IMPROVEMENT OF PICKING OPERATIONS AND DEVELOPMENT OF A WORK BALANCING MODEL

Johan Klevensparr
Oscar Meivert

BACHELOR THESIS 2014
Industrial Engineering and Management with specialization in Logistics and Management
This Bachelor Thesis is executed at the Technical University of Jönköping within the fields of Industrial Engineering and Management, with specialization in Logistics and Management. This thesis is a part of the three-year engineering program. The authors are responsible for stated opinions, conclusions and results.

Examiner: Eva Johansson

Supervisor: Roy Andersson

Scope: 15 hp (basic level)

Datum: 2014-05-05
Abstract

Purpose – The purpose of the thesis is to improve picking operations that kit materials to assembly lines and based on that, develop a model concerning work balancing in relation to varying demand. To achieve this purpose the following questions of issue are answered:

1. What difficulties can exist in picking operations that kit materials to assembly lines?
2. How can difficulties in picking operations that kit materials to assembly lines be resolved?
3. How can a model be developed that facilitates improvements concerning work balancing picking operations in relation to varying demand?

Method – Through a summary, major difficulties are identified with support of literature studies, interviews, observations and documentation performed at a case company. The collected data form the base of the developed work-balancing model aiming at allowing users to work balance their picking operations.

Findings – Initially, a comparison between literature studies, interviews and observations at the case company revealed five major difficulties: lack of parts, order handling, warehouse maintenance, standardization of picking operations and work balancing. When the first three difficulties are improved, a standardization of processes should be performed in order to achieve process perfection. Furthermore, as a last step in the developed four-step-improvement-process, work balancing could lead to improved resource utilization. Moreover, work balancing the picking operation at the case company through the developed model resulted in a reduced balancing loss of 39%.

Research limitations – The conducted case study is structured as a holistic single case study. Since companies differ it would be appropriate to conduct multiple case studies in order to generalize results. Furthermore, the authors want to expand the extensive literature studies to identify all difficulties and alternative solutions. Nevertheless, this is not achieved in relation to the scale of the work and time limitations.

Further research – If performing a similar investigation other factors need to be taken into consideration regarding gathering of time studies such as lack of parts, picking errors, deficiencies and other interruptions, this in order to acquire a accurate company reflection due to more precise measurements.

Key words – Lean production, work balancing, kitting, improvements, standardization, picking operation, varying demand
TABLE OF CONTENT

1 Introduction ............................................................................................................. 5
   1.1 BACKGROUND ................................................................................................. 5
   1.2 PROBLEM FORMULATION .............................................................................. 6
   1.3 PURPOSE ........................................................................................................... 7
   1.4 SCOPE AND DELIMITATIONS ......................................................................... 8
   1.5 DISPOSITION ................................................................................................... 9

2 Methodology .............................................................................................................. 11
   2.1 WORK PROCESS ............................................................................................... 11
   2.2 RESEARCH APPROACH .................................................................................. 12
   2.3 CASE STUDY ..................................................................................................... 13
   2.4 DATA COLLECTION ......................................................................................... 14
   2.5 DATA ANALYSIS .............................................................................................. 17
   2.6 RELIABILITY AND VALIDITY ......................................................................... 18

3 Frame of reference .................................................................................................. 21
   3.1 LINKED THEORY ............................................................................................. 21
   3.2 MATERIAL FEEDING SYSTEMS ....................................................................... 22
   3.3 WAREHOUSE .................................................................................................. 23
   3.4 LEAN PRODUCTION ......................................................................................... 25
   3.5 ELIMINATION OF WASTE ................................................................................ 25
   3.6 FIVE PRINCIPLES WITHIN LEAN PRODUCTION ............................................. 28
   3.7 JUST IN TIME PRINCIPLE ............................................................................... 29
   3.8 5S ..................................................................................................................... 29
   3.9 WORK BALANCING ........................................................................................... 30

4 Empirical data .......................................................................................................... 33
   4.1 CASE STUDY ..................................................................................................... 33
   4.2 EMPIRICAL FINDINGS ...................................................................................... 33

5 Result and analysis .................................................................................................. 35
   5.1 DIFFICULTIES IN PICKING OPERATIONS ...................................................... 35
   5.2 HOW DIFFICULTIES CAN BE RESOLVED ...................................................... 38
   5.3 DEVELOPMENT OF A WORK-BALANCING MODEL ...................................... 42

6 Discussion ................................................................................................................ 47
   6.1 RESULT DISCUSSION ....................................................................................... 47
   6.2 METHOD DISCUSSION ..................................................................................... 50

7 Final Conclusions ..................................................................................................... 53
   7.1 CONTRIBUTIONS AND RECOMMENDATIONS .............................................. 53
   7.2 CONCLUSIONS ................................................................................................. 54
   7.3 FURTHER RESEARCH ..................................................................................... 55

References ..................................................................................................................... 57

Attached files ............................................................................................................... 63
TABLE OF FIGURES

FIGURE 1. SCOPE AND DELIMITATIONS OVERVIEW ................................................................. 8
FIGURE 2. THESIS DISPOSITION ............................................................................................ 9
FIGURE 3. WORK PROCESS SCHEDULE .................................................................................. 11
FIGURE 4. QUESTION OF ISSUE LINKED TO CHOICE OF METHOD ........................................ 12
FIGURE 5. REALITY AND APPROACHES (PATEL AND DAVIDSON, 2011) ................................ 13
FIGURE 6. DATA ANALYSIS .................................................................................................... 17
FIGURE 7. QUESTIONS OF ISSUE LINKED TO THEORY ......................................................... 21
FIGURE 8. ILLUSTRATION OF WORK BALANCING ............................................................... 31
FIGURE 9. WORK BALANCING MODEL .................................................................................. 45
FIGURE 10. FOUR-STEP-IMPROVEMENT-PROCESS ............................................................... 53

LIST OF TABLES

TABLE 1. LIST OF OBSERVATIONS ........................................................................................ 15
TABLE 2. CASE COMPANY INTERVIEWS ................................................................................. 16
TABLE 3. LIST OF CURRENT STATE OPERATION TIMES ....................................................... 34
TABLE 4. CURRENT BALANCING LOSS .................................................................................. 34
TABLE 5. SUMMARY OF IDENTIFIED DIFFICULTIES ........................................................... 35
TABLE 6. IMPROVED STATE OPERATION TIMES .................................................................... 41
TABLE 7. IMPROVED BALANCING LOSS ............................................................................... 42
TABLE 8. MODEL DESCRIPTION, STEP ONE ........................................................................ 42
TABLE 9. MODEL DESCRIPTION, STEP TWO .......................................................................... 43
TABLE 10. MODEL DESCRIPTION, STEP THREE ................................................................. 43
TABLE 11. MODEL DESCRIPTION, STEP FOUR ....................................................................... 44
TABLE 12. DIFFICULTIES AND SOLUTIONS .......................................................................... 55
I Introduction

This chapter introduces the thesis concerning an improvement of picking operations. It will present the background of the purpose together with a problem formulation, followed by scope and delimitations. Finally, the thesis disposition is presented.

1.1 Background

The 21st century’s auto-manufacturing companies are currently facing difficulties with material feeding systems for assembly lines due to today’s explosion in product variation (Fredriksson, 2002). As a result of increased market competition, companies need to customize their products to meet the global market’s demand. Nonetheless, companies tend to have difficulties adapting to the required change and have instead kept similar processes and material-feeding systems as initially implemented. This mentality has been firm, even though several changes regarding companies’ market aim have been made (Goldratt and Cox, 1992; Millington et al., 1998; Fredriksson, 2002; Douglas and Craig, 2011). However, the material feeding systems used have recently become more complex, due to broadening within product lines (Johansson and Johansson, 2006; Fasth, 2009).

The recent trend aiming at customization and diversification of products have had a massive impact on companies’ flexibility. The areas of concern are among others; layout, storage, space at assembly stations and production lines, number of workers, and finally takt time, which tend to affect companies’ performance regarding maintainable productivity (Millington et al., 1998; Fredriksson, 2002; Fasth, 2009). Hua and Johnson (2010) suggest that companies that manufacture products with a high degree of customization that demands a lot of components, should today use kitting as the standard material feeding system for assembly lines and pre-assembly stations. This is also strengthened by Johansson (1991) who states that kitting is the most suitable material feeding system for assembly stations with many components, or components of high value.

Assembly lines and stations working with products of a high degree of customization can be supplied by workers who pick parts in kits, often from a supermarket1, to reduce cost and increase efficiency of assembly workers (Ding and Puvitharan, 1990; Johansson, 1991; Hua and Johnson, 2010). However, there are several factors that need to be taken into consideration when implementing this material feeding system, such as lay-out, resources, what parts to kit and storage capacity (Johansson, 1991). A reason to implement kitting as a material feeding system could be limited space at assembly lines or stations. Such stations are clearly not suited for continuous supply nor batch supply, since those principles tend to result in increased space consumption (Millington et al., 1998; Fredriksson, 2002; Fasth, 2009). Another reason for choosing kitting as a material

---

1 A Supermarket is a inventory facility aiming at supplying downstream processes with continuous supply of merchandise (Srinivasan, 2012)
feeding system is a well placed supermarket or storage, i.e. the walking distance for picking operations between supermarkets and assembly lines are negligible. It is however important to keep the picking operations as lean as possible, since a manual picking operation is considered as a highly labor-consuming activity within a warehouse (Coyle et al., 1996).

Picking operations within a warehouse with manual systems is by authors considered as a labor-intensive operation (Coyle et al., 1996; Le-Duc, 2005). On the other hand, it is also considered a very capital-intensive operation in warehouses carrying automated systems (Burinskiene, 2009; Tompkins et al., 2010). It is therefore very important for a competitive company to keep these operations as efficient as possible, since picking operations can consume as much as sixty percent of all labor activities carried out within a warehouse (Coyle et al., 1996). According to Tompkins et al. (2010), the cost of order picking is estimated to be as much as fifty five percent of the total warehouse operating expense. For the stated reasons above warehousing professionals are considering picking operations as the primary priority for productivity improvements (Le-Duc, 2005). Hence, to improve these operations difficulties must be eliminated and a work balancing need to be performed.

The objective when performing a work balancing is according to Johnson (1988) to reduce the necessary number of stations with a given cycle time, and thereby minimize laboring costs. This is possible by assigning each task to one station instead of decentralizing assignments to several stations (Johnson, 1988). The outcome of a work balancing will evidently show an overflow in work capacity, which in this case concerns pickers, which could be utilized in some other way or somewhere else necessitated. This will further lead to a more cost-effective manufacturing process throughout a whole factory.

1.2 Problem formulation
A problem that auto-manufacturing companies today face concerns maintaining productivity in relation to a varying demand. This issue is a result of a growing global consumption, which directly affects companies’ takt times (Chopra and Sodhi, 2004; Er and MacCarthy, 2006). To be able to meet the market demand and to prevent similar problems from occurring, manufacturing companies need to maintain continuous improvements to ensure a sustainable production-rate. This is especially critical for manufacturing companies that are in the starting phase and receives a varying demand (Er and MacCarthy, 2006). A variation in demand could also lead to difficulties regarding utilization of resources in an efficient way, to keep the manufacturing as lean as possible. However, investigating the material flow and work balancing the including operations could prevent this problem from occurring. This solution will let companies free resources or replacing them for a better utilization. Nevertheless, a common problem when balancing an operation within a factory is not the calculations per say, but to get valid and reliable measurements to be able to perform such
calculations, for example correct processing- and operation-times. Furthermore, the number of units, takt time and picking time must be carefully considered, since they easily can be increased or reduced, depending on variations in demand (Fisher and Ittner, 1999; Er and MacCarthy, 2006).

Today, companies often use similar processes and material-feeding system as they always have, even though several changes in the company have been made, due to product variation (Goldratt and Cox, 1992; Millington et al., 1998; Fredriksson, 2002; Douglas and Craig, 2011). This countervails a company’s ability from reaching process perfection regarding material flow (Womack and Jones, 2003). The majority of today’s manufacturing companies are using pre-assembly stations that are supplied by workers who pick and collect parts, this to increase efficiency for assembly workers and reduce cost (Ding and Puvitharan, 1990; Johansson, 1991; Hua and Johnson, 2010). However, a lack of academic work has been discovered addressing balancing picking operations towards assembly lines with customized products (Becker and Scholl, 2006). Since picking operations is a very labor-intensive activity, it is therefore important that this matter of interest is further investigated with the aim of reducing difficulties, in order to match future demand, while creating a lean material flow as a whole (Le-Duc, 2005).

1.3 Purpose

It is known that variation in demand could be problematic for manufacturing companies, since higher demand results in lower takt times, which finally affects the work balance in certain areas within a factory. When facing varying demand, it is vital to keep the manufacturing as lean as possible, while still matching the demand in a suitable way. Therefore, as previously discussed, it is important to improve the picking operations as much as possible, since picking operations heavily affect the overall material flow towards assembly lines. The purpose of the thesis has therefore been formulated as followed:

"The purpose is to improve picking operations that kit materials to assembly lines and based on that, develop a model concerning work balancing in relation to varying demand."

To achieve this purpose, it has been broken down into three questions of issue. In order to increase the efficiency of the picking operations, the difficulties that may appear in the current state need to be identified. The first question of issue has therefore been formulated as followed:

1. What difficulties can exist in picking operations that kit materials to assembly lines?

In order to improve a process within a material flow, it is essential to know what problems already occur. Thus, will the result of the first question of issue make it possible to identify ways of handling the problems related to the picking operations. Hence, the second question of issue is formulated as:

2. How can difficulties in picking operations that kit materials to assembly lines be resolved?
The third and final question of issue, concerning development of a model used to assist companies with resource utilization, is structured to apply the outcome of the two questions of issue above, since data from them are necessary to answer the following question:

3. How can a model be developed that facilitates improvements concerning work balancing picking operations in relation to varying demand?

The purpose of this thesis is answered once the third question of issue is responded, i.e. the combined result presents information concerning improvement of picking operations to assembly lines with customized products and varying demand.

1.4 Scope and delimitations
The scope of the thesis concerns picking operations that functions within a factory. The in-plant material flow consists of several areas, these are goods handling, warehouse, supermarket and picking zone, assembly stations and finally finished goods and distribution. Due to the thesis area of concern, the delimitations have been drawn as stated in Figure 1.

Moreover, the delimitations have been cautiously regulated in order to maintain a focus on improving picking operations between the supermarket and assembly line. Therefore, questions related to labor or investment costs and interruptions of any kind have not been taken into consideration when performing times studies at the case company. The aim is only to explain the major difficulties identified due to time limitations. Moreover, difficulties with picking operations and kitting are hereby looked upon as the same, since those to are closely linked and the activities are similarly performed. The developed model is based on the case company's current situation regarding picking operations, as well as number of workers and operations performed. However, the model allows the user to adjust these limitations in order to fit the specific company in a better way, in order to be generalized. The model does not take sequencing into consideration but allows the user to adjust the operations routing. The model does not provide any solutions
the objective is only to give an overview of a specific situation and work as support when facing situations requiring decision-makings.

1.5 Disposition

Contributing to the thesis structure the content is divided into different chapters, where each chapter describes its subject with an in-depth character. The development of a following figure will help to clarify how each chapter is linked together throughout the thesis.

Figure 2. Thesis disposition

Initially in chapter one, the background of the thesis is described, followed by a more detailed problem formulation regarding improvement of picking operations. These two sections lead to the purpose of the thesis, which is broken-down into three questions of issue. The chapter ends with a presentation of the thesis scope and specified delimitations regarding the area of concern.
Chapter two presents information regarding the methods used to meet the purpose of the thesis. Initially, the work process is explained, followed by a detailed figure overlooking the thesis time frame. This chapter also includes the case study and how the data collection is structured and carried out. Lastly, the second chapter presents information concerning the thesis reliability and validity.

The third chapter presents the theoretical frameworks that form the base of this thesis. The most relevant theoretical areas included in this thesis are, “Material feeding systems”, “Production” and “Assembly line balancing”, where the last stated term from now on is referred to as “work balancing”. The chosen frameworks support results, analysis and conclusions throughout the thesis.

In chapter four, an overview description of the case study are given along with empirical findings where information concerning measurements of picking operations and observations are provided.

Chapter five present the result and analysis of the data collected, which aim to answer the three questions of issue, and thereby accomplish the purpose of this thesis. New theory will be mentioned in chapter five in order to provide the reader with information regarding difficulties of picking operations since that information cannot be negligible. The reason for having new theory in chapter five is to properly analyze and develop solutions for the difficulties identified in a candor way. Further more, chapter five presents a summary of identified difficulties where the five major difficulties originate from the case company. The five major difficulties identified at the case company are in-depth described supported by theory.

The thesis continues with chapter six, where discussions addressing the result of the thesis and the methods used. Lastly in chapter seven, practical and theoretical contributions are presented followed by suggestions for further research, which are discussed and promoted.
2 Methodology

The following chapter presents information regarding the work process and methods used to achieve the purpose of this thesis. Initially, the work process is explained, followed by the research approach, case study, data collection and data analysis. The methodology ends with information concerning the thesis reliability and validity.

2.1 Work process

The thesis work process has been designed and based on five different clauses that can be visualized as a Gantt-schedule in Figure 3. The Gantt-schedule was the most suitable choice as it clarifies the different clauses running parallel to each other. As the figure below illustrates, the work process has been ongoing since February 2014, even though some preparations and pre-studies were made in January 2014.

Figure 3. Work process schedule

To achieve the purpose of this thesis while securing a high level of reliability, a case study was performed. The thesis instigated in February, when the first meeting was held with the managers of the case company. A quick briefing followed this meeting, where suggestions regarding the proceeding process were stated. Agreements followed concerning the chosen topic of the thesis and the specific case study, where work balancing the picking operation were highlighted.

The methods used in order to answer the questions of issue have both been of deductive and inductive character, meaning that data has been collected from literature studies and scientific articles, complemented by a case study and then analyzed.
The topics studied and discussed within this report follow the authors’ knowledge gained from education in Industrial Engineering and Management, with specialization in Logistics and Management. Productivity and increased efficiency, material flow analysis, process analysis and work balancing, are all approaches recurrent in several courses taken. Therefore, great opportunities and possibilities were identified to use learned theory and put them into practice. To ensure rationality throughout the thesis, the purpose was divided into three questions of issue to further explain the reasoning process. Through these three questions of issue the purpose can be achieved.

2.2 Research approach

This thesis is characterized by an abductive approach, an individual case, which formulates a conclusion that can be generalized and explained in a thesis (Patel & Davidson, 2011). The research approach performed in this thesis has been made in three steps; (1) a preliminary idea was formulated deductively, based on literature studies and scientific articles with similar topics, (2) theory was later applied to a specific case inductively, (3) finally a result and conclusions was developed abductively. The abductive approach is a combination of a deductive and inductive approach and is used consistently throughout the thesis (Kovács and Spens, 2005). In order to form a theory regarding how to improve the picking process, a deductive approach was performed. This included studying theoretical articles and literature similar to the thesis’s topic. A deductive approach is seen as a form of interference, in which existing theories draw conclusions about
individual phenomena (Patel and Davidson, 2011). Furthermore, Patel and Davidson (2011) describe this approach as "an already existing theory that decide what information to collect, how to interpret this information, and finally how to relate the result to the existing theory". This is a quantitative method of collecting data from existing theories, which is compared to the empirical data retrieved.

The inductive approach has been made through an exploratory approach since literature and previous studies in the area of focus are limited. For this thesis, it has meant that qualitative exploratory surveys have been made by observations and interviews, which generated general assumptions complementarity with theory. This thesis is a mixture of two relatively unexplored subject areas, work balancing and increased efficiency regarding picking operations toward assembly lines with customized products, therefore is an exploratory approach even more obvious (Becker and Scholl, 2006). The first and second questions of issue can be argued to be exploratory as it aims to investigate the area of concern through observations, interviews and documentations retrieved from the case study. Based on the model made of Patel and Davidson (2011), Figure 5 presents what research approach has been used in relation to reality.

![Figure 5: Reality and approaches (Patel and Davidson, 2011)](image)

**2.3 Case study**

A case study has been performed at a case company operating within the automotive manufacturing industry. The case company’s specializes in manufacturing of trucks, with distribution within the South East Asian region, as well as Australia and surrounding areas. The case company’s factory consists of several divisions, however, this case study was performed in the production area, which involves a supermarket that supplies the picking operations with material, hence the flow towards the assembly lines. In order to retrieve accurate data needed to support the purpose, observations were made throughout the case study, parallel to interviews of managers in different positions. According to Yin
validity is established when data is properly collected and interpreted, so conclusions accurately reflect and represent the real world that was studied and therefore, the case study was performed in real-world settings with people in their real-life roles. Yin (2010) states that a case study goes hand in hand with doing a qualitative research. With this strategy, it is common that data collection is collected through interviews, observations, and by studying documents (Eisenhardt, 1989; Yin, 2010). Moreover, the choice using a case study is based on the limitations in literature and previous case studies addressing the area of concern. The performed case study is of single character since it is easier to perform than multiple case studies, therefore, less time consuming and let’s the practitioners maintain its focus. One disadvantage of a single case study is the possibility of generalization (Yin, 2003).

2.4 Data collection

The theoretical framework was created based on literature studies, which has subsequently been supplemented by a case study where data collection was carried out through observations, interviews and by studying documentations. The information obtained has been investigated and studied with relevant data collection methods described in detail below.

2.4.1 Observations

Observations were performed in order to obtain an insight of the warehouse, but also to explain what resources and which employees that are of great significance for this thesis. Yin (2010) describes an observation as follows; “observing can be an invaluable way of collecting data because what you see with your own eyes and perceive with your own sense is not filtered by what others might have (self-) reported to you”. Yin (2010) further explains that information retrieved from observations is a form of primary data. Before doing self-observation, it is needed to decide when, where and what to observe. Therefore the observations in this study were made in two ways, observations together with a mentor and self-observations. A list of observations is illustrated in Table 1.
The observation with a mentor provided an insight and understanding of the company. As a result, it was discovered that the observations performed together with the mentor exposed several areas which required further investigations. However, in order to provide data for the purpose of the thesis, self-observations were performed in order to create a self-made overview and maintain a qualitative research. The observations performed focus only on picking operations that feed material to the assembly line.

### 2.4.2 Interviews
An interview can be explained as an interaction between an interviewer and a participant. An interview can fall into two types: structured interviews and qualitative interviews (Yin, 2010). This thesis is characterized by qualitative interviews, which is more of an open interview where no script is needed nor a questionnaire with a list of questions Yin (2010). The qualitative interviews were performed to collect data, which were non-retrievable by observations. The data collected were personal opinions on how the assembly line is performing today and how to improve the material feeding system and picking operations. A qualitative interview is well-known method used to complement the observations made (Jacobsen, 2002; Creswell, 2009).
The qualitative interviews were performed with a Production Controller, Senior Logistics Engineers and a Warehouse Manager to further discover difficulties related to the questions of issue. The interviews were carried out in a room at the Logistics Office with both authors present. During the interviews, one of the authors took notes while the other had more of a leading role. In order to reduce possibilities of misunderstandings between the authors and the participant, the interviews were recorded.

Table 2. Case company interviews

<table>
<thead>
<tr>
<th>Work role</th>
<th>Number of interviews</th>
<th>Total time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production controller</td>
<td>1</td>
<td>45</td>
</tr>
<tr>
<td>Senior Logistics Engineer 1</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Senior Logistics Engineer 2</td>
<td>1</td>
<td>45</td>
</tr>
<tr>
<td>Senior Logistics Engineer 3</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>Warehouse Manager</td>
<td>1</td>
<td>50</td>
</tr>
</tbody>
</table>

In addition to the qualitative interviews, conversations with the Logistics Director and Senior Logistics Engineer (1) have been ongoing throughout the whole thesis.

2.4.3 Documentation
To further identify what aspects and processes that are of concern, documentation from the case company has been studied and analyzed. The documentation that has been shared consists of various information regarding overview of storage layouts, supply flow, forecasts on present and future demand, takt time, SKU:s\(^2\) related to product structures and current material supply systems (see attachment 5). The information has been used to create a situation assessment, which later were compared to the authors’ self-obtained information.

2.4.4 Literature studies
Literature studies have been performed in order to establish a solid base within the area of concern, which have benefited as a reference and framework throughout the whole thesis. Initially, the literature was mainly used to create an understanding of the area of concern and clarify what techniques to use, in addressing the problem formulation. The literature studies used are mainly acquired from previous courses taken, which were complemented by scientific articles and researches. The search engine of University of Jönköping’s library has been used as the primarily search engine complemented by Google scholar, which has generated reports and articles obtained through databases such as Emerald, Taylor and Francis, DiVA, ABI/INFORM, Business Source Premier (EBSCO)

---

\(^2\) Stock-Keeping-Unit is a way of sorting parts and provide them with individual numbers (Lumsden, 2012)
and Science Direct. The keywords used when searching were “material feeding”, “kitting”, “work balancing”, “picking operations”, “Lean Production”. However, “efficiency”, “improvement” and “variation in demand” were added to most of the keywords in order to narrow down the search. These keywords resulted in several hits of scientific articles, which led to new paths. The information gathered from literature studies and databases have been used as a support for the case study and the authors’ conclusions.

2.5 Data analysis

Collected data has been continuously analyzed during this thesis. To assure that no data has been misplaced, material has been summed up and structured when gathered, to ensure accuracy in the analyzing process. The connection between data collection and data analysis is difficult to separate, making the analysis an iterative process (Jacobsen, 2002). The empirical data retrieved from observations and documentation has been structured and analyzed in MS Word and Excel. The data, which was collected through individual interviews, has been structured and summarized in a Word-document. These documents have further been compared with other interview participants and then summarized. The time studies have been analyzed in Excel, in order to create structure and facilitate calculations in relation to varying demand.

In order to answer the first and second question of issue, data retrieved from observations has been analyzed and compared to the theoretical framework gathered. This was made to identify differences and similarities on how to improve picking operations and how to balance working correspondingly. The result of the first two questions was then applied on the third question of issue where a model was developed in MS Excel. On some occasions the authors identified lack of information in the theoretical framework, which could be retrieved from observations in the case study. The abductive approach between theory and empirical data ensured that the theoretical frameworks were sufficiently detailed and covered the areas intended to examine. Furthermore, Merriam (1994) argues that this approach is essential to screen out information that is unclear, repeats of what is already known or is too broad to be analyzed. The result of the thesis can be explained as a process as illustrated in Figure 6.

Figure 6. Data analysis
As mentioned earlier, the data collection was obtained by literature studies and a case study. The case study provided the empirical data, which was compared and analyzed in relation to the theoretical framework that finally supported the result of the thesis. The double-arrow between the theoretical framework and data analysis represent an iterative process, which was necessary to complement gaps discovered in the frame of reference.

2.6 Reliability and Validity

In order to prove credibility and be reliable, the authors have continuously been working to strengthen the reliability and validity of the thesis. The following section presents clarifications of reliability and validity and how they can be reflected and why these two criteria’s are essential for this thesis.

2.6.1 Reliability

Reliability indicates how reliable or credible a measurement method is (Andersen, 1994; Bell, 2006; Patel and Davidson, 2011). A good reliability is achieved when a measurement can be repeated with the same results iteratively (Yin, 2003; Thomas, 2009; Patel and Davidson, 2011). To create the conditions for a high degree of reliability in this thesis, several methods of data collection has been used, observations, interviews and documentation. This approach is usually called triangulation and allows a broader perspective throughout the case study (Yin, 2003).

The observations performed in this thesis have been carried out at different times, at different days (attachment 2). By asking similar questions to various respondents and comparing answers, the credibility and reliability in the interviews has been strengthened, (attachment 1). Furthermore, interviewing individuals in different positions can strengthen triangulation, therefore have several employees in the logistics department been interviewed in this study with similar results (Yin, 2003). As a whole, the theoretical and practical data collected and the outcome of this data has been causally analyzed, in order to increase the reliability of the thesis. Bell (2006) states that a measure of the reliability is an approach that presents the same response at different times. Patel and Davidson (2011) believe that reliability is enhanced if the different responses are compared and analyzed.

2.6.2 Validity

Validity concerns knowing what is being investigated and that right things are measured (Patel and Davidson, 2011). In other words, validity is measured based on the thesis credibility and to which extent the results are consistent with reality (Andersen, 1994; Merriam, 1994; Bell, 2006). In order to generalize the result and increase the validity of this thesis, several interviews with employees have been performed, were the outcome later been compared with real-life observations and theoretical frameworks (Yin, 2003). In this way the authors assured that the right processes were analyzed and measured.
Shortly after each interview and observation the result was discussed, summarized and analyzed. Patel and Davidson (2011) argue that this approach is essential while the information is still new and fresh in memory, which reduces the risk of valuable information obtained, becomes misplaced or lost. In order to increase the internal validity, external factors that could interrupt a result have not been taken into consideration while performing interviews and observations.

Through a briefing of the developed model, a validity check has been performed by the case company. To verify the model developed a test at the case company was performed with satisfaction, which resulted in an approval by the case company that increases the validity of the model and the thesis itself. Since the model is not in direct relation to the case company it allows the user to type in own data that reflect their reality, which increase the generalization of the model, thus increase the external validity (Persson, 2003).
3  Frame of reference

This chapter summarizes the most important and relevant theoretical frameworks included in this thesis. Initially, the theory is linked together with the purpose of the thesis, followed by in-depth information of every theoretical framework.

3.1  Linked Theory

The thesis main area of concern is to investigate if balancing work throughout the delimited material flow can increase efficiency of the picking operations in relation to a variation in demand. It is previously discussed in the background and purpose why there is a need for such analysis to be made and developed. The theoretical framework has been carefully chosen to assist and facilitate the result of this thesis. The theoretical framework constitutes the base for the techniques that will be used during this thesis, which also supports the investigation of the three questions of issue that are addressed in Figure 7.

![Questions of issue](image)

Figure 7. Questions of issue linked to theory

The three questions of issues are answered with support of several theoretical frameworks that were found appropriate. Therefore, the first question of issue is analyzed with support from material feeding systems and Lean production, which addresses the issue of possible difficulties with picking operations and kitting. As Figure 7 illustrates, Lean production is used in all questions of issue to support
analyzing the picking process and address the issue of improvement by identifying and eliminate waste such as wait, unnecessary movement and in-plant transportation. Since the question of issue number two is targeted to solve difficulties, Lean production is the primary related theoretical framework used throughout this thesis. Furthermore, this helped identifying possible difficulties in storage layout and unnecessary walking. Warehouse, specifically picking operations and work balancing will support the analysis of question of issue number three, when creating a model based on picking operations in relation to takt time and varying demand.

3.2 Material feeding systems

In-plant material supply primarily implicates what system to use for feeding material to a workstation or an assembly line. Johansson (1991) define three different systems of feeding materials to an assembly station as; (1) kitting, (2) batch supply and (3) continuous supply. However, in addition to the three traditional material feeding systems, Johansson and Johansson (2006) define a fourth system, sequential supply. The categorization of the systems can be explained by whether a selection of parts numbers, or all part numbers, are displayed at the assembly station, or, whether the components are sorted by part numbers or assembly objects. According to Johansson (1991), there are two main variables influence the choice of material feeding system for small components, which also can be used for large component; (1) the number of parallel flows in the assembly system, (2) the characteristics of the assembled product. Furthermore, Johansson (1991) states that these three systems can exist simultaneously and for different kinds of parts complement each other. Furthermore Johansson, (1991) argues that there are a large variety of solutions within each system and pure systems can hardly be defined.

3.2.1 Kitting

According to Johansson (1991) kitting can be explained as a process where components are supplied to an assembly line. The components are sorted and placed together in specific containers according to the assembly object in predetermined quantities to minimize errors (Johansson, 1991). Bozer and McGinnis (1992) define a kit as “a specific collection of components and/or subassemblies that together support one or more assembly operations for a given product or ‘shop order’”. Furthermore, kitting is suitable for assembly systems with parallelized flows, product structures with many components, quality assurance and components of high value. This means that one kit consists of a set of parts for one assembly object but it doesn’t necessarily mean that several kits could not supply all at once (Johansson, 1991). A kit can be stationed at an assembly station or in case of assembly along an assembly line or follow the object along the assembly line (Hanson and Medbo, 2012). Moreover, Brynzer and Johansson (1995) states the possibility of using kit containers, which has a formal structure so that each part has a fixed position, this to create an overview for the assembler. Furthermore, Ding (1992) and Limere et al. (2011) argues that a kit container can be a large kit rack, consisting of multiple levels where several kits
can be stored. Moreover, Medbo (1999) exemplifies a large kit rack holding parts for an automobile assembly, including an entire exhaust pipe. However, Brynzer and Johansson (1995) states that a kit container may implicate limited flexibility. According to Limere et al. (2011) it is easier to fit an additional part into an existing kit. This will reduce the man-hour consumption per part as the transport of kits will include a large number of parts and therefore are small parts preferable.

Based on a literature review by Hanson and Medbo (2012), advantages with kitting can be summarized as followed:

- Space efficient parts presentation
- Improved assembly quality
- Shorter learning curves
- A greater understanding of the assembly work
- Time saving for assembler fetching parts and reduced walking distance

Disadvantages and limitations with kitting:

- Kit preparations consume time and effort with little or non-value added to the product (Bozer and McGinnis, 1992; Brynzér and Johansson, 1995)
- Increase of administrative work, mainly order handling (Bozer and McGinnis, 1992; Brynzér and Johansson, 1995)
- Increased storage space if kits are prepared (Bozer and McGinnis, 1992)
- Cost of assembling kits (Limere et al., 2011)
- Decreased flexibility (Swaminathan and Nitsch, 2007)

### 3.3 Warehouse

According to McGinnis et al. (2007), warehouses have many functions where these functions are essential for how the picking operations are being performed. Further more, Le-Duc, (2005) summarizes the major functions for a warehouse as followed: (1) achieve production economies (e.g. make-to-stock production policy), (2) achieve transportation economies (e.g. combine shipment, full-container load), (3) take advantage of quantity purchase discounts and forward buys, (4) maintain a source of supply, (5) support the firm’s customer service policies, (6) meet changing market conditions and uncertainties (e.g. seasonality, demand fluctuations, competition), (7) overcome the time and space differences that exist between producers and customers, (8) accomplish least total cost logistics commensurate with a desired level of customer service, (9) support the just-in-time programs of suppliers and customers, (10) provide customers with a mix of products instead of a single product on each order (i.e. consolidation), (11) provide temporary storage of material to be disposed or recycled (i.e. reverse logistics) and (12) provide a buffer location for trans-shipments (i.e. direct delivery, cross-docking). Further more, McGinnis et al. (2007) divides warehouses
into two underlying categories, which are described below.

3.3.1 Warehouse design
Lambert et al. (1998) states that warehouses often involve large investments and operating costs, which affect decisions concerning the internal layout of the warehouse and how to design the picking operations. Warehouse design aims at the overall layout of the warehouse affecting the picking operations (McGinnis et al. 2007). Since warehouse design involves what picking method to use, Koster et al. (2007) states that a proper layout must be chosen accordingly. The layout have several underlying decisions concerning how many storage blocks or rows there should be but also the length and number of aisles (Koster et al. 2007). Layout and lack of space within the aisles are closely associated with decisions regarding where to locate various departments within the factory (Le-Duc, 2005). Furthermore, Koster et al. (2007) states that the common objective with layout design is minimizing the handling cost, which in many cases is related to the travel distance.

3.3.2 Warehouse operations
Warehouse operations is a term used by McGinnis et al. (2007) and involves four major processes; (1) receiving, (2) storage, (3) order-picking, and (4) shipping, all which needs to be separately constructed and dealt with. Receiving and shipping mostly involves activities such as loading and unloading goods, inspection, inventory control and transportation (Koster et al. 2007). Storage and order-picking consists of sub-processes; department allocation, zoning, storage location assignment, batching, routing and sorting which all aim to increase the efficiency of warehouse operations and space utilization as well as fast picking (McGinnis et al. 2007). In order to accomplish fast and efficient picking, space between aisles must be highly prioritized combined with routing and sequencing (McGinnis et al. 2007). Moreover, Chan and Chan (2011) argue that routing combined with heuristics will allow higher flexibility. How parts can be picked is more in-depth described below.

3.3.3 Picking operations
There are a number of methods that can be used when it comes to picking operations and how it is carried out. Which method should be used depends on whether the articles picked belong to one or several orders, and also where the picking takes place inside a warehouse. The four picking principles are: zone-, order-, batch- and article-picking (Lumsden, 2012).

- **Zone picking** – An order is printed and then split on multiple pickers in several areas. When a picker is finished with its part of the order is placed the order over to some other pickers.

- **Pick by order** – An order prints and articles from around the warehouse picked for this order. The advantages are that items from different orders are not confused which increases correct picking (Lumsden, 2012).
• Pick by batch – Several orders are printed simultaneously and picked during a picking round where the picking is done throughout the store. The sort of articles is done while the picker puts the articles in boxes, but it can also be done afterwards in a separate sorting process (Lumsden, 2012).

Pick by article – Several orders are printed simultaneously (Lumsden, 2012) and it is common to need items for a full day picked at one. The articles are then transported via automated conveyors to a sorting area where the order is combined (Lumsden, 2012).

3.4 Lean production
The Toyota Motor Company is recognized as the birthplace of Lean Production (Womack et al., 1990). The term “Lean” in manufacturing environments describes a philosophy that incorporates a set of tools and techniques into business processes to accomplish waste reduction due to optimization of time, human resources, assets and productivity, while improving quality levels on products or services (Womack and Jones, 2003). In the book Lean Thinking by Womack and Jones (2003), Lean Production is defined as the western model of the Toyotas Production System, due to the developments and changes that has been made from the original philosophy regarding Just-In-Time (JIT) production, originally founded by Kiichiro Toyoda (Womack et al., 1990; Hines et al., 2004).

“Lean Production is lean because it uses less of everything compared with mass production—half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products.” (Womack et al., 1990).

The beginning of the Toyotas Production System (TPS) can be traced back to the World War II, when Taiichi Ohno inspired by Henry Ford’s book, Today and Tomorrow, started to expand upon and experiment with Kiitchiro Toyodas Just-In-Time concept (Womack and Jones, 2003). With the help of Shigeo Shingo, the Toyota Production System was created, also known as TPS. The basic idea of TPS was to implement a pulling system that could initiate a product when needed. The result of the concept was to reduce the work activities and processes that did not add value to the product, also known as waste management. Ohno (1988) and Shingo (1989) state that waste of different kind leads to uncertainty in the material flow and provides unnecessary costs on the product or service that is requested.

3.5 Elimination of waste
The most important starting point in Lean Production thinking is minimizing non-value-adding activities along the value stream, so called waste. All non-value adding activities or processes are considered as waste. According to Lumsden (2012) will waste of various types leads to uncertainty in material flow and unnecessary costs for the product or service that is in demand. If waste is identified, resources could according to Srinivasan (2012) be freed in the form of
personnel, time, area or equipment. Taiichi Ohno, founder of the Toyota Production Systems identified seven wastes, which are summoned below. According to Liker and Meier (2006) there are now eight identified wastes, the additional two are unused creativity among employees, and poor working conditions. Every waste is explained in the following section with results and actions.

### 3.5.1 Waste from overproduction
Waste from overproduction is considered as the most serious waste, due to its contribution to the other six wastes (Marchwinski and Shook, 2003). Producing goods or services result in costs, it is therefore unnecessary to manufacture products that aren’t demanded. To prevent overproduction, Askin and Goldberg (2002) mean that machines and humans should only be busy working when they have strict tasks to accomplish. It is crucial for a Lean production company to let the customers demand set the pace of production, both internal and external, to prevent products from being pushed through the factory and out to the market (Rother and Harris, 2001). According to Segerstedt (2008) will orders that are released before being demanded be handled, counted and stored. Stored products in inventory will run the risk of becoming outdated, and defect products will remain hidden in inventory queues until the demand pulls the system and the defective product are discovered by the customer (Rother and Shook, 2003).

### 3.5.2 Process waste
Askin and Goldberg (2002) means that incorrectly designed processes are a source of waste. Internal processes must therefore always be continuously reviewed and improved, i.e. companies should implement the Japanese phrase kaizen. Activities in a process can function in three ways: (1) be a value-added activity for the customer, (2) be essential for the functionality of the process, (3) be a non-value-adding activity for the customer. There are ways to eliminate or simplify activities within a manufacturing process, examples are changing design on parts, limiting functionally unnecessary tolerances or rethinking process plans (Askin and Goldberg, 2002). A tool used for identifying and possibly eliminating a non-value-adding activity in processes is process mapping (Brassard and Ritter, 1994). Process mapping identifies each step in a process by using graphical symbols for different activities, which are lastly linked together with arrows showing the product and information flows. A well presenting and detailed value map of a process will often reveal unnecessary stages and sequences, and can therefore be used to improve the process design (Brassard and Ritter, 1994).

### 3.5.3 Waste of time
Waste of time often occurs in many different ways. When time is being used ineffectively, then the waste of waiting occurs (Hines and Rich, 1997). Inside a factory, the waste of waiting occurs whenever products aren’t moving downstream or being worked on, which affects goods and humans who’s both is standing still and spending time waiting. LEIS (1999) sums some examples of waste; waiting for

---

3 Kaizen is a Japanese word for continuous improvements used in Lean environments (Srinivasan, 2012)
correction, products waiting to be processed, machines waiting for their operators or waiting for material to arrive.

### 3.5.4 Waste of motion

Motion is both time- and energy-consuming. Waste of motion involves the ergonomics of production where operators have to bend, stretch or pick up tools or components within a production step or station, when these actions could be avoided (Hines and Rich, 1997). To prevent waste of motion, managers should overlook the designing of new workplaces, processes, operation procedures etc. Reducing waste of motion involves everything from describing detailed hand motions in assembly to selection of machines and design of fixtures to reduce the time for set-ups and material handling (Askin and Goldberg, 2002). Waste stated in this section could according to Hines and Rich (1997) be tiring for the employees and is likely to lead to poor productivity and often even to quality problems, which affects the next waste, defective products.

### 3.5.5 Defective products

As stated before, unnecessary motion can lead to tired employees and affect the quality of the product being produced, meaning defective products, or in the worst-case lead to scrapping of products, which is an unnecessary cost. This is in line with Karlsson and Åhlström (1996) why defect products are considered as one of the seven wastes. Furthermore, Askin and Goldberg (2002) states that defective products incur cost, deplete resources, and are lastly a negative impact of the customers’ perception. The Toyota philosophy means that defects should be regarded and treated as opportunities to improve, rather than something to be traded off against what is ultimately poor management. Defects are so seized on for immediate kaizen activity (Hines and Rich, 1997). A tool used to prevent defective products is continuous controls and process improving.

### 3.5.6 Waste of transportation

Transportation waste include all the unnecessary transportations of material that do not add any value to the product, and also add unnecessary manufacturing lead-time (Karlsson and Åhlström, 1996). Hines and Rich (1997) states that all transportation within a factory can be looked upon as waste, therefore companies should strive towards minimization of internal transportation. In a system that is well designed are work and storage areas positioned to minimize transportation (Askin and Goldberg, 2002). However, Shingo (1989) mean that it is important to distinguish between rationalization of transportation and removal of the need for transportation. Unnecessary transportation is often looked upon as a consequence of bad production layout, however is not often easy to find the optimal layout according to Segerstedt (2008). The layouts of modern factories are often designed after a mass production perspective. Tooling and machinery are nowadays often grouped together on a functional basis. The functional layouts often cause a lot of transportation between the functional areas, which could be seen as unnecessary (Slack et al., 2001).
3.5.7 Excess inventory

Storing parts and products in inventory is considered within Lean production being a non-value adding activity. Hayes (1981) argues that in manufacturing environments, inventory in the form of work in process is especially wasteful and should be reduced. Besides from being a non-value adding activity, keeping inventory will also hide other problems linked with the product, such as quality and prevention of improvements. However, Karlsson and Åhlström (1996) state that it is not suitable to eliminate inventory in a careless way. Instead, the reason for the existence of inventory must first be identified and then removed, according to Karlsson and Åhlström (1996).

3.6 Five principles within Lean Production

Lumsden (2012) and Dahlgaard and Dahlgaard-Park (2006) highlights that companies can be more resource-minimised by following the five principles stated in the section below.

3.6.1 Specify Value

The critical starting point for Lean thinking is value (Womack and Jones, 2003). Womack and Jones (2003) state that the ultimate customer can only define the definition of value and that it’s only meaningful when expressed in terms of a specific product or service, which meets the needs of the customer at a specific time at a specific price. In other words, it would be profitable for a customer to buy a certain product if the customer value is higher than the market value.

3.6.2 Identify the Value stream

The value stream is defined by Womack and Jones (2003) as the set of all the specific actions required to bring a specific product or service through the three critical management tasks of any business: the problem-solving task running from the concept through detailed design and engineering to production launch. The information management task running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product on the hands of the customer (Womack and Jones, 2003).

3.6.3 Flow

As a next step in the five-principle-procedure made by Womack and Jones (2003), is the remaining value-creating activity, flow. The goal of step flow is mainly that a product should flow through a system without encounter interruptions of any kind. Interruptions can exist in forms of queues, resource failures or just possible delays. To prevent this, a couple of techniques have been developed; these are lowering order quantities to avoid waiting time and introduction of the repetitive manufacturing approach to strive against manufacturing perfection (Womack and Jones, 2003).

3.6.4 Pull

According to Womack and Jones (2003) it is possible to eliminate a forecast when applying a pull-flow. A pull-flow means that the system is initiated by a customer
order or a request, i.e. letting a customer pull products from a system, rather than pushing products onto the customer, often unwanted (Womack and Jones, 2003). Choosing a system based on this flow type will according to Gaury et al. (1998) often contribute to minimized or reduced inventory, since the customer gets the product instantly when finished.

### 3.6.5 Continuous Improvements
Continuous improvements are the last step of the five principles within in Lean Production. After a company has specified the customer value, mapped the value stream and made a value creating flow and finally let customers pull value from the company, it is time to maintain and improve the factors affecting perfection (Womack and Jones, 2003). Kaizen, the Japanese word for continuous improvements, is an important part of Lean production. A company’s value flow should always be continuously improved and refined to accomplish perfection (Womack and Jones, 2003).

### 3.7 Just in time principle
Just-in-time manufacturing system, also known as “JIT”, is a philosophy founded by Toyota Motor Corporation. Its primary objective is to achieve zero inventories throughout the entire supply chain (Hutchins, 1999; Monden, 2011). According to Hutchins (1999) this can be accomplished only through all aspects of management. JIT can be described as an eternal system, which focuses on continuous improvements, quality and efficiency by producing necessary items in correct quantities at the right time (Monden, 2011). Calvasina et al. (1989) defines JIT as followed:

“JIT is a system of production control that seeks to minimize raw materials and WIP inventories; control (eliminate) defects; stabilize production; continuously simplify the production process; and create a flexible, multi-skilled work force.” – Calvasina et al. (1989)

The difference between a traditional material control and the Just-in-time principle are mainly that in JIT, adapted packaging for production is sent from the suppliers, smaller batches are ordered and delivered more frequently, where simplified ordering routines are established and implemented (Lumsden, 2012).

### 3.8 5S
5S is a tool within Lean Production, which was constructed to create a standard and stability to a system. 5S was developed by Toyota Motor Company in Japan, which purpose was to facilitate work at the workplace by standardization and organizing (Srinivasan, 2012). 5S is based on five simple activities, which according to Srinivasan (2012) can be described as followed:

- Sorting (Seiri): Identify and eliminate unnecessary items such as tools, material and other scrap by organizing the workstation.
• Storing (Seiton): Place tools and material in such a way that they easily can be picked when needed.

• Sanitizing (Seiso): After usage, tools should be placed at the originate location and the working station should be clean and cleared from dirt in order to improve the efficiency, identify and prevent possible defects.

• Standardizing (Seiketsu): All previous steps should be performed as a routine, which involves maintenance of the workstation, machines and tools. Instructions on how to perform work properly and solve complications should be constructed in order to minimize deficiencies.

• Sustaining (Shitsuke): Develop a routine for the entire company through continues improvements and evaluation of the flow. It is essential for operators to work together, in the same direction towards future goals and remind each other to maintain the “orderliness”.

According to Heizer and Render (2011), in order to eliminate waste and at the same time maximize output with a minimum level of input, 5S should be implemented. Moreover, Srinivasan (2012) state that 5S improves safety, work efficiency, productivity and provides employers with a sense of ownership. However, there are major fallbacks when not committing to “lean journey” by discontinue a full Lean implementation.

### 3.9 Work balancing

In order to achieve an efficient manufacturing system, the workload needs to be balanced, but only after deciding what takt time and number of stages exist within the flow (Hitomi, 1996). According to Kilbridge and Wester (1962) and Bhattacharjee and Sahu (1987), there are three main goals with work balancing: (1) minimize the number of operators (2) minimize the cycle time (3) minimize the balance delay, which is defined as the amount of idle time on the line caused by the uneven division of work among operators or stations. In addition to the three goals above, Boysen et al. (2008) extended that list by adding (4) maximize efficiency, (5) minimize costs, (6) maximize profits and (7) smoothen the stations times. When the top three goals above are achieved, the line is operated efficiently, however not necessary optimal (Becker and Scholl, 2006).

Moreover, Baudin (2004) argues that the reasons to perform work balancing can either be a request to increase productivity, managing an increase or decrease of demand.

Boysen et al. (2008) describes several techniques for line balancing involving simple heuristics to complex computational algorithms, however there are two main situations that implicate work balancing (Fogarty et al., 1989):

• The takt time is fixed due to production requirements, and the intention is to minimize the number of workstations.
• The number of workstations is pre-established, and the objective is to minimize the cycle time and create a workload balance.

Balancing diagram is a graphic helping tool for creating continuous flow in a multi-stage, multi-operator process by distributing the operators work element relative to the takt time (Duggan, 2012). When deciding to balance work, simply start loading the workstations with operations until full and does not over exceed the cycle time. Then continue to load the following operations the same way until all operations are accounted for and the precedence relationships are not broken (Sule, 1994).

![Figure 8. Illustration of work balancing](image)

As Figure 8 illustrates, the stations are being loaded with operations without exceeding the desired takt time. According to Ortiz (2006) it is suggested not to use the actual takt time as a limit, since that tends to create instabilities for assembly lines. Therefore, a loading level pending between 85% and 90% is appropriate (Hitomi, 1996; Ortiz, 2006). In order to perform a work balancing and make it reliable, should according to Olhager (2000) precedence relation’s needs to be considered. A precedence diagram is a method that uses nodes or boxes to represent activities and links them with arrows that illustrate dependencies. Russell and Taylor (2010) describe seven steps that need to be followed in order to make a work balancing successful, which are found in attachment 5.

### 3.9.1 Takt time

“Takt time” is defined as the customers pace in demand. The takt time describes the pace at which the customer requests a product under a specified period of time (Liker and Meier, 2006). Takt time can be expressed in minutes, hours, days, weeks, as long as the same unit found in the numerator and denominator (Srinivasan, 2012). The following example is made up to further clarify what takt time is: A company has in one day 500 minutes of effective production time. Customers are demanding an average of 250 items a day. The following formula illustrates how to pursue the calculation:

\[
\text{Takt time} = \frac{500 \text{ minutes}}{250 \text{ units}} = 2 \text{ minutes per unit}
\]
This means that a customer in this case demands a unit every two minutes. In order to satisfy the customers’ needs must then the company complete a product every two minutes.

### 3.9.2 Cycle time

The cycle time is linked to the internal processes of a company. Cycle time can be explained in two ways: as the frequency in which a product comes out of a process or the time required to implement all the steps in a process. Duggan (2012) exemplifies cycle time as if it would take a machine 60 seconds to process a product, from start to stop, the cycle time is 60 seconds. The cycle time can vary, from a few seconds to several minutes, completely dependent on the product complexity and resource capacity. If the product undergoes a designed assembly flow where several stations are used, usually balanced flow so all operators have equal amount of work, called line balancing. Using the following formula can calculate the final balancing loss (Duggan, 2012):

\[
D = \frac{n \cdot c - \sum t_i}{n \cdot c}
\]

In the above formula balancing loss is stated by the letter D, since “n” stands for the number of stations that are in the flow, and “c” stands for the maximum allowable cycle time per station. \( \sum t_i \) stands for the sum of the total cycle time for all stations by the flow.
4 Empirical data

The following chapter presents the case study together with information concerning the empirical findings. A short introduction of the case company is initially presented followed by information and calculations regarding takt- and operation-times in relation to the current working state. Complementing empirical data will be further presented in chapter five together with the result and analysis.

4.1 Case study

The authors have performed a case study at Volvo Group’s factory in Bang Na, called TSA, located in the outskirts of Bangkok, Thailand. TSA was established in 1976 and are today a part of Volvo Group Truck Operations in the APAC region, which produces and ships Volvo trucks, including the Volvo FM, cab and Volvo Bus, with a main distribution focus on the Southeast Asian market, as well as Australia and New Zealand with surroundings.

Within the factory, the production is line-based with several different assembly lines, one of which is the Cab-Trim assembly line, which is discussed in this thesis. This line assembles the cab-leg, under cab, as well as outer and inner-materials. Pickers today supply the assembly line with the material feeding principle kitting. Kitting is used due to the limited station space at the assembly line, the high component value and to ease the work for assembly workers, which is in line with Johansson (1991) and Fredriksson (2002). This can be seen as a type of quality check, as all the parts supplied to the line are involved in a certain assembly step. When kitting, pickers need to use a kit rack in order to put the right component in the right place to reduce confusion and make the assembly line workers more efficient. There are today seven workers included in the picking operation that supply parts to eight different stations. These eight stations demand different parts due to customized orders, the operation times for every kit rack are therefore individually measured, see attachment 2.

4.2 Empirical findings

Today the TSA factory produces 15 trucks per day. However the demand will increase in the future, so strategies are needed in order to work balance the picking operations according to the new takt time. The current takt time for the Cab-Trim assembly line is 28,5 minutes based on the actual working time of 427,5 min per day divided by actual demand 15 units per day. Furthermore, this means that the picking time for each kit rack cannot exceed 28,5 minutes. If exceeded the kit rack must be picked by two workers to lower the operation time. The observations performed by the authors have resulted in several time studies for each kit rack illustrated in attachment 2. In order to illustrate the current situation precise operating times has been used. The actual operation time for operation 5 is 21,50 minutes and 27,57 minutes for operation 7. However, since there is two

---

4 Thai-Swedish assembly (Co. Limited)
5 The APAC region covers Asia and the Pacific, including Australia, New Zealand with surroundings
workers performing the same picking operation the operation times are divided by two as seen in Table 3.

Table 3. List of current state operation times

<table>
<thead>
<tr>
<th>Operation</th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
<th>Worker 4</th>
<th>Worker 5</th>
<th>Worker 6</th>
<th>Worker 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4,57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4,98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12,38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>10,71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>10,92</td>
<td>10,92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>11,29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,98</td>
<td>13,98</td>
</tr>
<tr>
<td>8</td>
<td>10,39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total time</td>
<td>19,94</td>
<td>12,38</td>
<td>10,71</td>
<td>22,20</td>
<td>10,92</td>
<td>13,98</td>
<td>13,98</td>
</tr>
<tr>
<td>Tact time</td>
<td>28,5</td>
<td>28,5</td>
<td>28,5</td>
<td>28,5</td>
<td>28,5</td>
<td>28,5</td>
<td>28,5</td>
</tr>
<tr>
<td>Slack</td>
<td>8,56</td>
<td>16,12</td>
<td>17,79</td>
<td>6,30</td>
<td>17,58</td>
<td>14,52</td>
<td>14,52</td>
</tr>
</tbody>
</table>

The picking operations have not been balanced in relation to current demand, mostly since there have been no previous studies regarding operation times for each picking operation performed by the case company. In order to better utilize resources, work balancing is essential to achieve an efficient manufacturing system (Hitomi, 1996). According to Duggan (2012) a balancing diagram will support and create an overview over the operations and reveal balancing loss. In order to calculate the current balancing loss, the total time of all eight picking operations need to be added together, which results in 104,1 minutes. Maximum total time for all workers are 28,5 minutes per picking operations, multiplied by seven workers, which equals 199,5 minutes. Hence, the balance loss is 48% with approximately 95 minutes of wasted time per day. This implicates that the picking operations today may be overstaffed.

Table 4. Current balancing loss

<table>
<thead>
<tr>
<th>Total operating takt time:</th>
<th>199,5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual operating takt time:</td>
<td>104,1 minutes</td>
</tr>
<tr>
<td>Fixed formula (1-X):</td>
<td>1,052 %</td>
</tr>
<tr>
<td>Balancing loss:</td>
<td>48 %</td>
</tr>
</tbody>
</table>

This balancing loss is naturally an issue that has to be solved. In order to do that, issues making the picking operation less efficient need to be identified. The following section states the important difficulties followed by possible solutions.
5 Result and analysis

The following chapter presents the result and analysis of every question of issue, starting with the difficulties that been identified, followed by suggested solutions and finally the developed work-balancing model. To properly analyze the difficulties and develop possible solutions, additional in-depth theory and empirical data is presented below.

5.1 Difficulties in picking operations

Through theory and the case study, there were several difficulties identified, both general and direct regarding picking operations. General difficulties identified could all be linked and applied to picking operations, such as Lean Production, which is linked to standardization and why a process should be standardized. During interviews and observations several difficulties were identified and can be summarized as; layout, lack of space, flexibility, lack of parts, order handling, routing and sequencing, storage and zoning, warehouse maintenance, lack of standardization, WIP\(^6\) and work balancing. The theory exposed several difficulties concerning picking operations, which were obtained by scientific articles and can be summarized as followed; layout, lack of space, flexibility, lack of parts, order handling, picking time, routing and sequencing, storage and zoning, lack of standardization and WIP. The identified difficulties aims both at kitting and picking, however, picking operations and kitting are looked upon as the same, since those to are closely linked and the activities are similarly performed.

Table 5. Summary of identified difficulties

<table>
<thead>
<tr>
<th>Difficulties in picking operations</th>
<th>References</th>
<th>Theory</th>
<th>Interview</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouse design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout</td>
<td>Le-Duc, 2005; Koster et al, 2007; McGinnis et al, 2007; Chan and Chan, 2011</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Swaminathan and Nichols, 2007; Chan and Chan, 2011</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lack of parts</td>
<td>Kumar and Ponnavans, 2007; Chan and Chan, 2011; Faci et al., 2013</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Order handling</td>
<td>Le-Duc, 2005; McGinnis et al, 2007; Tompkins et al, 2011</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Picking time</td>
<td>Le-Duc, 2005; McGinnis et al, 2007</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage and zoning</td>
<td>Le-Duc, 2005; Koster et al, 2007; McGinnis et al, 2007</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse maintenance</td>
<td>Discussed through case study</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of standardization</td>
<td>Womack and Jones, 2003; Srinivasan, 2012</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>WIP</td>
<td>Bozer and McGinnis, 1992</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work balancing</td>
<td>Discussed through case study</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

In order to narrow down all difficulties, theory and the case study were compared in Table 5. In order to sort out the major difficulties, each difficulty in the theory was given an “X” and when a similar difficulty was exposed in the case study they received an “X”. When a difficulty had been identified in all methods, three “X’s” should be listed. Based on Table 5, three major difficulties are identified; (1) lack of parts (2) order handling and (3) lack of standardization. In addition to the three major difficulties discovered, the case study revealed two difficulties beside the

\(^6\) Work-In-Process partly finished goods waiting to be further processed (Srinivasan, 2012).
identified ones that were not discovered in theory; these were warehouse maintenance and work balancing. Through the difficulties a Four-step-improvement-process has been developed consisting of four steps; (1) identify difficulties, (2) eliminate difficulties, (3) standardize process and finally (4) work balance. Thus will the difficulties be presented as followed; (1) Lack of parts, (2) order handling, (3) warehouse maintenance, (4) Lack of standardization and finally (5) work balancing. Initially, lack of parts, order handling and warehouse maintenance is presented, to fit in the first step, “identify difficulties”. When difficulties are identified, possible solutions are developed in order to eliminate the identified difficulties. The answers to questions of issue number two should therefore be placed in the second step of the developed four-step-improvement-process model, “Eliminate difficulties”. When this is done and the process or in this case operation is functioning smoothly, a standardization should be performed, to facilitate the most effective way of performing the operation or process. When this is finished and the process is standardized, work balancing should be performed in order to secure a lean operation to maximize resource utilization. By doing so, possible over or underflows of personnel may appear which could contribute to a more suitable utilization.

5.1.1 Lack of parts
Inside the TSA factory, replenishment trains and forklifts supply the supermarket directly from the warehouse. The replenishment train is operated manually, where bins with low level of components left are ordered. When observations were made on the case company, the authors identified issues with this material replenishment system, which resulted in lack of parts for the picking operations. When picking, workers often find empty bins in the supermarket, even though the part existed in the warehouse. There is currently no information system that informs or initiates the replenishment of materials to the supermarket used by pickers. The lack of parts is very time consuming for pickers, since they have to find and communicate with the forklift drivers in order supply them with the part needed, since picking is according to Kumar and Panneerselvam (2007) and Facci et al. (2013) a critical operation. As for the warehouse maintenance, simple occurrences like the last stated are highly time consuming, when striving towards a continuous flow. Trash and leftovers in bins, as well as lack of parts will increase the operation times and decrease the efficiency of the picking operation as a whole. Worst-case scenario is according to Becker and Scholl (2006) that the assembly line suffers due to lack of parts where the production comes to a standstill, which Koster et al. (2007) says often results in high costs due to unproductivity.

5.1.2 Order handling
In the current state, pickers need to go to a certain area to collect their orders manually. As today, there is no order handling station for the pickers to collect their orders. Since the operation is performed manually and by paper, it is important to keep a good structure when it comes to order handling. Today workers spend several minutes fetching and preparing the picking orders as well as the kit rack where the chassi number need to be attached. These unnecessary
activities are iterative and happen everyday, which results in a relation to Womack and Jones (2003) thoughts of the seven wastes of Lean production, more specific waste of time. This may be especially true during the mornings where confusion often arises regarding what order to pick, where the orders are located and if there are any pending orders.

5.1.3 Warehouse maintenance
Observations performed by the authors revealed that several parts in the picking operations supplied from the warehouse are covered with protecting material, either plastic layers or cardboards. When this material or component is supplied in an unprepared way, pickers are forced to remove the protection in order to pick the certain part. If the picker throws the leftover trash in the bin from where the part was taken, it will result in a pile of trash and waste time for the next picker searching for the part needed. Additionally, trash and litter will collect dust and create unhealthy working conditions. Another problem identified during observations were poorly positioned pallets of material. The pallets were placed in the front of the supermarket bin in the aisles, which made it impossible for pickers to reach the part needed. Problems like the stated does according to McGinnis et al. (2007) and Peters et al. (2012) tend to narrow the aisles, since pallets are highly space consuming. Incidents similar to this often result in a worker have to communicate with the warehouse manager, who in return makes the forklift drivers replace pallets. These situations are time consuming, which is in line with Le-Duc (2005) who states that interruptions similar to the stated are unacceptable when striving towards a continuous flow.

5.1.4 Lack of standardization of picking operations
The picking process is not standardized in terms of how it is performed, where to pick up kit racks, where to start and how many units to pick simultaneously. Today, pickers perform the picking operations in a faster pace than the production requires. This will result in spare time, which means that the worker can perform another job instead. However, this becomes problematic when each worker is unproductive due to no assigned work tasks. Moreover, workers perform picking operations in their own way, which results in high variation of operation times making it difficult to balance work. Training of new workers becomes both longer and more difficult due to several different ways of performing the picking operation, which is in line with Nembhard (2000) who states that more complex processes lead to longer learning curves and faster forgetting. Another issue is that workers only pick a certain kit rack, which limits the possibilities to increase efficiency and continuous flow. Furthermore, workers spend several minutes trying to find kit racks to be able to initiate the picking operation, which can be directly linked with Womack and Jones (2003) and their thoughts of waste of time. The picking operations are also too fast for the line, which results in kit racks standing as WIP beside the pre-assembly stations or somewhere along the assembly line, which could be linked with the waste of overproduction according to Womack and Jones (2003).
5.1.5 Work balancing
In the studied material flow, several underlying difficulties have been identified. The authors have discovered that each of the underlying difficulties within work balancing contributes to inefficiency of picking operations as well as the assembly line. The underlying difficulties that contribute to inefficient picking operations and make balancing challenging can be summarized as followed; takt time, operation time, number of operations, number of workers, precedence relation of operations and balance delay. The takt time depends on the demand and can be explained in what pace the customer needs a product (Womack and Jones, 2003). In the studied material flow the current and future demand is known (see attachment 6) which makes it possible to calculate current and future takt times that simplify further analysis of how to balance work correspondingly. To balance work operation times are needed for each operation, which are loaded on each other until the takt time is reached. This takt time is according to Ortiz (2006) an 85-90% limit, to prevent uncertainties within the process. However, Srinivasan (2012) argues that the takt time should be maximized to increase pickers motivation and enhance their potential in discovering new ways to make the process more efficient. Furthermore, there were discovered potential precedence relations of picking operations but nothing that affect the efficiency of the current material flow. However, it still needs to be carefully considered for future changes in order to achieve an efficient manufacturing system. Moreover, the number of workers affects the operation time for every output since the operation time can be reduced in half if two workers perform the operation simultaneously. In the current state, the pickers are underutilized which mean that they perform the picking operation faster than needed due to an inefficient work balancing. This leads to unnecessary costs and inefficient personnel utilization since the overflow in work capacity could be better needed elsewhere within the factory.

5.2 How difficulties can be resolved
In order to create a Lean continuous flow through the picking operations, the difficulties stated in the previous section need to be resolved. The main difficulty identified is to work balance the picking operations in a suitable way, which works in the real-life situation on the case company. The objective with solving these difficulties is to improve picking operations that kit material to an assembly line. These include elimination of waste and personnel utilization, which according to Womack and Jones (2003) will help to make a process more cost effective and increase the overall productivity.

5.2.1 Lack of parts
The lack of parts originates according to Kumar and Panneerselvam (2007), when a material replenishment system does not work as planned, which often depends on lack of information when to begin a material replenishment process. The authors have identified two possible solutions aiming at this problem. The first affecting factor can be solved by existing resources and concerns the replenishment worker who needs to make routes more frequent in order to keep up with the picking operations. Since there is no system or activity initiating the
replenishment process today, the replenishment worker needs to be proactive in work insuring that parts exists when needed. However, this solution cannot be supported financially since the transportation will increase and time be wasted for continuous control.

The second solution involves investments of a replenishment system like Kanban\(^7\) that control production flow, inventory and allows information to be shared. The primary function in this situation is to signal the replenishment worker and initiate replenishment of material at the correct location. Moreover, this saves time for the replenishment worker since the signal replaces the frequent “route checking” resulting in less transportation and movement. An alternative similar to this can according to Domingo et al. (2007) be consolidating and coordinating milk runs\(^8\) in order to provide stability replenishment system reduce unnecessary transportation and idle. A less expensive alternative is to invest in a simple order point system that initiates the replenishment process. Both solutions utilize the same procedures when it comes to the exchange of parts. Therefore when changing pallets or bins the left over parts for the previous container needs to be moved into the new one. By doing so space utilization can be accomplished and at the same time accidents and issues can be avoided instead of having workers reaching for the last part.

### 5.2.2 Order handling

In order to achieve a more efficient flow through the picking operation and to reduce the operation time even further, a structured order handling system could be introduced and implemented (Tompkins et al., 2010). The overriding issue with the current system is that picker need to get physical orders from binders placed in a box next to the line. The binders contain orders for all picking stations making it rather time consuming to search and identify next orders manually. The authors believe that the best solution to this problem is to introduce a whole new order handling system. It could involve a simple solution as having shelves standing on a table with the right station name attached to them and thereby reducing confusion. The shelf should contain three compartments, where the top compartments hold the “new orders”. The middle compartment should show “pending orders” since orders that for example come across any lack of parts while picking will be put as WIP, while a new order is initiated and processed. However, the pending orders should be prioritized since they are queued and must be assembled in the right order. The bottom compartment should hold the “finished order”.

The current working state let pickers throw away orders when finished eliminating the chance of controlling an order if something goes wrong. If saved, it would be possible to back-trace the right chassi-number to the order and identify errors. Moreover, this is in line with Tompkins et al. (2010) who states that

\(^7\) Kanban is a pull replenishment system within Lean Production to ease production scheduling and contain inventory (Kumar and Panneerselvam, 2007; Srinivasan, 2012).

\(^8\) Milk runs are a system characterized by a delivery vehicle, replenishing material in-plant in a predetermined route from the central storage to the supermarket (Ciemoczołowski and Bozer, 2013).
documentation of saved orders will set the base for future measurements and provide statistics that could be used for different improvements, in this case regarding picking operations.

5.2.3 Warehouse maintenance

In order to solve the warehouse maintenance issues, the warehouse manager needs to select a worker in charge as a maintenance manager. By doing so, the maintenance manager’s responsibilities and obligations are to keep the aisles clean and clear from obstacles, which McGinnis et al. 2007 states would allow workers to execute the picking operations at maximum potential. The occasional misplaced pallets are of major concern for pickers considering this issue doesn’t only affects the operation times but also the efficiency of picking operations as well as material replenishment.

In order to solve the issue with pallets blocking the aisles, maintenance managers frequently need to Go-Gemba\(^9\) and inform the workers of the importance of having the aisles and bins clean from trash and dirt. Moreover, garbage stations needs to be suitably positioned, for example at the end of the each aisle. Since the plastic covers and cardboards are relatively insignificant for a picking operation, a complementing solution is to have a small trash bin attached at each kit rack that can be dumped along the picking path. This solution can be linked with two of the seven wastes of Lean production, waste of transportation and movement (Womack and Jones, 2003).

5.2.4 Standardization of picking operation

Womack and Jones (2003) state that standardization of any operation is essential if one wants to achieve process perfection, which the authors have found that picking operations in TSA factory are not standardized. There are many factors contributing to an unstandardized process, which basically mean that the processes within the picking operations vary with time where every picker has developed own approaches to the picking task. Furthermore, this issue concerns more areas than the picking operation such as warehouse maintenance, order handling and replenishment. In order to solve this issue, 5S should be implemented and followed. Within the factory 5S are mentioned, however, the authors believe that it is more of a guideline than actually followed. To achieve a standardized process it must be performed the same way at the same time every time it is performed. Askin and Goldberg (2002) states that incorrectly designed processes are a source of waste. Internal processes must therefore always be continuously reviewed and improved, i.e. TSA should therefore implicate the Japanese phrase kaizen within their processes. The difficulty with an unstandardized process can be linked the wastes of Lean production, especially “process waste”, but also “waste of motion”. Unstandardized processes let the worker develop own paths and working methods and not the most optimal. Motion is both time- and energy-consuming since it involves unnecessary walking distances where could be avoided through standardization (Hines and Rich, 1997).

\(^9\) Go-Gemba is a Japanese term for go and see where the problem is identified (Liker and Meier, 2006).
5.2.5 Work balancing
As previously stated in question of issue one, inefficient work balancing can contribute to several different kinds of waste which further leads to high costs; in the end it is unnecessary if they could be reduced or eliminated. By performing work balancing it is possible to discover a potential overflow in the work capacity. If discovered, enhanced personnel utilization would be a more effective option. In the specific case company, the picking operation is currently heavily overstuffed since pickers perform the factory’s entire daily demand in approximately 3-4 hours in a seven hours effective working time per day. This could be linked with overproduction, since the picking operation is faster than the current takt time, which results in WIP, which is according to Womack and Jones (2003) one of the seven wastes of Lean production. Askin and Goldberg (2002) states that a way to prevent overproduction, machines and humans should only be busy working when they have strict tasks to accomplish so the waiting time when the pickers are finished are pure waste. To solve this issue there is two options, (1) work balance the picking operations and minimize the balancing loss or (2) create a better utilization of pickers when they are finished with the daily demand. The authors believe that option one is the most suitable, since Tompkins et al. (2010) states that picking operations are highly cost intensive operations that according to Burinskiene (2009) need to be as lean as possible while greatly efficient to create a competitive product.

In order to balance the picking operations in an efficient way, the authors created an MS Excel file to get an overview of the picking operation and how to balance the work according to the current takt time. As previously stated, precedence relations were identified, however, these were considered negligible. In order to reach the maximum working capacity of every picker, operation times were loaded on each worker until the takt time was nearly reached, as seen in Table 6.

Table 6. Improved state operation times

<table>
<thead>
<tr>
<th>Operation</th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
<th>Worker 4</th>
<th>Worker 5</th>
<th>Worker 6</th>
<th>Worker 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation 1</td>
<td>4.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 2</td>
<td></td>
<td>4.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 3</td>
<td>12.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 4</td>
<td></td>
<td>10.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 5</td>
<td>10.92</td>
<td>10.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 6</td>
<td></td>
<td>11.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 7</td>
<td></td>
<td>13.98</td>
<td>13.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation 8</td>
<td>10.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total time</td>
<td>27.34</td>
<td>26.62</td>
<td>25.26</td>
<td>24.90</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Takt time</td>
<td>28.5</td>
<td>28.5</td>
<td>28.5</td>
<td>28.5</td>
<td>28.5</td>
<td>28.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Slack</td>
<td>1.16</td>
<td>1.88</td>
<td>3.24</td>
<td>3.60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As seen in the above table, the outcome of the work balancing resulted in a reduced the number of pickers down to four. As a result of this, pickers could be utilized in some other way, for example warehouse maintenance, some other assembly line, or repositioned where better needed. Furthermore, the improved state resulted in lower total operating takt time that equals 114 minutes.
Table 7. Improved balancing loss

<table>
<thead>
<tr>
<th>Total operating takt time</th>
<th>114.0 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual operating takt time</td>
<td>104.1 minutes</td>
</tr>
<tr>
<td>Fixed formula (1-x)</td>
<td>1.052 %</td>
</tr>
<tr>
<td>Balancing loss</td>
<td>9 %</td>
</tr>
</tbody>
</table>

The outcome of these calculations performed seen in Table 7 above showed that the work balancing resulted in an improvement of 39%. Furthermore, the improvement of operation times illustrates reduced slack time, however, none of the workers are exceeding the maximum takt time of 28.5 minutes, which according to Hitomi (1996) and Ortiz (2006) may contribute to process uncertainties. Srinivasan (2012) states that maximizing the takt time could lead to errors, nevertheless, Srinivasan (2012) argues that it may enhance employee’s ability to individually solve problems that might occur.

5.3 Development of a work-balancing model

In order to develop the model illustrated in Figure 9, simplifications have been made. The base of the model is created on the real-life situation that occurred at the case company, where the picking operation involved seven workers picking eight operations on eight kit racks. However, the model’s flexibility allows users to add or reduce these numbers to better fit various companies, divisions or processes. Figure 9 illustrates an example of the work-balancing model in the users perspective. An enlargement of the model illustrating the case company is found in attachment 2, where a short users manual also can be find. However, to get an instant deeper understanding the following presents the consisting parts of the model.

5.3.1 Model description

The first part is the most vital since every other section within the MS Excel model is connected to the first part’s consisting cells. For the model to properly work and illustrate the reality in a reliable and correct way, the user must be very cautious when typing in the numbers so every digit is the exact one.

As a first step when using the model, the daily effective working time and the daily demand need to be identified, in order to calculate the takt time. The user will also be told to type in the total number of workers, which will contribute to the calculations in step four.

Table 8. Model description, step one

<table>
<thead>
<tr>
<th>Enter effective working time / day:</th>
<th>200 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter daily demand / day:</td>
<td>10 units</td>
</tr>
<tr>
<td>Current takt time:</td>
<td>20.0 minutes</td>
</tr>
<tr>
<td>Enter number of workers:</td>
<td>7 operators</td>
</tr>
</tbody>
</table>

In the second step the user is told to type in the operation assigned to each worker with the correct operation time. As seen in Table 9, the model calculates the total
time per worker together with slack time. The total time of each worker are then added up and connected to step four, actual operating takt time.

Table 9. Model description, step two

<table>
<thead>
<tr>
<th>Operation</th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
<th>Worker 4</th>
<th>Worker 5</th>
<th>Worker 6</th>
<th>Worker 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15,00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>9,00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>12,00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>24,00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14,00</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,00</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,00</td>
</tr>
<tr>
<td>Total time</td>
<td>15,00</td>
<td>9,00</td>
<td>12,00</td>
<td>24,00</td>
<td>16,00</td>
<td>14,00</td>
<td>10,00</td>
</tr>
<tr>
<td>Takt time</td>
<td>20,00</td>
<td>20,00</td>
<td>20,00</td>
<td>20,00</td>
<td>20,00</td>
<td>20,00</td>
<td>20,00</td>
</tr>
<tr>
<td>Slack</td>
<td>5,00</td>
<td>11,00</td>
<td>8,00</td>
<td>-4,00</td>
<td>4,00</td>
<td>4,00</td>
<td>6,00</td>
</tr>
</tbody>
</table>

The third step is automatically calculated and connected when typing in the right numbers in step one and two. The total slack time, called "difference" will appear when finished with step three, which gives an overview of how much time in minutes is lost in different waste within the picking operation. This “difference” makes it possible to better utilize the resources and assign them with other tasks such as; maintenance of supermarket and bins, locating and coordinating kit racks or preparations for next kit racks being picked. Srinivasan (2012) states that the target is to reduce the slack time to a minimum, in order to accentuate work motivation and productivity. However, according to Ortiz (2006) it is suggested not to use the actual takt time as a limit, since that tends to create instabilities for operations or processes. Therefore, a loading level pending between 85% and 90% is appropriate, which leaves the slack time level 10-15% of the actual takt time.

Table 10. Model description, step three

<table>
<thead>
<tr>
<th>Kit rack</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15,00</td>
</tr>
<tr>
<td>2</td>
<td>9,00</td>
</tr>
<tr>
<td>3</td>
<td>12,00</td>
</tr>
<tr>
<td>4</td>
<td>24,00</td>
</tr>
<tr>
<td>5</td>
<td>16,00</td>
</tr>
<tr>
<td>6</td>
<td>13,00</td>
</tr>
<tr>
<td>7</td>
<td>5,00</td>
</tr>
<tr>
<td>8</td>
<td>5,00</td>
</tr>
<tr>
<td>Total</td>
<td>100,00</td>
</tr>
<tr>
<td>Takt time</td>
<td>20,00</td>
</tr>
<tr>
<td>Difference</td>
<td>40,00</td>
</tr>
</tbody>
</table>

Step four is the last step that is fully automatically typed, as a result of the other steps. It provides a summed total operating takt time and actual operating takt time. The difference between these two is the sum of the slack time mentioned in the third step. Lastly, step four provides the user with the final result, the total balancing loss.
To reduce the balancing loss percentage, the only solution available is to perform a work balancing. Ortiz (2006) explains this method as loading operations on another till the takt time limit subtracted by the appropriate slack time is reached. By doing so, an efficient work balancing can contribute to a better utilization of resources, which according to Srinivasan (2012) could prevent unnecessary costs due to waste.

5.3.2 Work balancing model
As seen in Figure 9, when a user has typed in every necessary input needed for the work-balancing model to properly function, a diagram appears. The diagram illustrates the different operations or processes carried out within the chosen area of concern, in this case the picking operation. This helps the user get a practical understanding over the chosen area as well as provide data which can ease many situations concerning decision making. Illustrated in the figure below, worker four is currently exceeding the takt time, which lead to lack of parts for the assembly line since the demand pace is faster than worker four can deliver. Also seen in the figure below, worker seven performing two operations after one another. However, worker seven still has 10 minutes of slack time, which makes the worker inefficient, since there still is room for another operation, with a maximum of 85-90% of the takt time limit.
Figure 9. Work balancing model

The work-balancing model has been approved and tested at the case company (attachment 4), which provides and secures reliability of the model reflecting a real-world situation in a practical manner. Authors such as Yin (2003), Thomas (2009) and Patel and Davidson (2011) all state that a good reliability is achieved when a measurement can be repeated with the same results iteratively, which the authors believe is achieved. Therefore, the model is appropriate to use at different companies experiencing similar issues, concerning a need for a more efficient utilization of resources. For the model to function in a proper way and to enhance the user friendliness a model description has been made where every step is closely explained, see attachment 3.
6 Discussion

This chapter presents discussions concerning the empirical data of the thesis and methods used to achieve its purpose. To facilitate a good structure, the discussion will be based on the questions of issue followed by the method discussion that address strengths and weaknesses of approaches and how well the thesis’ purpose has been achieved. Finally, the chapter ends with a discussion concerning the thesis’ reliability and validity.

6.1 Result discussion

The purpose of this thesis is to improve picking operations that kit materials to assembly lines with customized products and based on that, develop a model in relation to varying demand. The following discussion is structured to follow the three questions of issue that has been broken down from the purpose.

6.1.1 Difficulties within picking operations

The background of this question of issue was to identify possible difficulties within a material flow and what might contribute to an inefficient picking operation. The studied literature made it possible to identify such difficulties that were later also identified in a real-life situation when performing observations at the case company. The main difficulties were selected through a summarized document where literature, interviews and observations agreed on the same problems, however, warehouse maintenance and work balancing was not discovered in theory. When performing this summary, five main difficulties were highlighted and answered; the identified difficulties are lack of parts, order handling, warehouse maintenance, lack of standardization of picking operations and work balancing. There could perhaps be more important difficulties that need to be taken into consideration when improving picking operations. However, the first question of issue does only emphasize the major difficulties identified, which provide a basis for the second question of issue where possible solutions could be developed.

Finding relevant scientific research regarding difficulties within picking operations that kit material towards assembly lines has been very time consuming since it appears to be a gap in the research addressing this subject where little information is available. However, the major difficulty identified from the literature was standardization of processes that could be linked to Lean productions waste management more specifically process waste. The standardization of the picking operation within the case company’s factory is affected by three major difficulties: warehouse maintenance, lack of parts and order handling systems. Through the performed case study, the authors confirmed these difficulties as contributing factors to inefficient picking operations affecting the operation time in a negative way. What differs the literature from the case study concerning the most important difficulty is that the case company has great issues with work balancing the picking operation. However, there are also a lot of factors that underlie this problem, especially the relation between takt time and operation times. The author’s believe that the only way to reduce the operation times is by executing
and eliminating the other difficulties mentioned earlier. If this succeeds, it would be possible to work balance the picking operation in a suitable way to prevent capacity overflow and inefficient utilization of personnel.

6.1.2 How can difficulties be resolved

The second question of issue was formed to analyze possible solutions to the difficulties identified in the case study. Possible alternate solutions have been presented to the respective difficulty that could contribute to an inefficient picking operation. Thus, the authors believe that the query has been answered satisfactorily. The second question of issue will form the basis for achieving a great part of the purpose answering how to improve picking operations that kit material to assembly lines with customized products. How the answer is structured can be linked to the first question of issue, where the analysis provided a basis for solution alternatives. If other difficulties had been identified the result in the second question of issue would have turned out differently than the current difficulties identified. The solutions that have been presented have primarily been based on established theories within Lean production where the objective is to reduce or eliminate wastes or processes that fail to bring any value to a certain product. The authors found the frameworks highly relevant, which is the main motive as to why that framework was chosen. To improve a picking operation and create a lean and productive process, companies have to examine their processes carefully, all linked to Lean productions waste management and work balancing. The most important when striving towards process perfection, in the authors’ opinion, is standardization of the picking process. In order to decrease the operation time to match future demand when the tak time lowers, every picker must perform the same work at the same time, every time, this to discover possible difficulties and following solutions. A summary of the processes that has to be organized and analyzed within a picking operation are:

- Lack of parts – this difficulty is mainly linked to a replenishment system. Construct and coordinate a more structured replenishment system within the supermarket to prevent unnecessary wastes downstream the warehouse.

- Order handling – this must run smoothly in order to function in an efficient way. In addition, this will make it possible to control the outcome the specific picking station.

- Warehouse maintenance – establish some kind of trash bin system within or beside the aisles, in order to prevent pickers from putting cover material back in the component bins. In addition, this will contribute to bad air filled with dust particles affecting the pickers health adversely.

- Lack of standardization – As mentioned before, companies should standardize all the processes above in order to achieve an improved state concerning the efficiency of picking operations linked to continuous improvements.
Work balancing – In order to get a lean process and discover possible overflows in working capacity, a work balance should be performed. This method will result in better resource utilization and provide an overview for managers when facing decisions regarding picking operations or operations management in general.

Hutchins (1999) states that in order to maximize profit and reduce unnecessary costs, Just-in-time manufacturing should be implemented, where Monden (2011) says that the primary objective is to achieve zero inventories throughout the entire supply chain. According to Hutchins (1999) this can be accomplished only through all aspects of management. The Just-in-time principle can be described as an eternal system, which focuses on continuous improvements, quality and efficiency by producing necessary items in correct quantities at the right time (Monden, 2011). There are ways to eliminate or simplify activities within a manufacturing process to achieve all these objectives. Examples of this are according to Askin and Goldberg (2002) changing design on parts, limiting functionally unnecessary tolerances or rethinking process plans, which is a type of standardization. When this is done, a work balance could be performed accordingly to identify balancing loss and free possible resources for better utilization, preferably through a model.

6.1.3 Developing a model in relation to varying demand

The literature studies indicated that a model regarding work balancing the picking operations should be simple to use and update, while at the same time illustrate reality enough to be used for the intended area. The case study revealed that the respondents had similar views about the model concerning user friendliness and the simplicity for updates. Otherwise the risk would be that the users choose not to use the model for lack of time or commitment due to difficulties or non-updated versions. The model will then only be a reflection of the current situation when not taking advantage of the flexibility and updating input in order to plan or experiment for future variation in demand. Thus, time and energy has gone into the model's ease of use, which has been achieved by demonstrating the model for the intended end users together with a created user manual.

According to the authors’ knowledge, most of today’s companies have a broad knowledge of MS Excel and use it on a daily basis. By developing the model in this program increase the possibility of the model being used in real-life situations and result in short learning curves for end users. The authors were already familiar with MS Excel that eased the process and led to shorter development time. Within the case company, and more specific the picking operations, the problem were to identify how many resources were needed to match the current daily demand. The case company has today no time studies regarding the different kit racks within the picking operation, which complicates an optimal solution for work balancing and improving. The developed model is created to ease the process for managers letting them observe the practical view of the picking operation, both current and future states, where the possibility to simulate and experiment different outcomes are achievable. Furthermore, this will enhance the understanding of the picking
operations for pickers in relation to strategies regarding operation- and takt- times, presenting an overview over the chosen operation. This also provides opportunities for experiments and employee assessments. The model is based on a company’s ability to identify several key numbers that are necessary for the model to work properly. These include effective working minutes per day, daily demand, the current takt time, number of machines or workers, and all operating times as the various workers have. Based on this, several key numbers are presented which includes a chart formation that allows the user to see which operations the worker performs in a practical way. As a result, the user can choose to change operations between workers to balance work as efficient as possible, in order to ultimately be able to utilize resources in a more efficient manner.

6.2 Method discussion

The methods used to achieve the purpose of this thesis are based on a single case study and literature studies. The data collection of the case study originates from methods concerning observations, interviews and documentation. The authors believe that the methods used have worked adequately and therefore a relevant choice when collecting necessary data for the purpose. By using several different methods, the data collected from one method could be strengthened by another method used.

6.2.1 Case study

The case study and literature studies, which in combination results in an abductive approach, have contributed to a broaden perspective of the area of concern. However, the authors argue that there are also weaknesses with the combination of these methods since the output from one method can affect the input from other methods. For example what has been studied in literature can affect what has been identified in the case study and vice versa. However, this is not considered to have affected the result since the authors have had an objective approach on the area of concern throughout the thesis. In order to obtain a wider range of empirical data, the authors wanted to conduct several case studies, however it would have been impractical in terms of resources, based on the scope of the thesis. By using a case study as a method, the linkage between ”real world settings” and theory was identified, which contributed to answer the questions of issue. The unlimited access and direct contact with employees at the case company simplified the case study. In addition to observations, interviews and documentation, conversations with the Logistics Director and Senior Logistics Engineer have been ongoing throughout the entire case study. This resulted in support and guidance where the authors were able to discuss the accuracy of the information retrieved.

6.2.2 Observations

The primary source for data collection and information regarding the area of concern was obtained by observations. The observations performed at the case company can be divided into two categories, observations with a mentor and self-observations. The reason for this separation was due to each observations purpose
where all observations except for the first one were to observe a predetermined scope. The decision to not conduct more observations with employees was based on remaining the case study qualitative. Therefore, eight self-observations were performed in order to create a “self-made” overview and maintain the information retrieved uninfluenced. The observations mainly involved times studies since no previous time studies had been performed before. The authors found this problematic since in order to compare and validate the result previous data were needed. Therefore, the authors want to enlighten the importance of qualitative as well as quantitative time studies when performing a single case study.

6.2.3 Interviews
All four interviews that were conducted in the case study have been open interviews, since the purpose was to obtain qualitative information to enhance and complement the data from other methods. The authors believe that this type of interviews functioned satisfactorily when prepared questions used while the discussion was open, meaning that some of the data the authors have not thought of is obtained.

6.2.4 Documentation
The documentation provided by the case company complemented and supported the observations and interviews performed. Moreover, the documentation allowed the authors to create an overview of the company. But due to the limitations of documentation within the area of concern the authors were forced to perform further research. Since documentation is secondary data, it needs to be analyzed cautiously which the authors have done throughout the case study. The documentation has not been essential for the result but still necessary.

6.2.5 Literature studies
The literature used is mainly based on scientific articles retrieved from databases that the university library provides where relevant keywords was used in the searching process. However, databases such as Emerald, DiVA and Science Direct provided essential complementary information. Moreover, course literature has been used in addition to the scientific articles and journals obtained from databases. Two different sources has at least been compared and set against each other when searching that the authors consider has increased the credibility of the data collected. The data collected from literature and the case study has been gathered, summarized and analyzed which turned out to be time consuming. Therefore the authors have identified a handful difficulties and from these the most prominent solution options. Due to limited research within the area of concern, the authors had to combine different frameworks in order to answer the purpose. Further more, the authors wanted to expand the extensive literature studies to identify all difficulties and alternative solutions. Nevertheless, this was not achievable in relation to the scale of the work.

6.2.6 Reliability and validity
Several methods and sources have been used and compared with each other, therefore the authors consider the validity and reliability of the thesis to be high.
In addition, the methods and work process are well described, which indicates that a third party could perform the same study and obtain similar results. Moreover, it is considered that the situation studied is representative of similar industry problems, therefore, generalizations should not be seen as a problem. Furthermore, the authors have recognized the importance of multiple case studies on several companies in order to further validate and strengthen a thesis result, which will be kept in mind for future research. Furthermore, the authors believe that other research will identify same or similar difficulties, however, one must remember that the observations made are specific to the case company. The time studies might differ due to changes in picking routines and continues improvement for picking operations.

The model developed has been approved and tested by the case company, which further strengthens the validity of the thesis. For the model to properly work and illustrate the reality in a reliable and correct way, the user must be very cautious when typing in the numbers so every digit is the exact one, this to increase the of the model since reliability according to Andersen (1994) and Bell (2006) indicates how reliable or credible a measurement method is. Yin (2003), Thomas (2009) and Patel and Davidson (2011) all state that a good reliability is achieved when a measurement can be repeated with the same results iteratively, which is main objective of the model’s outcome. Since time is a major obstacle when performing multiple case studies, the authors argues that the model is appropriate to use at different companies experiencing similar issues concerning a need for a more efficient utilization of resources.
7 Final Conclusions

The following chapter presents the authors' contribution in a research and practical perspective where the developed four-step-improvement-process is discussed, followed by recommendations. Finally, the chapter ends with conclusions and further research.

7.1 Contributions and recommendations

Within this thesis has information regarding how to improve picking operations been presented. The approach for achieving the thesis purpose has been determined by answering the three questions of issue. The result shows that the most vital difficulty when improving picking operations is to reduce waste and standardize the outcome. The thesis brings up several difficulties that can contribute to process inefficiency, however, similar companies or organizations may have different problems that need to be improved. It is therefore essential for any company to identify own difficulties within picking operations in order to accomplish process perfection.

7.1.1 Research and practical contributions

The main difficulty that the authors could identify is the lack of standardization concerning picking operations. This is a result of performed actions that are according to Womack and Jones (2003) classified as waste. In order to achieve efficient flow, three major identified difficulties need to be further investigated. When the difficulties have been identified and solved, standardization should be performed, i.e. a process or operation should be performed in the same way, at the same time, regardless which worker carries out the process or operation. To reduce cost and secure high productivity work balancing should be performed, since the difficulty elimination reduces the operation times where new operation times need to be measured. By doing so, possible over or underflows of personnel may appear which could contribute to a more suitable utilization. This could be seen as a continuous process or cycle consisting of four main steps that is illustrated in Figure 10.

![Figure 10. Four-step-improvement-process](image-url)
The reduction of wastes will lead to a more efficient picking operation, where the operation times will be reduced as a result of the improvement. When the processes are standardized and at an improved state, a work balancing should be performed. Through work balancing it will be possible to identify whether the picking operations are over or under capacitated and if there is room for added or reduced resource utilization. This is very important when planning for varying demand since the takt time change when demand varies. For the case company, the demand is increasing according to forecasts. In order to smoothly transition from one takt-time to another, strategies must be made to facilitate the most improved state of the operation. This will let companies maintain resource utilization to a maximum while still be highly productive and efficient.

7.1.2 Recommendations
When the thesis were finished it was found that there are several opportunities to improve picking operations towards assembly lines with customized products. However, one must take into consideration that this case study has been performed on only one case company meaning that there is a need to conduct similar studies in similar situations at other companies. This would generate a more generalizable result that could be used by other companies within the automotive manufacturing industry. Since the model is based on the measurements regarding number of workers, takt times and operation times conducted from the case company it will need to be updated with new input to illustrate the new users current state. Regarding the measurements, it has not taken interruptions into consideration, it would therefore be interesting to see the difference with the operation times by doing so and finally compare them. Lastly, the authors want to highlight culture and motivation as major factors affecting picking operation times and how they are performed. A research regarding work ethics and behavior in Operation Management would further strengthen and justify future result addressing similar topics.

7.2 Conclusions
The thesis has highlighted the importance of improving picking operations since it is according to Le-Duc (2005) and Burinskiene (2009) considered as a labor intensive and costly operation. Moreover, the thesis result shows that resource utilization can be achieved through improved picking operations and the developed work-balancing model. Through observations, time studies and literature studies, the authors have identified five major difficulties that can occur within a picking operation linked to Lean Production and the waste management according to Womack and Jones (2003):
Table 12. Difficulties and solutions

<table>
<thead>
<tr>
<th>Difficulties</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of parts</td>
<td>Frequent replenishment routes</td>
</tr>
<tr>
<td></td>
<td>Kanban</td>
</tr>
<tr>
<td></td>
<td>Order point system</td>
</tr>
<tr>
<td>Order handling</td>
<td>Order handling station</td>
</tr>
<tr>
<td></td>
<td>Order system</td>
</tr>
<tr>
<td>Warehouse maintenance</td>
<td>Maintenance manager</td>
</tr>
<tr>
<td></td>
<td>Well placed trash bins</td>
</tr>
<tr>
<td>Lack of standardized picking operations</td>
<td>Continues improvements</td>
</tr>
<tr>
<td></td>
<td>Just in time</td>
</tr>
<tr>
<td></td>
<td>5S</td>
</tr>
<tr>
<td>Work balancing</td>
<td>Resource utilization</td>
</tr>
<tr>
<td></td>
<td>Operations overview</td>
</tr>
<tr>
<td></td>
<td>Support decision making</td>
</tr>
</tbody>
</table>

Moreover, difficulties seen in Table 12 were identified by comparing theory with a single case study and can therefore be strengthened as important factors affecting the efficiency of picking operations. This thesis can work as a support for further research focusing on similar area of concern by narrow down difficulties in order to be further analyzed.

### 7.3 Further research

The result of this thesis is based on comparing difficulties identified in theory with the ones identified in the case study. Since difficulties identified in theory varies from the case study, additional research needs to be performed. The authors haven’t had the time to analyze or investigate all difficulties identified in picking operations, as well as all factors influencing picking operations. Therefore difficulties mentioned but not addressed in this thesis should be further investigated. Moreover, this thesis is based on a continuous flow without any interruptions, therefor should further research also address ANOVA-analysis in order to count for lack of parts, flaws and deficiencies within the material flow towards assembly lines.
References


Srinivasan, M. (2012). *Building Lean Supply Chains with the Theory of Constraints*. USA:


Attached files

Initially the attached files begin with the interviews performed at the case company, followed by observations and measurements. The following section illustrates the model developed and how to use it. This is followed by the seven steps to a successful work balancing made by Russell and Taylor (2010). The last attachments involve the case company’s documentation and supply flow.

**Attachment 1 - Interview questions**

<table>
<thead>
<tr>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your current position in the company and what are your main responsibilities?</td>
</tr>
<tr>
<td>Are you satisfied how the picking operations are performed today?</td>
</tr>
<tr>
<td>Can you think of, or have identified any problems or bottlenecks in the picking operation?</td>
</tr>
<tr>
<td>How would you solve identified problems within your area of concern?</td>
</tr>
<tr>
<td>Do you see any difficulties with varying demand for the picking operations?</td>
</tr>
<tr>
<td>How do you think work balancing would affect the picking operations?</td>
</tr>
<tr>
<td>Does any particular tools or frameworks exist in order to support when solving work-balancing problems?</td>
</tr>
<tr>
<td>If a model existed, would you consider using it?</td>
</tr>
<tr>
<td>If a model could be developed, how would you want it to look like and what factors should be taken in consideration?</td>
</tr>
</tbody>
</table>
Attachment 2 - Observations and measurements

The following figure presents the observation measurement performed on the case company in order to identify the operation times for every kit rack.

<table>
<thead>
<tr>
<th>Kit rack</th>
<th>Obs. 1</th>
<th>Obs. 2</th>
<th>Obs. 3</th>
<th>Obs. 4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation 1</td>
<td>4.29.47</td>
<td>4.31.08</td>
<td>4.35.02</td>
<td>4.40.02</td>
<td>4.34.00</td>
</tr>
<tr>
<td>Operation 2</td>
<td>5.12.16</td>
<td>5.14.10</td>
<td>4.43.02</td>
<td>4.46.32</td>
<td>4.59.00</td>
</tr>
<tr>
<td>Operation 3</td>
<td>11.20.58</td>
<td>11.21.52</td>
<td>13.32.01</td>
<td>13.16.23</td>
<td>12.22.48</td>
</tr>
<tr>
<td>Operation 4</td>
<td>9.11.10</td>
<td>9.06.56</td>
<td>12.29.47</td>
<td>12.03.32</td>
<td>10.42.51</td>
</tr>
<tr>
<td>Operation 5</td>
<td>10.12.16</td>
<td>10.13.54</td>
<td>12.06.59</td>
<td>12.35.21</td>
<td>11.17.08</td>
</tr>
<tr>
<td>Operation 6</td>
<td>21.09.11</td>
<td>21.06.12</td>
<td>22.08.43</td>
<td>22.56.54</td>
<td>21.50.15</td>
</tr>
<tr>
<td>Operation 7</td>
<td>28.09.12</td>
<td>28.07.02</td>
<td>27.40.43</td>
<td>27.53.04</td>
<td>27.57.30</td>
</tr>
<tr>
<td>Operation 8</td>
<td>10.12.16</td>
<td>10.13.23</td>
<td>11.09.50</td>
<td>9.59.03</td>
<td>10.23.38</td>
</tr>
</tbody>
</table>

The figure below describes the current state of the case company’s picking operations and what kit racks pickers has been assigned to.

<table>
<thead>
<tr>
<th>Kit rack</th>
<th>Operation 1</th>
<th>Operation 2</th>
<th>Operation 3</th>
<th>Operation 4</th>
<th>Operation 5</th>
<th>Operation 6</th>
<th>Operation 7</th>
<th>Operation 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker 1</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Worker 2</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worker 3</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worker 4</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worker 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worker 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Worker 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Step one (1): Type in effective working time per day in minutes.  
(Minutes consist in a working day – breaks)  
Type in daily demand in units.  
Current takt time will be calculated.  
Type in current number of workers or machines.

Step two (2): Type in operation times in every cell assigned to the correct worker.  
Total time, takt time and slack time will be seen in bottom of the section.

Step three (3): Step three is fully automatic where the summed slack time is presented, which is seen as “Difference”.

Step four (4): Step four is fully automatic where the final balancing loss is presented.
**Attachment 4 - Work balancing improvements**

Daily demand, 15 units (current state):

![Current State Table]

Daily demand, 15 units (improved state):

![Improved State Table]
Daily demand, 20 units (future state):

![Future State Chart]

Daily demand, 20 units (improved future state):

![Improved Future State Chart]
Attachment 5 - Seven steps to a successful work balancing

(1) A precedence diagram is made to sort the different picking operations in correct order they need to be performed. The different picking operations are represented by the circles, which are linked together by arrows and illustrates in what order the picking operations must be performed.

(2) A precedence schedule is formed in order to create an overview of the different operations and cycle times.

(3) Calculate desirable cycle time with the formula below:

\[ Cd = \frac{AWT}{D} \]

Cd = Desirable cycle time  
AWT = Available Working Time  
D = Demand

(4) Calculate the scarcest number of stations possible (n)

\[ n = \text{number of stations} \]

\[ t_i = \text{available time} \]

\[ Cd = \text{Desirable cycle time} \]

\[ N = \frac{\sum_{i=1}^{j} t_i}{Cd} \]

(5) Arrange operations based on tact time and precedence limitations.
6) Define actual cycle time and clarify which operation is the most time consuming with the support from the time studies.

(7) Calculate the efficiency for the assembly line and decide the balancing loss. In order to calculate the balancing loss, you take the efficiency subtracted by one.

\[
E = \frac{\sum_{i=1}^{j} t_i}{n \cdot C_a}
\]

- E = Efficiency
- n = number of stations
- Ca = Actual cycle time
- ti = Total available time
**Attachment 6 - TSA documentation**

The documentation provided by Volvo Global Truck Operation has been essential for this thesis since an understanding of the layout and different flows was illustrated in the following sections. First, a overview of the factory is illustrated, which is followed by future demand graph and finally a supply-flow of all kit racks investigated in this thesis.

**Overview TSA Factory**

![Diagram of TSA Factory Layout]
Future demand

As the figure illustrate, the demand in March is 10 units, and in the beginning of April the demand rises to 15 units, which is consistent until July. In July the demand increases to 20 units and in August 36 units. In September the demand reaches 40 units and stays consistent.
Supply-flow of kit rack, Cab – Trim line
<table>
<thead>
<tr>
<th>Line</th>
<th>Main arm line</th>
<th>Code</th>
<th>Kit name</th>
<th>Kit CN</th>
<th>Location</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Diagram of layout with annotations]

- New Canopy
- Logistics office
- TM&B GR

Attachments
<table>
<thead>
<tr>
<th>No.</th>
<th>Kit name</th>
<th>Code</th>
<th>Location</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Kit Under CAB</td>
<td>F</td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>