitiveness of an organization. If a modular house manufacturing company considers implementation of an assembly line, it is essential to analyze if it is an adequate way to increase the production efficiency. This leads to the first research question of the study:

1. What are the benefits and drawbacks of using an assembly line for modular house manufacturing compared to traditional fixed position manufacturing?

As a next step in the process, before the actual design of the assembly line. It is important to consider several factors that are crucial for the assembly line to be successful. This leads to the second research question of the study:

2. What are the critical factors that needs to be considered when designing an assembly line for modular house manufacturing?

The critical factors identified provides a foundation for a careful design of the assembly line. This leads to the third research question of the study:

3. How may an assembly line for modular house manufacturing and the related material supply be designed?
A single case study will be conducted at a modular house manufacturing company in order to answer the research questions and fulfil the purpose.

1.4 Scope and delimitations

The scope of the study comprises the process flow of an assembly line with the related materials supply. It comprises a suggestion for an assembly line with specified work stations and related materials supply that is aligned with the manufacturing process of modular house manufacturing. Technical details are not taken into consideration for the proposal. Figure 3 illustrates the scope and delimitations of the study.

![Figure 3. Scope and delimitations of the study.](image)

The first research question is delimited only to address benefits respectively drawbacks of having an assembly line for modular house manufacturing. The second research question is delimited to address the critical factors when designing an assembly line for modular house manufacturing. The third research question is delimited to design of an assembly line for modular house manufacturing. Therefore, the study is delimited to the modular house manufacturing industry.

1.5 Outline

The remainder of this thesis is structured as follows. The second chapter presents the theories that are relevant and fundamental for the study in order to provide a deeper understanding of the problem area. The subjects covered are benefits and drawbacks, critical factors and design of assembly line. The third chapter presents the methods that has been chosen to fulfil the purpose of the study. The research approach, research strategy and techniques for data collection and analysis are presented. Further on, the trustworthiness of the research is appraised. The fourth chapter presents the findings from the empirical data that has been collected during the case study. This data is further on analyzed and the research questions of the study are answered. Finally, the fifth chapter presents a discussion of the findings that has been obtained along with implications of the research. Further on, based on the findings, conclusions are drawn and presented.
2 Frame of reference

The following chapter presents the theories that has been set as the foundation for the study. As an introduction, an overview of the theoretical frame of reference will be presented along with its connection to the research questions. Further on, the theories will be presented.

2.1 Components of the frame of reference

The theory that is fundamental in order to support the research questions of the study is being described in the following chapter. Figure 4 illustrates the relation between the research questions and theory.

The fundamental theory for the first research question comprises characteristics and criterions for when it is adequate to have an assembly line. Further on, the characteristics of modular house manufacturing is being covered. This will provide a base for identification of benefits respectively drawbacks of implementation of an assembly line for the modular house manufacturing industry.

The fundamental theory for the second research question comprises modular house manufacturing characteristics that needs to be considered as critical factors in relation to design of an assembly line. This will provide a base for the actual design of an assembly line for modular house manufacturing.

At last, the fundamental theory for the third research questions comprises the main aspects that needs to be decided in order for the assembly line to be adequate for the products being produced along with the demands that need to be met.

Figure 4. Relation between research questions and theoretical frame of reference.
2.2 Benefits and drawbacks

2.2.1 Assembly lines
When manufacturing large volumes with few product variants, which has a high and even demand; a product-oriented assembly line is appropriate, where stations have an operating system that is specialized for homogeneous products (Kucukkoc and Zhang, 2017). The stations are often close and interconnected to one another where the product moves in a flow direction, thus value is being added to the product by the use of the resources at each station (Limère et al. 2012; Ikuma et al. 2010). Each station is performed in a predetermined working pace, also known as cycle time (Atasagun and Kara, 2013).

In an assembly line; the operators have relatively simple working tasks, due to specialized equipment and standardized work procedures that facilitates the work process (Xu and Xiao, 2009). An assembly line requires extensive balancing between all stations (Sancı and Azizoğlu, 2017). Therefore, even the slightest disturbance in the manufacturing process can cause the entire production to be decelerated (Xu and Xiao, 2009; Gurevsky et al., 2013).

![Assembly line layouts](image)

Figure 5. Types of assembly line layouts (Kara et al. 2010).

Kara et al. (2010) explains that there are five different types of assembly line layouts (Figure 5). The two most common types are the traditional straight assembly line and the U-shaped assembly line (Kara et al. 2010) whereas the second mentioned provides higher flexibility and quality compared to the traditional straight assembly line according to Atasagun and Kara (2013).

2.2.2 Modular house manufacturing
Modular houses are manufactured in factories, under controlled conditions and by qualified specialists (Mullens and Kelley, 2004). Modular house manufacturing companies are following the same laws and legislations as other construction companies; however, the production is characterized by manufacturing and assembling the units in a central location using standardized methods of practice before the final formation (Molavi and Barral, 2016; Nasereddin et al. 2007).
The construction of the modular houses can be for example schools, offices and residents (Lee et al., 2016). The modular houses can be built up to 95% degree of completion in the factory (Ikuma et al., 2011).

The finished modular houses are transported from the factory to the construction site and assembled into a unitary modular unit (Nasereddin et al. 2007). The high level of completion derived from technology and a standardized manufacturing process saves time and costs as well as improving the efficiency and quality (Steinhardt and Manley, 2016) along with avoiding the problems that may arise due to weather conditions thus create a safer working environment (Ikuma et al. 2011; Molavi and Barral, 2016).

According to Molavi and Barral (2016); the cost can be an advantage for modular house manufacturing. Modular house manufacturing imply a lower production cost due to the need of less and cheaper labor without obstacles such as bad weather compared to a traditional construction site. On the other hand, design engineering, contract administration, and procurement are departments that increases in costs for the modular house manufacturing industry (Molavi and Barral, 2016).

A disadvantage for modular house manufacturing is the need for materials. Units can require more extensive solutions in order to accomplish the necessary structural performance compared to traditional techniques. Due to the extensive amount of fabrication as well as transportation; the complexity of planning and scheduling will enhance (Molavi and Barral, 2016).

2.3 Critical factors

2.3.1 Line balancing

A classical problem in manufacturing industries is the balancing of the assembly line (Pereira, 2015; Xu and Xiao, 2009; Gurevsky et al. 2013). Line balancing is a challenging task due to complexity and constraints in the process of the modular house manufacturing industry; such as dry time and bulky materials (Corominas et al. 2011; Ikuma et al. 2010). To continue, the complexity also adheres to the level of standardization whereas it is common to address mixed-model assembly lines for industries that offers variety in their products. Product variation implies deviation in processing time at each assembly line workstation (Boysen et al. 2011).

When the tasks of the manufacturing process are evenly distributed; i.e. the cycle time at each workstation is equal; the production efficiency will increase (Roy and Khan, 2010; Sancı and Azizoğlu, 2017). The challenge behind this issue are precedence constraints that adheres the need for completing some tasks to be able to undertake another task (Blum, 2010; Roy and Khan, 2011).

2.3.2 Dry time

In relation to line balancing, the dry time included in the manufacturing process of the modular house manufacturing industry is an issue (Yaghubian et al. 1999). Gluing of roof and floor carpets needs to reach a desired dry state before further production can be carried on (Sterley et al. 2012). The same goes for the dry time of paint and spackle (Steinhardt and Marley, 2016).

2.3.3 Bulky materials

The material supply has a large impact on the production efficiency of the assembly line thus the layout needs to be designed in a way that the material can feed the line with the right amount at the right time (Lee et al. 2016). One critical factor within the issue of having a good material supply for the modular house manufacturing industry is the bulky materials (Steinhardt and Manley, 2016). Bulky materials result in inflexibility for placement of materials; i.e. having the materials close to the working
stations. Further on, loading of materials can be challenging due to space occupation. In relation to the assembly operation; bulky materials require aid such as traveling cranes to facilitate the material handling (Nasereddin et al. 2007).

2.4 Design of assembly line

2.4.1 Tact and tact time

The tact time of the assembly line is set based on the tact of the customer demand; i.e. the annual production volume the customer requires (Battaïa et al. (2015). The tact can be calculated by dividing the annual production volume with the available production time (Sungur and Yavuz, 2015). Equation 1 illustrates an example of how the tact can be calculated.

\[
\text{Equation 1. Calculations of tact.}
\]

\[
\text{Tact} = \frac{\text{Annual production volume}}{\text{Available production time}} = \frac{10 \text{ units/day}}{8 \text{ h/day}} = 1,25 \text{ units/h}
\]

If the annual production is 10 units per day and the available production time is 8 hours per day; the tact of the production is 1,25 units per hour. To continue, all stations of the assembly line are depended on the tact time; which means that when a tact ends, the product is moved to the next station. The tasks that are assigned to each station needs to be executed during the time that is set as tact time (Battaïa et al. (2015). The tact time can be calculated by dividing the available production time with the annual production volume (Sungur and Yavuz, 2015). Equation 2 illustrates an example of how the tact time can be calculated.

\[
\text{Equation 2. Calculation of tact time.}
\]

\[
\text{Tact time} = \frac{\text{Available production time}}{\text{Annual production volume}} = \frac{8 \text{ h/day}}{10 \text{ units/day}} = 0,8 \text{ h/unit}
\]

If the annual production and the available production time is the same as in the previous example; the tact time should be 0,8 hours per unit. The time interval for each product to be finished and ready for customer delivery is determined by the tact time (Battaïa et al. (2015).

2.4.2 Cycle time

The time it takes for an operation to complete all the procedures once; and the operation starts over again; is defined as cycle time. In an assembly line, the cycle time can be determined as the time it takes for one product to complete the procedures at one station. In order to be able to meet the customer demand; the cycle should be aligned with the tact and tact time. It is important to have an efficient line balance in order to not have a variety in cycle time among the work stations (Zeltzer et al. 2017).

2.4.3 Material supply

The purpose of material supply is to carry out materials movements safely and efficiently, (Chakraborty and Banik, 2005; Lin et al. 2000) as well as to ensure that the requested material is delivered in the right amount to the right recipient at the right time without damaging the materials along the movement route (Green et al. 2010; Lin et al. 2000).

The important matter of material supply is that it facilitates productivity that in turn leads to increased profitability for the organization (Chakraborty and Banik, 2005). Many companies use similar equipment in their production to increase the efficiency;
and in order to stay ahead of competitors, a decisive factor is further development in terms of material supply (Green et al., 2010; Lin et al. 2000).

Material handling systems are considered particularly important for achieving efficient production utilization such as equalization of the manufacturing process, increased productivity and maximization of labor as well as utilization of the infrastructure area (Chakraborty and Banik, 2005). These factors have a major impact on both lead time, cycle time and tact time but also on the total cost of the end product. Layout design is therefore an important aspect of the production layout for optimizing the flow, which minimizes costs and maximizes the fill rate (Green et al., 2010). This can be accomplished by logistic, where high-frequency components should be easily accessible near the manufacturing process, so that the transport distance becomes shorter, while low-frequency components can be located at a longer distance. Components comprises materials, equipment and tools (Green et al. 2010). It is important that organizations design a layout that is aligned with the ambition of achieving the optimum production flow for the given conditions (Green et al. 2010; Lin et al. 2000).

2.4.4 Exploitation of resources
A resource can be defined as an asset needed during the manufacturing process (Zhang et al. 2017; Vincent and Hu, 2014). Exploitation of resources has a significant impact on the production efficiency; thus, it is important to do careful planning of resource allocation for a manufacturing plant to ensure that the available resources has a high degree of exploitation. A high degree of exploitation of resources leads to enhanced productivity and in turn enhanced profitability due to fewer resources with higher occupancy (Vincent and Hu, 2014).

2.4.5 Quality and productivity
Quality and productivity are two concepts that are related to each other. Productivity is the measure of output divided by the measure of input; thus, the total quantity of finished goods that are ready to be distributed to the customers. Productivity entails efficiency in performance for an organization. Quality is the performance of a product divided by the customers’ expectations (Kumari and Anurhadha, 2013).

It can be stated that the relation between these two concepts is that both concerns performance; whether it is in regard to product, service or system; the performance is being measured in different ways. Therefore, organizations incorporates quality controls in the manufacturing process to ensure high quality which in turn has a positive impact on the productivity (Kumari and Anurhadha, 2013).
3 Method and implementation

The following chapter presents the research approach, research strategy and techniques for data collection and data analysis that has been done in order to fulfil the aim of the study. At last, an evaluation of the research quality is presented.

3.1 Research approach

The research approach impacts the way theoretical and empirical data is collected. Three different approaches can be adopted in research; deductive, inductive and abductive. The deductive research approach starts from development of a hypothesis from an already existing theory, which is further on tested in order to state conclusions. The opposite from the deductive research approach is the inductive research approach hence it starts from collection of empirical data followed by theoretical propositions (Suddaby, 2006). The abductive research approach uses both deductive and inductive perception to derive conclusions (Kovács and Spens, 2005).

The research approach that has been adopted for this study is the abductive research approach. By adopting an abductive research approach, the process of obtaining in-depth knowledge of the studied phenomena was facilitated by establishing a back-and-forth process between the collection of theoretical data and empirical data. When collecting theoretical and empirical data adopted by an abductive research approach; empirical data will have an impact the collection of theoretical data and reversed. Figure 6 illustrates the abductive research approach of this study.

Further on, Patel and Davidson (2011) describes three ways to collect and analyze data for the research; quantitative method, qualitative method and a mix between the quantitative and qualitative method. The quantitative method is mainly numerical data being analyzed by the use of statistical techniques to examine the correlation between variables (Patel and Davidson, 2011). The qualitative method examines data that is non-numerical thus requires verbal data analysis (Devaney and Yin, 2016). A mix between the quantitative and qualitative method is a combination of both numerical and non-numerical data (Patel and Davidson, 2011).

The techniques for data collection of empirical data has been interviews, observations and document studies that has required verbal data analysis. Therefore, a qualitative research approach has been followed during the collection of empirical data, in order to answer the research question thus fulfil the aim of this study. A qualitative research approach is appropriate when there is limited knowledge about the area being studied.
Method and implementation

(Patel and Davidson, 2011). The problem area of this study is relatively unexplored, as there is limited knowledge about assembly lines for modular house manufacturing.

3.2 Research strategy

A research strategy is chosen to answer the research questions and fulfill the purpose of the study in the most suitable way. There are several types of research strategies such as; surveys, experiments and case studies (Patel and Davidson, 2011). Surveys are adequate for answering questions that aims to know “who” and “where”; experiments are adequate for examining the correlation between variables and case studies is adequate for exploring a problem area inside its context. By taking the purpose and research questions of the study into consideration; the research strategy that has been chosen is a case study.

3.2.1 Case study

The choice of conducting a case study has been based on two key aspects. First, Yin (2013) explains that a case study provides the opportunity to study a research area within a practical context. Therefore; doing a case study has made it possible to investigate how an assembly line with related material supply may be designed for the modular house manufacturing industry within a real-life context. Second, the literature within the area of assembly lines in relation to the modular house manufacturing industry is limited. Therefore; conducting a case study has provided the opportunity to investigate the characteristics of modular house manufacturing by the use of data collection techniques such as interviews, observations, and document studies. This in turn made it possible to adapt the gathered data for it to fit to the characteristics of assembly lines; thus, develop an assembly line for modular house manufacturing.

In Figure 7, four different ways of conducting case studies described by Yin (2013) are illustrated. The dimensions that characterizes the case studies are; single or multiple case and holistic or embedded case.

![Figure 7. Case study designs (Yin, 2013).](image)

The case study design that has been chosen for this study is single and holistic case study. The reason behind this choice is that it provides the opportunity to gain rich and in-depth data about the phenomena being studied. According to Yin (2013), multiple case studies does not have the same prerequisites for gaining rich and in-depth data as single case studies.
The case study has been conducted at Zenergy AB in Skillingaryd, Sweden. Purposive sampling has been used for the choice of the case company. Purposive sampling is of non-probability character and adheres that the researchers choose a sample that they consider have the right characteristics in order to represent a larger group (El-Masri, 2017). The criterions for the choice of the case company is that they are in the modular house manufacturing industry; and are interested in implementing an assembly line with the intention of increasing the efficiency in the manufacturing process of modular houses. There is also an interest in analyzing advantages respectively disadvantages for having an assembly line for their products. The interests of the case company are well compatible with the aim of the study.

3.3 Data collection

The results of the study have been obtained by the use of multiple techniques for data collection (i.e. method triangulation). Also, triangulation has been adopted by having two researchers for this study along with multiple sources of data and theories. Triangulation can result in different perspectives of findings which in turn develops a comprehensive understanding of the studied area (Carter et al., 2014). In addition, triangulation enables reevaluation of the findings (Yin, 2013).

3.3.1 Primary data collection

Interviews, observations as well as document studies has been used for primary data collection.

*Interviews*

The main motive behind the choice of using interviews for the collection of qualitative data is that it is an appropriate method when there is an interest in providing a deeper understanding on a problem area (Blomkvist and Hallin, 2014; Williamson, 2002). There are three different types of interviews; *structured, semi-structured and non-structured* (Williamson, 2002). Interviews with open questions are categorized as semi-structured interviews, whereas they provide flexibility for the ones conducting the interviews in terms of the ability of adapting the follow-up questions according to the answers given by the respondents (Williamson, 2002). Furthermore, another benefit with this strategy is that it provides freedom for the respondents to answer the questions by expressing their own ideas and thoughts thus provide comprehensive answers. Therefore, the interviews that has been conducted for this study has chosen to be of a semi-structured character. The respondents chosen for the interviews has roles within the organization that are directly related to the problem area being studied. In Table 1, an overview of the completed interviews is presented.

*Table 1. Overview of the completed interviews.*

<table>
<thead>
<tr>
<th>Role</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVD/COO</td>
<td>Products/Materials/Work procedure</td>
</tr>
<tr>
<td>CFO</td>
<td>Products/Materials/Work procedure</td>
</tr>
<tr>
<td>Production Manager</td>
<td>Products/Materials/Work procedure</td>
</tr>
<tr>
<td>Sourcing Manager/Supply Chain Manager</td>
<td>Products/Materials/Work procedure</td>
</tr>
<tr>
<td>Quality Manager</td>
<td>Work procedure</td>
</tr>
<tr>
<td>Project Manager</td>
<td>Work procedure</td>
</tr>
<tr>
<td>Teamleaders</td>
<td>Work procedure</td>
</tr>
<tr>
<td>Operators</td>
<td>Work procedure</td>
</tr>
</tbody>
</table>

Interview forms with the majority of open questions were created in order to provide well-structured interview sessions. To attain a high response rate, the interview sessions were face-to-face (Williamson, 2002). Individual interviews as well as group
Method and implementation

Interviews has been carried out and the time has varied from thirty minutes to three hours for each interview session. The time span for the interviews has been from January to May 2018, whereas at least three interview occasions has been done on a weekly basis.

Observations
Observations can obtain complementary information to the interviews thus increase the reliability (Yin, 2013). Observations create an independent image of what is happening in reality, thus rely on more than the point of views and perceptions of others (Jacobsen, 2002). Observations has been carried out in this study, thus resulted in deeper knowledge and understanding of the studied phenomena. Aspects such as work procedure, material flow and equipment has been studied. In Table 2, an overview of the completed observations is presented.

Table 2. Overview of the completed observations.

<table>
<thead>
<tr>
<th>Area of observation</th>
<th>Method</th>
<th>Nr of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>Passive</td>
<td>2</td>
</tr>
<tr>
<td>Pre assembly</td>
<td>Active</td>
<td>1</td>
</tr>
<tr>
<td>Pre assembly</td>
<td>Passive</td>
<td>4</td>
</tr>
<tr>
<td>Assembly</td>
<td>Active</td>
<td>12</td>
</tr>
<tr>
<td>Assembly</td>
<td>Passive</td>
<td>12</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Active</td>
<td>1</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Passive</td>
<td>2</td>
</tr>
</tbody>
</table>

The majority of the observations has mainly been passive but also several active observations has been carried out. All observations have been done with documentation in form of notes, pictures and videos. According to Blomkvist and Hallin (2014), the validity of the study can be enhanced by having a proper documentation. Using passive observations provides the benefit of that the probability of obtaining an image that is compatible with reality is higher than by using active observations only (Holme et al. 1997). On the other hand, active observations can reduce the risk of misinterpretations (Yin, 2013). During the active observations, the construction workers has described the work procedure in detail during the process. During the passive observations, the work procedure was observed in order to ensure that the described work procedure is aligned with reality. The time for the observations that been carried out has varied from one hour to four hours. The time span for the observations has been from January to May 2018.

Document studies
In order to answer the research questions with the intention of obtaining an image of the reality throughout the facts being presented, document studies have been done (Williamson, 2002). In Table 3, an overview of the completed document studies is presented.

Table 3. Overview of the completed document studies.

<table>
<thead>
<tr>
<th>Date</th>
<th>Purpose</th>
<th>Method</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018-01-22</td>
<td>Forecast documents</td>
<td>Structured</td>
<td>0.5</td>
</tr>
<tr>
<td>2018-02-05</td>
<td>Production process information</td>
<td>Structured</td>
<td>8</td>
</tr>
<tr>
<td>2018-02-08</td>
<td>Products and materials information</td>
<td>Structured</td>
<td>8</td>
</tr>
</tbody>
</table>

Documents that has been studied concerns the manufacturing process, product specifications and resources. Documents regarding forecasts has also been studied.
The information obtained has been used in the process of designing an assembly line with and the related material supply for modular house manufacturing.

3.3.2 Secondary data collection
It is mentioned previously that the use of multiple techniques for data collection can increase the research quality. In addition to the interviews, observations and document studies that has been carried out; a literature review has been conducted in order to enrich the quality of the study. The literature review has provided a foundation for the study. According to Williamson (2002), it saves time in the process of data collection by the use of secondary data. However, it is only safe to use secondary data when its real meaning is known (Williamson, 2002). Bearing this in mind, the data sources has been selected critically in order for it to be relevant and trustworthy for this study.

Literature review
The opportunity to identify and analyze concepts that are related to assembly lines and modular house manufacturing has been provided by the use of a literature review. Further on, deeper knowledge and understanding of the studied phenomena has been obtained by the use of a literature review (Williamson, 2002). The literature review has formed the theoretical framework necessary for answering the research questions. The following areas has been covered in the literature review:

1. Benefits and drawbacks
2. Critical factors
3. Design of assembly line

The main source for the literature review has been search engines and databases, such as Primo and Scopus. The search results from the search engines and databases has been scientific reports and articles. Keywords, such as; production layout, production efficiency and assembly line has been used in order to find literature that is relevant for the study.

3.4 Data analysis
Data analysis of qualitative data does not have a standardized approach. Saunders et al. (2012) describes that the process of data analysis depends on the research approach. In addition, the deductive- and inductive research approach has rather clear connection with the choice of data analysis approach compared to the abductive research approach. Yet, there is a general approach for the abductive research approach (Saunders et al. 2012), that has been selected for this thesis.

Data analysis has been a continuous process practically throughout the whole study. Figure 8 illustrates the process of data analysis in regard to the data collection consisting of literature reviews and case study.
The literature review and case study phase has collected information regarding assembly lines in general and in relation to the modular house manufacturing industry. The empirical data collection has been done by the use of qualitative methods with data collection techniques such as interviews, observations and document studies. The collected data from the literature review has been compiled to a theoretical framework. The theoretical framework has been adjusted according to the empirical data by means of pattern matching (Yin, 2013) and further on data analysis was done thus the results of the study were acquired.

To minimize the risk to lose vital data, discussion and compilation has been done immediately after the data has been collected. The data collected from each interview, observation and document study has been compiled in a separate document. Further on, comparison has been done between the documents and in turn compiled together; for each data collection technique.

3.5 Trustworthiness

In order to ensure that the results of the study are of high quality, validity and reliability are two criteria measurements that is usually applied in order to judge the quality of the study (Yin, 2013). However, these two criteria are mostly relevant for quantitative studies. In a response to that, Lincoln and Guba (1985) has presented trustworthiness as a concept including four criteria measurements; credibility, transferability, dependability and confirmability to evaluate the research quality of qualitative research. Therefore, trustworthiness has been the concept chosen for evaluating the research quality of this study. Table 4 presents a summary of the research quality evaluation for this study.
In the following sections, a detailed evaluation of the research quality evaluation is presented.

3.5.1 Credibility
Credibility concerns with to what extend the data is trustworthy. This is evaluated based on the way the researchers ensure that the empirical data being presented is in line with the point of view from the respondents (Patton, 2015). The sub-criterions for credibility are; prolonged engagement, persistent observation, triangulation, peer debriefing and member checks.

Prolonged engagement concerns that the researchers have obtained understanding of the studied phenomena by ensuring that there has been sufficient involvement in the empirical setting (Lincoln and Guba, 1985). To ensure the prolonged engagement, the researchers have spent enough time in order to speak with the majority of the employees in the organization. Also, understanding of the organizational culture as well as the phenomenon being studied has been obtained.

Persistent observation concerns that the researchers are allocating time that is sufficient in order to enhance depth in the research (Lincoln and Guba, 1985). The scope that has been provided in terms of prolonged engagement for the study, has resulted in in-depth knowledge due to persistent observation. During the research process, the main aspects for the problem area has been identified and further on set in focus.

Table 4. Summary of trustworthiness evaluation for the study.

<table>
<thead>
<tr>
<th>Trustworthiness Criterion</th>
<th>Description</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Credibility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Prolonged engagement</strong></td>
<td>Sufficient involvement in the empirical setting to understand the studied phenomena.</td>
<td>Enough time has been allocated for talking to employees and get an understanding of the culture and the studied phenomena.</td>
</tr>
<tr>
<td><strong>Persistent observation</strong></td>
<td>Allocate sufficient time to enhance depth in research.</td>
<td>Identification of main aspects for problem area and further on set in focus.</td>
</tr>
<tr>
<td><strong>Triangulation</strong></td>
<td>Crosschecking data by the use of multiple researchers, methods, theories and sources of data.</td>
<td>Research conducted by two students by the use of multiple techniques and sources for data collection.</td>
</tr>
<tr>
<td><strong>Peer debriefing</strong></td>
<td>Discovery of aspects from peers.</td>
<td>Involvement of peer debriefers throughout the whole research process.</td>
</tr>
<tr>
<td><strong>Member checks</strong></td>
<td>Allow respondents to review the data.</td>
<td>Member checks has been done throughout the whole research process.</td>
</tr>
<tr>
<td><strong>Transferability</strong></td>
<td>Detailed description of the research process that provides the opportunity for a transfer of the findings.</td>
<td>Chosen respondents has organizational roles that is directly related to the studied phenomena.</td>
</tr>
<tr>
<td><strong>Dependability</strong></td>
<td>The possibility for the reader to examine the study.</td>
<td>Accurate documentation of data collection has been carried out.</td>
</tr>
<tr>
<td><strong>Confirmability</strong></td>
<td>No bias is added to the findings.</td>
<td>Careful preparation of data collection techniques has been done to ensure alignment with the purpose of the study.</td>
</tr>
</tbody>
</table>
Method and implementation

Triangulation concerns the use of multiple techniques for data collection (Yin, 2013). The study comprises multiple techniques for data collection thus ensuring triangulation. Also, the triangulation has been enhanced furthermore because the completed interviews has depended on individuals with different roles in the organization. Blomkvist and Hallin (2014) points out that another form of triangulation is to do research together with another person or several other persons. This research has been done by two students, whereas both have been involved in the various stages of data collection and data analysis thus the risk of misinterpretations has been reduced.

Peer debriefing concerns discovering aspects from peers that may not be considered by the researchers (Lincoln and Guba, 1985). Peer debriefs has been involved throughout the whole research process, both in the context of research by support from supervisors as well as in the practical setting by support from employees at the case company.

Member checks concerns that the respondents review the data obtained (Lincoln and Guba, 1985). Member checks has been carried out during the whole research process by having a continuous discussion of the development of the research in order to ensure that the interpretations of the researchers are correct.

3.5.2 Transferability
Transferability concerns if the findings of the study can be generalized (Patton, 2015). It concerns that the researchers have described the research process in detail which provides the opportunity to conduct a similar study (Lincoln and Guba, 1985). Because of the fact that each case study is unique, replicability is not the focus but rather providing information of how to conduct a case study in a similar context. In order to enhance the transferability, the respondents chosen for the collection of empirical data has roles within the organization that are directly related to the problem area being studied, in combination with a detailed presentation of the methods used and data obtained.

3.5.3 Dependability
Dependability concerns if the study can be examined by the reader (Lincoln and Guba, 1985). In other words, the researchers should document the research process to make it traceable for the readers. Also, the researcher should ensure that there is logic behind the research process (Patton, 2015). In order to ensure the dependability, accurate documentation of techniques for data collection has been done throughout the study, thus the study can obtain similar results if it would be conducted again.

3.5.4 Confirmability
Confirmability concerns that bias is not added to the findings of the study (Patton, 2015). The findings of the study need to be supported by the theoretical and empirical data collected (Lincoln and Guba, 1985). In order to enhance the confirmability, careful preparation of interview forms and measurement instruments has been done in order to ensure that the data collected is relevant for the study. This implies that the various techniques chosen for data collection needs to be consistent and aligned with the problem formulation, purpose and research questions (Blomkvist and Hallin, 2014). In addition, pattern matching has been adapted during the data analysis to ensure that the empirical data is well compatible with the theoretical framework.
4 Findings and analysis

The following chapter provides a description of the company that has been chosen for the case study followed by the existing manufacturing process. Further on, benefits and drawbacks for having an assembly for modular house manufacturing will be presented, followed by critical factors to consider when designing an assembly line for modular house manufacturing along with a suggestion of a possible future manufacturing process for the case company.

4.1 Case company description

This master thesis has been carried out in collaboration with Zenergy AB in Skillingaryd, Sweden. Zenergy AB is a company that produces construction site cabins, building blocks and modular houses. The products are of a bulky nature and vary in size but also in terms of complexity depending on the area of usage. The company has 18 employees and a turnover that reached 40 MSEK in year 2017.

Zenergy AB uses prefabricated building elements; such as floor structures, roofs and walls in their production. Their products are produced and handled in a factory that is not located by the construction site. Zenergy AB assembles the prefabricated building elements to a unit and then transports the almost finished product to the construction site to be attached in a final assembly to become useable.

Currently, Zenergy AB produces their products by the use of a fixed position layout. Due to a rising customer demand, thus a need of increasing the efficiency in their manufacturing process of modular houses; they are willing to invest in an alternative solution; assembly line implementation; for their production.

4.2 Existing manufacturing process

At present, the units are located in a fixed position where the flow of information and resources moves to the product (Figure 9).

![Figure 9. Present state of the production layout.](image-url)
There are eleven positions for the building the units, six on one side of the factory respectively five on the opposite side of the factory. This is where the main assembly is taking place, illustrated as a blue marking in Figure 9. The units on respective side are separated by a driveway for the forklifts. The production of the units is divided in a pre-assembly process (carried out in the working station areas) and a main assembly process (carried out in the unit areas).

The different units vary from six to eleven meters in length and from three to 3,6 meters in width. The most common product variant are nine meters long and 3,6 meters wide. The height is the same for all product variants. For the future, there are no plans in building units that are longer than 11 meters in length and wider than 4,15 meters, because special transportation is required in larger dimensions. The lead times for the different product variants differs, due to the fact that some of the product variants have more operations than others in order to be finished. The lead times varies from 100 to 400 hours.

There were many similarities regarding the production of the various product variants. Despite the similarities, no standardized process is used. The production supervisors are heavily congested, which results in short-term problem solving.

4.2.1 Pre-assembly
The exterior walls, floor and ceiling elements (ZIP-elements) of Zenergy AB consists of two magnesium oxide boards glued to PIR-insulation. This unique solution causes the ZIP-element to get a lower U-value than traditional walls with equivalent thickness, but also a fire classification of EI60. Bonding and curing of the ZIP-elements are done in a separate pre-assembly area. Further on, they are being transported to another pre-assembly area where cutting of the ZIP-elements takes place in order to adjust them to the correct sizes. These areas are illustrated as a red marking in Figure 9.

To minimize cold bridges in the units, the ZIP-elements are glued together into a solid unit, and then reinforced by a steel structure that works as the carrying structure of the unit.

4.2.2 Main assembly
Inside and outside working operations are carried out in the main assembly area. For example, installations of electricity, ventilation, water and sewage are considered as inside working operations and windows, doors and facade as outside working operations. A detailed description of the working procedure per working day (nine and a half hours), for the most complex product variant, is presented in the Tables 5 to 15. It takes approximately two working weeks to finish one modular house and the current tact is one unit per day; with the goal to increase the tact to two units per day in association with an implementation of an assembly line. Table 5 illustrates the working procedure for day one.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame pipes and assemble wall profile</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Build walls</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Working procedure – Day 1.

Two work activities are taking place during the first day of the main assembly of the modular house. Frame pipes and assemble wall profile requires two operators and it takes six hours (twelve hours in total) to complete the activity. Further on, the activity “build walls” starts. This activity requires two operators and it takes five hours (ten
hours in total) to complete the activity. One working day is nine and a half hours; thus, the activity is not completed in the first day. Table 6 illustrates the working procedure for day two.

Table 6. Working procedure – Day 2.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Build walls</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble glulam beam</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Assemble roof blocks</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Cut out corners of roof block</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Build inside walls and schakt</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Spackle the roof</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Electrics (Cable box)</td>
<td>2</td>
</tr>
</tbody>
</table>

Before a new activity can start in the second day of the main assembly of the modular house; “build walls” needs to be completed. To continue, the glulam beams is being assembled which requires five operators and it takes four hours (20 hours in total) to complete the activity. Then, the roof blocks are being assembled by six operators and it takes one hour (six hours in total) to complete the activity. Further on; two activities are started in parallel – “Cut out corners of roof blocks” and “Build inside walls and schakt”. “Cut out corners of roof block” requires one operator and it takes one hour to complete the activity and then “Spackle the roof” starts which requires one operator and takes five hours to complete; thus, the activity continues the next day. “Build inside walls and schakt” also requires one operator but it takes seven hours to complete the activity. Therefore; the remaining four hours is being executed the next day. At the end of the day, two electricians start their work that requires nine hours (18 hours in total). Table 7 illustrates the working procedure for day three.

Table 7. Working procedure – Day 3.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Build inside walls and schakt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spackle the roof (Drying time)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Electrics (Cable box)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Inside isolation and gips</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tile</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble plates around the unit</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble roof carpet</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble metal beams</td>
<td>2</td>
</tr>
</tbody>
</table>

Two and a half hours into the day the activity “Inside isolation and gips” starts. The activity requires two operators and takes six hours (twelve hours in total) to complete. Right after; the activity “Tile” starts which requires one operator and takes five hours to complete. Therefore; the activity will be finished during day four. In parallel with “Inside isolation and gips”; the activities “Assemble plates around the unit” and “Assemble roof carpet” is being done. The first mentioned requires one operator and takes two hours to finish; whereas the second mentioned requires two operators and takes three hours (six hours in total) to finish. At the end of the day, “Assemble metal beams” starts and continues the next day requiring two operators and five hours (ten hours in total) to finish. Table 8 illustrates the working procedure for day four.
Findings and analysis

Table 8. Working procedure – Day 4.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Tile</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble metal beams</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble wood on roof</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Outside work (Facade etc.)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Gips on ceiling</td>
<td>2</td>
</tr>
</tbody>
</table>

When the first two activities that started during the previous day finishes; the activity “Assemble wood on roof” which requires two operators and takes three hours (six hours in total) to finish; starts. Further on, “Outside work (Facade etc.)”; which requires two operators and takes ten hours (20 hours in total) to finish; and “Gips on ceiling”; which requires two operators and takes three hours (six hours in total) to finish; starts. Both activities are being finished during day five. Table 9 illustrates the working procedure for day five.


<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Outside work (Facade etc.)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Gips on ceiling</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Floor (1.5 h drying time)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble rainpipe</td>
<td>1</td>
</tr>
</tbody>
</table>

The activity “Floor” starts when “Gips on ceiling” is finished. “Floor” requires two operators and it takes twelve hours (24 hours in total) to finish whereas six hours is drying time. The activity continues the next day along with “Assemble rainpipe” which requires one operator and takes two hours to finish. Table 10 illustrates the working procedure for day six.

Table 10. Working procedure – Day 6.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Floor (Drying time)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Assemble rainpipe</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble schakt block</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Paint schakt block</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble acoustic- and floor carpet</td>
<td>2</td>
</tr>
</tbody>
</table>

Three activities are started and finished during day six. “Assemble schakt block” requires on operator and it takes four hours to finish and then “Paint schakt block” starts; requiring one operator and three hours. “Assemble acoustic- and floor carpet” requires two operators and five hours (ten hours in total). This activity has its starting point when there is on hour remaining on the activity “Assemble schakt block”. Table 11 illustrates the working procedure for day seven.


<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Assemble ventilation system</td>
<td>2</td>
</tr>
</tbody>
</table>
Findings and analysis

Day seven consists of one activity requiring two operators and ten hours (20 hours in total) to finish. Therefore; the remaining half an hour of “Assemble ventilation system” is done in day eight. Table 12 illustrates the working procedure for day eight.


<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Assemble ventilation system</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Spackle the ceiling</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Spackle the inside walls</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Grind and spackle the ceiling</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Grind and spackle the inside walls</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Inside paint (First layer)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Wallpaper</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Make the slope in the shower</td>
<td>1</td>
</tr>
</tbody>
</table>

Spackle of ceiling respectively inside walls followed by grind and spackle again is done in a sequence on after another. Each activity requires two operators and takes two hours (four hours in total) to complete. Further on, the activity “Inside paint (First layer)” starts; requiring two operators and three hours (six hours in total); and is finished in day nine. The activities “Wallpaper” and “Make the slope in the shower” are not dependent on the other activities and are therefore started in parallel when “Spackle the ceiling” starts. “Wallpaper” requires two operators and takes six hours (twelve hours in total) to finish and “Make the slope in the shower” requires one operator and takes three hours to finish. Table 13 illustrates the working procedure for day nine.


<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Inside paint (First layer, 1 h drying time)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Inside paint (Second layer, 1 h drying time)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Electrics (Connecting cables)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble bathroom carpet</td>
<td>1</td>
</tr>
</tbody>
</table>

When the first layer of “Inside paint” is finished; the second layer is being done requiring two operators and three hours (six hours in total). Then, one electrician starts the activity “Connecting cables” which takes five hours and therefore will be finished in day ten. In parallel, “Assemble bathroom carpet” starts; requiring one operator and six hours; and finishes in day ten. Table 14 illustrates the working procedure for day ten.


<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Electrics (Connecting cables)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble bathroom carpet</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble doors</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble windows</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble bathroom cabinets</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble roof pipes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble floor molding</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble kitchen and electrics</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Assemble bathroom plumbing system</td>
<td>1</td>
</tr>
</tbody>
</table>
Findings and analysis

Four activities are started at the same time. “Assemble doors”, requiring one operators and four hours; “Assemble windows”, requiring two operators and three hours (six hours in total); “Assemble bathroom cabinets”, requiring one operator and two hours; and “Assemble roof pipes”, requiring one operator and one hour. When “Assemble doors” is finished, three activities start whereas two of them will be finished in day eleven. “Assemble floor molding” requires one operator and takes seven hours to finish. “Assemble kitchen and electrics” requires two operators and takes four hours (eight hours in total) to finish. Lastly, “Assemble bathroom plumbing system” requires one operator and takes six hours to finish. Table 15 illustrates the working procedure for day eleven.

Table 15. Working procedure – Day 11.

<table>
<thead>
<tr>
<th>Day</th>
<th>Work activity</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Assemble floor molding</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Assemble bathroom plumbing system</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Testing of electrics and plumbing system</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cleaning the unit</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Covering the unit</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Documentation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Take out the unit from the factory</td>
<td>4</td>
</tr>
</tbody>
</table>

The modular house is finished in day eleven. “Testing of electrics and plumbing system” is done by one operator in one hour. Further on, “Cleaning the unit”, requiring one operator and three hours is being done followed by “Covering the unit”, requiring four operators and two hours (eight hours in total) and “Documentation” requiring one operator and one hour. At last, the unit is being transported out from the factory by four operators for one hour (four hours in total).

4.2.3 Materials and resources

The materials are located in a small warehouse, against the walls and anywhere where there is space inside the factory. There are also materials being stored outside the factory. There is also an importance in mentioning that materials for electrics is stored in the warehouse; which is inconvenient for the electricians. Figure 10 illustrates the placement of the materials in the factory.
Findings and analysis

The materials are being transported to the respective unit being produced; which implies that the material flow is not standardized due to different routes depending on where the units are placed.

4.2.4 Quality
The disadvantage of building the modular houses in a fixed position is according to the managers the fact that it is difficult to standardize the process and be able to properly control the workflow of each unit. This makes the errors usually not noticeable until the next procedure in the manufacturing process is carried out. The advantage is that individual units do not affect the other units during the manufacturing process, for example, if a customer has special requirements that may lead to extra operations in the manufacturing process.

The assembly of the units is done by hired personnel, where the workers usually have cross-functional skills that allows them to work with different operations in the production. This increases the work-force flexibility. As the company does not use aids such as robots, machines or cranes; the heavy lifting is performed manually by the workers or by forklifts. According to the production manager, this is not optimal for the production itself but also in terms of safety aspects.

The Production Manager also states that the complexity of the products causes the quality of the assembly to deteriorate under stress, which means that the final quality is likely to be affected. It is vital for Zenergy AB to achieve high quality of their products, especially when they work towards energy-efficiency, and fireproof solutions. In order to ensure efficient production of high quality, Zenergy AB works simultaneously with various Lean improvement tools such as 5S, 5 Whys and Kaizen.

There is a language barrier in the production, where the blue-collar workers and the production supervisors are not speaking Swedish. Therefore, when the communication takes place between the various employees, it is going from Swedish to English, from English to Latvian, Polish or Russian; and reverse.
4.3 Benefits and drawbacks for having an assembly line for modular house manufacturing

Before deciding to implement an assembly line for modular house manufacturing; it is important to analyze the benefits and drawbacks in order to assure that the benefits overvalue the disadvantages.

Assembly lines are characterized by the fact that resources are organized according to a products manufacturing process, with closely linked manufacturing processes at respective workstation. This manufacturing system is suitable for mass production of standardized products with a consistent and high demand (Kucukkoc and Zhang, 2017; Limère et al. 2012; Ikuma et al. 2010). Modular house manufacturing however, rather produces in low volumes and different production series. On the other hand, Molavi and Barral (2016) and Nasereddin et al. (2007) are emphasizing that standardized methods of practice are used in the modular house manufacturing industry. At the case company; there are different time periods for the different product variants. The production is planned based on the current project. This implies that within a certain time span, one product variant is being produced but there can also be exceptions in terms of prototypes or customer complaints of other product variants that needs to be taken care of. The respondents from the interviews considers this to be a problem in relation to assembly line production; due to the fact that despite the similarities in the production of the various product variants, they do not have a standardized manufacturing process. On the other hand, they consider this to be a solvable problem. The level of standardization at the case company can be enhanced and it is something that the company is fully aware of and need to take into consideration if they want to implement an assembly line. As for all companies in the modular house manufacturing industry; by taking the level of standardization into consideration and striving for enhancing it; modular house manufacturing can have an assembly line production layout.

Assembly lines provides the opportunity to have a steady flow in the manufacturing process; due to each workstation being balanced against one another. This is a major issue in modular house manufacturing due to the drying times that are involved in working operations such as gluing, spackling and painting. Another issue is the bulky nature of the component parts of the units of modular house manufacturing (Molavi and Barral, 2016). These issues have been informed during the case study and they imply complexity in planning and scheduling if not considered carefully. Further on, an assembly line can be designed in several different ways; where the product that is being produced and the infrastructure of a company plays a decisive role (Kara et al. 2010; Atasagun and Kara 2013). Flexibility within modular house manufacturing is restricted, thus an U-shaped assembly line is to prefer due to the higher flexibility it provides (Atasagun and Kara 2013). This can further be confirmed by the data collected from the case study. The infrastructure of the case company is limited in regard to the traditional straight assembly line whereas it would result in a low number of workstations thus causing waiting time due to factors such as dry time that is incorporated in some working operations. This enhances the fact that it is important to ensure that there are enough workstations in the assembly line for modular house manufacturing to be able to handle the complexity in the working procedure. To continue, high focus on accurate planning of an assembly line for modular house manufacturing is key in order to obtain a higher efficiency in the manufacturing process.

An assembly line can be expected to reduce cycle time in the long run as experience with the operator increases over time (Xu and Xiao, 2009). Assembly lines can also reduce lead times and internal transports as well as facilitate material handling (Kucukkoc and Zhang, 2017); which are all decisive factors of efficiency in the
Findings and analysis

manufacturing process. The present manufacturing process at the case company is not standardized; which in some cases, can have a negative impact on the manufacturing efficiency due to the fact that the operators are constantly shifting between various tasks and how they perform them; even though if the process is similar from time to time. The employees at the case company consider that implementation of an assembly line would be beneficial in terms of better allocation between work tasks, standardized work procedures and more control in the overall manufacturing process. However, disadvantages of implementing an assembly line are low flexibility in product variations, and that interference sensitivity is high (Kucukkoc and Zhang, 2017).

An assembly line would imply simplifying the manufacturing process; that is carried out in-house under controlled conditions and by qualified specialists (Mullens and Kelley, 2004). This due to the fact that the manufacturing process obtains a higher level of standardization along with greater control of the manufacturing process by operators performing specific tasks in the assembly line; which is considered as huge benefits in regard to implementation of an assembly line at the case company.

It can be stated that the drawbacks of implementing an assembly line for modular house manufacturing are not critical if careful and accurate planning is carried out. By considering the characteristics of modular house manufacturing when designing an assembly line; implementation of an assembly line would have a positive impact on the efficiency of the manufacturing process.

4.4 Critical factors to consider when designing an assembly line for modular house manufacturing

There are three main factors that has been discovered during the literature review and the case study; line balancing, dry time and bulky materials.

4.4.1 Line balancing

When designing an assembly line for modular house manufacturing; one of the critical factors is line balancing. It is important that each workstation of the assembly line have equal workload in order to achieve an efficient manufacturing process. According to literature; this is usually problematic in manufacturing industries and especially in the modular house manufacturing industry due to complexity and constraints in the manufacturing process (Pereira, 2015; Xu and Xiao, 2009; Gurevsky et al. 2013; Corominas et al. 2011; Ikuma et al. 2010). Complexity in regard to line balancing is developed due to several reasons such as product variation, dry time and bulky materials. During the case study, it was stated that the product variation implies that it is high to achieve a high level of standardization; which is one of the main factors that characterizes assembly lines. Further on, the dry time is considered to be critical along with the bulky nature of the materials. The case company is well aware of that line balancing will be an issue in relation to implementation of an assembly line. Boysen et al. (2011) states that the cycle time of the assembly line workstations will differ among the various product variants. This is also seen as problematic at the case company due to the fact that it can imply a challenge in line balancing when special customer requirements occur that can add operations in the manufacturing process and it is therefore important to consider similarities and differences in the manufacturing process of the various product variants. Also, it is beneficial to try to reach an as high level of standardization as possible; both in terms of manufacturing process but also materials and aids that is being used to build the units.

Deciding which working operations that will be done at each workstation to have an equal workload is challenging because some tasks cannot start before a preceding task is completed (Blum, 2010; Roy and Khan, 2010; Sanci and Azizoğlu, 2017). Therefore; it is beneficial to determine which working operations that can and cannot be done in
Findings and analysis

parallel. For example, inside and outside working operations can be done in parallel at one workstation, which will facilitate the process of line balancing. As seen in the present manufacturing process at the case company; the majority of the working operations of modular house manufacturing have long cycle times that differs from one another; and therefore, it requires either parallel activities or a high number of workstations (one working operation can be divided among several workstations) on the assembly line.

4.4.2 Dry time
As mentioned in the previous section; dry time is one of the reasons behind the complexity of balancing the assembly line. Working operations such as gluing, spackling and painting comprises dry time that needs to be taken in consideration during the process of line balancing (Sterley et al. 2012; Steinhardt and Marley, 2016). This implies that when designing the assembly line; it is important to address this factor in order to ensure that the production efficiency will not decrease. For example; ensuring that other value adding working operations can be done in parallel with the dry time. Also, if there is a case when parallel working operations cannot be done due to the need of completed preceding activities; it is important to consider workstations in the assembly line that works as buffer stations. This results in a reduced risk of having a production that is detained during the dry time.

It has been stated during the case study that the dry time is the bottleneck of the modular house manufacturing. The reason behind this is that this part of the working operation cannot be reduced in time; and it is therefore important to plan the rest of the working activities to ensure an accurate working procedure that results in an increased efficiency of the manufacturing process.

4.4.3 Bulky materials
According to Lee et al. (2016), feeding the line with the right material at the right time is crucial in order to achieve an efficient manufacturing process. In addition; this leads to a critical factor that needs to be considered when designing an assembly line due to the characteristics of modular house manufacturing that implies bulky materials. Bulky materials are inflexible in terms of placement near the assembly line area, loading of materials and need for aid during the procedure of material handling (Steinhardt and Manley, 2016; Nasereddin et al. 2007). Something that has been discussed a lot during the interviews that has been conducted in the case study is that during the process of designing an assembly line for modular house manufacturing; it is vital to consider the bulky materials due to space constraints of the factory layout. Each workstation should have the prerequisite of having the materials needed close; to avoid unnecessary movements and transportations and in turn ensure that the efficiency of the working operation is not decreased. In addition, having the (bulky) materials close do not imply to store all materials by the station; but rather the amount that is needed for the moment. It can be material for being able to feed the line for one day; e.g. ensuring that there are ZIP-elements (bulky materials) available near the station to be able to meet the tact. Also, it should be possible to load materials without causing disturbance in the assembly line; which is problematic when handling bulky materials due to a high space occupancy.

4.5 Possible future manufacturing process
In section 4.3; it has been revealed that using an assembly line for modular house manufacturing is beneficial hence the next step; which is covered in section 4.4; has been to investigate critical factors to consider when designing an assembly line for modular manufacturing. The next step is to provide a possible solution of an assembly line for modular house manufacturing. In the following sections; an assembly line for modular house manufacturing and the related material supply will be generated. It
should be noted that the suggested assembly line is based on the prerequisites of the case company.

4.5.1 Production layout
Preconditions regarding space has a large impact on the choice of production layout. Due to higher flexibility and quality; a U-shaped assembly line is a good alternative for modular house manufacturing (Atasagun and Kara, 2013). A straight assembly line would result in a minor number of workstations due to space constraints in length; which would decrease the flexibility and quality on each workstation. There would be a higher number of working operations at each workstation, which would imply that the operators would focus on a variety of tasks thus risk for missing out quality errors. Also; lower flexibility in terms of delays of working operations thus a longer distance between e.g. early workstations and later workstations of the assembly line. Also; a higher number of workstations would enable the use of buffer stations to facilitate the line balancing process thus reduce the impact of the bottleneck; dry time.

To continue, it is important to consider the working procedure when designing the assembly line layout. As shown in the case study; the early working operations in the working procedure of modular house manufacturing requires a larger area of space than those working operations that are carried out later in the process; due to handling of bulky materials. This implies that it is important to ensure that there is enough space for material handling in the first workstations of the assembly line; for all lengths and widths of the product variants. After deciding to design a U-shaped assembly line; it is important to decide where the start and the end of the assembly line will be. In addition to the working procedure and area of space inside the factory; the area outside the factory needs to be considered in order to ensure that loading and unloading of the units can be done. Figure 11 illustrates a production layout of an assembly line for modular house manufacturing.
Figure 11. Assembly line for modular house manufacturing.

The U-shaped assembly line results in a higher number of workstations (17 workstations) than if a straight assembly line would have been chosen (eleven workstations). In addition; an extra transition is added between the second workstation and the last workstation. This implies that unfinished units; e.g. prototypes; can go through the production flow once again if necessary. Further on, the assembly line is designed to be able to assemble all product variants. There are four rails that carries the units whereas two rails are needed for the six meters long units; three rails for the nine meters long units and four rails for the eleven meters long units. Three rails are fixed; due to the fact that the nine meters long units are most common. The fourth rail is removable; in order to create more space for assembling and material handling during the working operations. When required; the fourth rail is assembled onto the assembly line. To continue; the assembly line is designed to have 2.5 meters between each working station for the most common width 3.6 meters. This provides sufficient area of space when doing outside working operations. Furthermore; the workstations are not fixed which provides the opportunity to have a minor area of space between the workstations thus up to two extra workstations on the assembly line. This results in higher flexibility of the assembly line; due to availability to carry out extra working operations for special customer requirements without affecting the tact or an increase in tact by shortening the cycle time by dividing the working operations among more workstations. This issue; line balancing; will be addressed in the next section.
4.5.2 Line balancing
The tact is set based on the annual production volume that the customer requires; i.e., the time interval between each finished unit that is ready to be delivered to the customer (Battaia et al. 2015). When balancing the line, it is important to consider the tact to ensure that the customer demand will be met. In addition, quality aspects need to be considered during this phase to ensure that the units are not only ready to be delivered to the customer but also that the performance of the product meets the customers’ expectations (Kumari and Anurhadha, 2013).

The working procedure is vital in the process of line balancing; whereas the working operations needs to be divided among the workstations ensuring that the workload is equal at each workstation of the assembly line. Figure 12 illustrates how the working procedure can be divided among the workstations in an assembly line to ensure balance; with reference to the working procedure of modular house manufacturing.

![Figure 12. Workstations of an assembly line for modular house manufacturing.](image-url)
consider during the process of line balancing; to establish that two units will be produced per day. To ensure that the tact is being met; the tact and the cycle time; the time required to complete the working operations at one station (Zeltzer et al. 2017); needs to be aligned. In order to meet the tact of two units per day, the cycle time should be no longer than four hours; counting on a nine and a half hour working day (including breaks). In addition to the total quality control at the last workstation; quality controls are incorporated at each workstation before moving the unit to the next workstation. Kumari and Anurhadha (2013) states that quality controls increase the productivity. Table 16 illustrates a detailed description of the working procedure of the assembly line in relation to time; ensuring that the cycle time does not exceed four hours.
Table 16. Assembly line working procedure.

<table>
<thead>
<tr>
<th>Assembly line working procedure</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>1.0</th>
<th>1.2</th>
<th>1.4</th>
<th>1.6</th>
<th>1.8</th>
<th>2.0</th>
<th>2.2</th>
<th>2.4</th>
<th>2.6</th>
<th>2.8</th>
<th>3.0</th>
<th>3.2</th>
<th>3.4</th>
<th>3.6</th>
<th>4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame pipes and assemble wall profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble roof blocks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble plates around the unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble glulam beam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble plates around the unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build inside walls and shaft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut out corners of roof block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spackle the roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build inside walls and shaft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrics (Cable box)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble roof carpet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble wood on roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble metal beams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside isolation and gips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gips on ceiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside work (Facade etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside work (Facade etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble shaft block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble acoustic and floor carpet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble rainpipe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble ventilation system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spackle the ceiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spackle the inside walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make the slope in the shower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grind and spackle the ceiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grind and spackle the inside walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside paint (First layer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wallpaper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside paint (First layer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside paint (Second layer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paint shaft block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrics (Connecting cables)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble bathroom carpet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble doors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble windows</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble bathroom plumbing system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble roof pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble floor molding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble kitchen and electrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble bathroom cabinets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble floor molding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing of electrics and plumbing system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning the unit, quality control and documentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covering the unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Findings and analysis

The working procedure of the assembly line is not exactly in the same sequence as the working procedure in the fixed position manufacturing. In the assembly line; it is beneficial if the similar working operations are at the same workstation or close to one another; in order to have common areas for materials and equipment. For example; all working operations that contains painting should be located in the same area so that placement of the related material and equipment can be together. Furthermore, the operating time for the working operations have shortened due to the fact that at the present state for the case company; a large amount of time of the working operations is waste such as searching for materials and equipment as well as various preparation tasks. Implementation of an assembly line would imply that the necessary material and equipment would be placed near the workstation and ready to be assembled. Therefore, the working procedure have some changes; in working procedure and operating time; that has been ensured to be practicable for modular house manufacturing.

4.5.3 Material supply
According to literature; material supply and resource allocation has a large impact on the production efficiency and it is important to do careful planning of where to locate material and equipment so that it can be available when needed safely, efficiently and with a high degree of exploitation. In addition; the choice of production layout provides the prerequisites for having an efficient production flow (Chakraborty and Banik, 2005; Green et al., 2010; Lin et al. 2000; Zhang et al. 2017; Vincent and Hu, 2014). The working operations that are being carried out at each workstation provides the foundation when planning the material supply of the assembly line. Figure 13 illustrates a framework for material supply of an assembly line for modular house manufacturing. Appendix 1 illustrates the framework in a more detailed and larger scale.
As described in Section 4.5.1; the working stations that contains working operations with bulky materials are the first six workstations of the assembly line. This implies that there should be enough space to store material to feed the line according to the tact. Therefore; the main reason behind the choice of from which way input respectively output of the units should be is that there is more space available from the chosen input side for storing bulky materials than the other side.

To start; at the right side of the first workstation; ZIP-elements and isolation material for two units are stored. At the left side of the first workstation; an entresol containing pre-assembly working operations such as cutting carpet on the second floor and sawing and painting on the first floor. Both of these pre-assembly working operations requires a large space area due to bulky materials; and are planned to feed the workstations three to nine; whereas three to six are most frequent. To continue; the materials for electrics that was stored in the warehouse previously; is now stored close to the assembly line on the second floor of an entresol with a working station underneath. This facilitates the electricians working operations by having the material and the working station in the same area as well as close to the assembly line. A third entresol is added in the factory; for storage and working station of pipes and ventilation. This entresol is placed near workstation ten; where assembly of ventilation is taking place. The pipes on the other hand; are assembled in the first workstation; but due to the fact that the pipes are lightweight and does not take a lot of space; assembled pipes that are able to feed the daily tact are stored next to the ZIP-elements. A table is placed next to the entrance/exit of the preassembly rooms for preassembly of roofbeams. Along the walls; there are shelves that are storing materials such as paint; screws; doors and windows and the related working station; placed near respective workstation of the
assembly line. At last, the pre-assembly rooms are used for the same preassembly operations as origin and the warehouse is further on used as a storage area.
5 Concluding discussion

The following chapter presents a conclusion of the study followed by theoretical and practical implications. Additionally, conclusions will be presented along with limitations and suggestions on future research.

5.1 Conclusion

This study originated from an interest in investigating how an assembly line for modular house manufacturing and the related material supply may be designed in order to increase the overall efficiency of the manufacturing process. During the pre-study it has been noticed that there is a gap in literature within this area; hence, the authors of this study found it meaningful to investigate if the characteristics of an assembly line can be aligned with the characteristics of modular house manufacturing. Further on; critical factors to consider during the process of designing an assembly line for modular house manufacturing followed by the actual design process. Based on these aspects; the following purpose for the study was formulated:

To investigate how an assembly line for modular house manufacturing and the related material supply may be designed in order to increase the overall efficiency of the manufacturing process.

Three research questions were formulated in order to fulfil the purpose of the study:

1. What are the benefits and drawbacks of using an assembly line for modular house manufacturing compared to traditional fixed position manufacturing?
2. What are the critical factors that needs to be considered when designing an assembly line for modular house manufacturing?
3. How may an assembly line for modular house manufacturing and the related material supply be designed?

Before the actual start of planning and designing an assembly line for modular house manufacturing; it was necessary to investigate and compare the benefits and drawbacks in order to ensure that it would be rewarding to continue the process of designing and assembly line for modular house manufacturing. Hence, formulation of the first research question was done followed by an investigation and comparison of assembly line- and modular house manufacturing characteristics. Even though that assembly lines are not adequate for low volume products that are large, bulky and with variation (Nasereddin et al. 2007); the analysis and results demonstrated that the benefits outvoted the drawbacks which in turn provided the foundation that builds up the further research.

After revealing that using an assembly line for modular house manufacturing is beneficial; the next step has been to investigate critical factors to consider when designing an assembly line for modular manufacturing thus to answer the second research question. A single case study was carried out in combination with a comprehensive literature review; whereas three main factors were identified. These critical factors were used as a framework when designing an assembly line for modular house manufacturing and the related material supply thus to answer the third research question. However; it needs to be highlighted that in combination with the critical factors; the results from the third research question were also based on the prerequisites of the case company. On the contrary; by following the design process presented in combination with the prerequisites of a modular house manufacturing company; an increased efficiency of the manufacturing process can be obtained.
To conclude, the fact that an increased efficiency of the manufacturing process of modular house manufacturing can be obtained by implementing an assembly line has been established by this study followed by describing the process of designing an assembly line for modular house manufacturing. An assembly line can have different layouts; whereas it is important to consider which type of layout is most suitable for the infrastructure of a modular house manufacturing company. The choice of production layout will have a significant impact on the upcoming steps in the design process and in turn on the success of the assembly line. When the production layout is set; line balancing needs to be done. Depending on the number of workstations; which is influenced by the choice of production layout; the working procedure needs to be divided equally among the workstations in order to ensure that there is an even workload thus reducing the risk of disturbances or delays in the assembly line. When this step is accomplished; planning of material supply needs to be done. The choice of production layout has a vital role in if there is enough space for placement of the related materials and equipment near the workstations. Ensuring a short distance between materials and workstations will have a positive impact on the efficiency of the manufacturing process.

5.2 Theoretical and practical implications
Assembly lines in relation to modular house manufacturing is unexplored in the literature; hence this study contributes to cover this identified gap. The analysis of benefits and drawbacks of using an assembly line for modular house manufacturing has contributed to knowledge about that an assembly line can have a positive impact on the efficiency of the manufacturing process despite the fact that the products of modular house manufacturing are not adequate for assembly line production. The study also contributes to knowledge about the actual design process of an assembly line for modular house manufacturing and the related material supply; by stating three critical factors to consider in order for achieving successful results.

Modular house manufacturing companies should be aware of the significant impact the choice of production layout has on the efficiency of the manufacturing process. Also, it indicates that companies in other industries that produces products that are not adequate for assembly lines; can achieve the significant impact implementation of assembly lines can have of the efficiency of the manufacturing process. What needs to be noted; is that it is important to adjust the assembly line according to the characteristics of the specific industry. The critical factors to consider when designing an assembly line for modular house manufacturing that has been identified in this study; has been vital in order to achieve the desired results. This implies for other industries as well.

Another aspect that companies should consider is the level of standardization the manufacturing process has. The working operations of an assembly line should have an as high level of standardization as possible. Therefore; this is something to consider during the design process. Some working operations for some product variants may have a need to be adjusted in order to match the working operations of other product variants. Otherwise, there is a high risk that there will be disturbances in the assembly line which will have a negative impact on the efficiency of the manufacturing process.

The study facilitates the design process for modular house manufacturing companies that are considering implementing an assembly line for their production. Recommendations to these companies; is to follow the design process presented by addressing it to the prerequisites of their company.
5.3 Limitations and further research

The chosen methods for this study has some limitations that needs to be addressed; and taken into consideration for further research. A single case study has been conducted which contributed to gaining in-depth knowledge about the modular house manufacturing industry because of the availability to allocate the available time in the empirical setting of one case company rather than allocating the available time between the empirical settings of multiple case companies. On the other hand; if a multiple case study was conducted for this study, a larger amount of empirical data could have been obtained. Also, it would have resulted in a higher generalization of the results. To continue, the disadvantage by the use of both primary- and secondary data is that there is a risk that they have influenced one another; i.e. the conducted case study may have influenced the results of the literature review and in reverse.

The findings of this study did not address automation. Automation could imply that the level of standardization would increase along with decreasing the risk for quality errors. Therefore; it would be interesting to investigate how automation can be applied in the modular house manufacturing industry; both for traditional fixed position production layout and for assembly line production layout.

Assembly lines associated to modular house manufacturing is a field within research that is relatively unexplored; probably due to the low level of standardization the industry implies along with products that are not adequate for an assembly line. Since the results of this study has shown that assembly lines are applicable for modular house manufacturing; it would be interesting to investigate whether assembly lines can be implemented for other products that are not adequate for an assembly line. This further research can provide an increase of assembly line potentials.
References


Search terms

abstract ................................................. 1
bakgrund .................................................. 4
delimitations .......................................... 4
discussion ............................................. 8, 9
figure text ............................................. 8
holistic ..................................................... 4
methods .................................................. 7
references ............................................. 10
research questions ................................. 4