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Location of kit preparation – A case study within the automotive industry

Master's Thesis in the Master's Programme Quality and Operations Management

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Abstract

There are different ways of providing material for assembly and kitting is one of the more commonly used methods. Certain material that is supposed to be assembled is presented in kits to facilitate the assembly operations. The kit preparation can be conducted at different places at a company. The choice of where to place the kit preparations can affect a company regarding different factors. Previous studies have made some findings with the placement of having the kitting centralised (i.e. gathered in one common location), or decentralised (i.e. several kit preparations spread around a plant). What has not been investigated so far is the choice of having the kit preparation outside the plant. Therefore, this thesis aims to investigate this area further. It will be done through case studies that are intended to be compared with each other. These two cases are well established companies within the automotive industry that have many years' experience of using kitting as a method of providing material.

In terms of having the kitting processes outside the plant, the thesis shows that it is more advantageous to have the kitting located in an area nearby the assembly, rather than having it outside the plant. A crucial performance area that is discussed, and affected by the kitting location, is the amount of transportation that increases in conjunction to having the kits prepared outside the assembly plant. Other crucial areas that are discussed are the quality of kit preparation and potential for visual control, which both positively affected by having the kits prepared nearby the assembly.

Contents

1. Introduction

In this chapter a background of the subject is presented which then leads to the purpose of this study. Furthermore, this section describes a problem analysis including the research questions and their aim. Finally, the scope is described in this section.

1.1 Background

Materials feeding is the way a company chooses to provide components and subassemblies to the shop floor to feed assembly stations. This can be done in various ways and there are different material feeding principles describing the way of working. The most common principle used by organisations has been continuous supply but nowadays more companies are considering kitting as an option. When working with continuous supply part numbers are supplied individually to the assembly line in containers. This way of delivering material is preferable when there is a high-volume and low-variety environment. Furthermore, it is suitable when the number of components assembled at each station is low and when assemblies are standardised. (Caputo et al., 2015)

Kitting is as mentioned an alternative to continuous supply. This method is based on certain components or subassemblies that are being gathered to common kit containers to later be assembled on a specific assembly object. This leads to assembly stations with less inventories of parts (Caputo et al., 2015; Bozer and McGinnis, 1992) since these are included in the kits. Bozer and McGinnis (1992) also explain that kits can either be “stationary” (i.e. supporting one assembly station) or “traveling” (i.e. supporting numerous assembly stations). Kitting is preferable when there is high product variety or customized products, as well as low production volumes. Furthermore, when small and lightweight parts are handled. A down-side with kitting is that it is resource demanding and costly due to the labour needed for preparation of kits (Caputo et al., 2015).

Companies working with kitting must choose a place where the kits are to be prepared. The placement of kit preparation is of importance since this has different effects on the company regarding various factors. Hanson et al. (2011) mention that this is an area that has not been studied a lot. However, in their research three places for kit preparation were studied. The places were; at the assembly line, in the main storage of the assembly plant and in a separate kit preparation area in between storage and assembly line. Hanson et al. (2011) investigated seven different factors that could possibly be affected by the placement of kit preparation. These were; amount of transportation, inventory levels and space requirements, potential for visual control, flexibility, efficiency of kit preparation, quality in the kit preparation and ability of continuous improvement. They concluded that there is a difference in these various factors depending on the placement. However, further research needs to be done to study other locations for kit preparation since current studies have only investigated placement and effects within the plant. An area that has not been studied yet is having the kit preparation in locations outside the plant.

1.2 Purpose

The purpose of this thesis is to investigate how the choice of location effects the kit preparation process.

1.3 Problem Analysis

The choice of kitting location carries consequences and difficulties that might arise (Hanson et al., 2011). The choice depends on different factors where the current situation of a company is one of them. This issue has not been studied a lot and this thesis aims to contribute to this field. The questions have, therefore, been formulated in a way that aim to find answers for the purpose. I.e. questions related to the kitting location, and how this affects the kitting itself seen from different aspects.

The questions have been developed from the framework by Hanson (2012) seen in Figure 1. The term "configuration of the in-plant materials supply system" is about how the design of the system is organised. This refers to all aspects of the system such as, materials feeding principles, unit loads, delivery routes within the plant etc. The term "context of the in-plant materials supply system" is about the aspects that are not included in the "configuration of the in-plant materials supply system" but have the potential to influence its performance. This could be the current situation of a company, including for instance production volume and different product characteristics (e.g. size and weight) etc. meaning factors that are beyond the control of the kit designer. The two terms mentioned lead to a certain "performance". This includes factors such as, man-hours, flexibility, quality etc. The following research questions have been chosen to study for this thesis:

- How does the context of the in-plant materials supply system affect the choice of location for kit preparation?
- What is the impact of choice of kitting location on the design of the kit process?
- How is the performance affected by the choice of location for kit preparation?

The aim of these questions is to get a picture of how it is to have kit preparation outside the plant in regards to different performance aspects. The questions seek to find out if the performance is affected. Hence, both context and configuration have been considered to get a picture of the performance aspects.

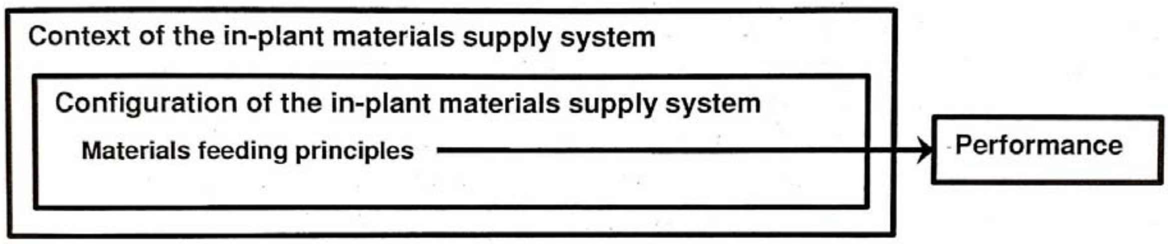

Figure 1: *Overview of the relation between materials feeding principles and performance, considering the configuration and the context of the in-plant materials supply system, Hanson (2012)*

1.4 Scope

The thesis was delimited to only studying the location of the kit preparation. Furthermore, the authors only looked at two cases, both working in the automotive industry. One case had the kit preparation beside assembly line and the second had it at an external location.

2. Methodology

In the beginning of the thesis, a literature review was carried out to create a theoretical framework as Bryman & Bell (2015) mention can be valuable to have as a foundation supporting the work process, and the theoretical framework was used as a basis to analyse the cases. The literature review was done through various methods, such as reading articles connected to the subject, as well as using Chalmers Library's database Summon and Google Scholar to search for further theories. Some keywords that were used as inputs for the search engines were; kitting, kit preparation, kit location etc.

According to Bryman & Bell (2015), it is of great importance to have a research strategy in order to get guidance when conducting the research. This thesis has used the strategy of qualitative research meaning that empirical data were gathered and later analysed. The empirical data were collected from two case studies consisting of interviews and observations. The quantitative research strategy was not chosen because it was considered too comprehensive to collect quantitative data. Furthermore, the quantitative data would not contribute to any value in this thesis since, these could not always be compared in a case study where cases differ in terms of setup.

A case study is described by Yin (1994, p. 13) as *"an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"*. The case studies, which consisted of interviews and observations, were done in two different companies in the automotive industry. The two cases were evaluated according to the nine performance areas mentioned in the theoretical framework (see *3.5.1 Kit location performance areas*).

Interviews were conducted at both companies with personnel working with the subject. The authors conducted semi-structured interviews meaning that the authors could discuss and ask follow-up questions in addition to the main questions (Bryman & Bell, 2015). The authors conducted ten different interviews with workers that were in direct connection to the kitting processes, such as kit pickers, technicians (and/or responsible staff for the kitting processes), as well as workers that are indirect connected to the kitting processes. This group includes workers such as assemblers, team leaders, and material handlers. Through the interviews the authors collected necessary information to seek answers for the questions mentioned in the problem analysis and to get a better overview over the kitting processes. The questions asked during the interviews can be seen in Appendix A.

The authors also conducted direct observations, meaning that the authors were the observers, to get a better understanding by looking at a practical example. Thus, the authors observed the processes that were directly and indirectly connected to the kitting processes in the different cases, by studying the daily work. Bryman and Bell (2015) mention that pilot research of both the interviews and observations are important to obtain as good results as possible. This was done by the authors by testing the questions before conducting the interviews. The collected data from the observations and interviews was later analysed to draw conclusions. The analysis in this thesis was carried out by comparing the two cases in regards to the theoretical framework, describing similarities and differences. The discussion chapter focused on the crucial performance areas from the analysis, describing pros and cons of each area. These were then summarised in a table comparing centralised and decentralised kitting location.

2.1 Trustworthiness

The trustworthiness of the research is discussed below

2.1.1 Confirmability

Confirmability is the degree of neutrality, meaning the researchers should prevent bias and personal motives, in the findings (Bryman and Bell, 2015). To avoid that the values of the authors intruded the results the questions for the interviews were tested before conducting these to avoid leading questions etc.

2.1.2 Credibility

Credibility is how assured the researcher is in the truth of the study's findings (Bryman and Bell, 2015). To get credible data, the authors tried to interview employees that were closely connected to the subject. Furthermore, the authors used some level of triangulation (i.e. using different ways/methods to collect data to strengthen the trustworthiness) by making observations as well as several interviews.

2.1.3 Dependability

Dependability is about the degree of the results being similar if other researchers conducted a related study (Bryman and Bell, 2015). The materials feeding process is believed to be similar in different automotive companies thus the authors believe that the results would be similar if a group were to conduct the same research process.

2.1.4 Transferability

Transferability is about if the findings are applicable to other contexts (Bryman and Bell, 2015). The authors believe that most material feeding processes are similar in automotive companies thus the results are believed to apply to other contexts. Furthermore, data in the theoretical framework was collected from areas beyond the automotive industry which could mean that the findings apply to other contexts as well.

2.2 Ethical issues

Ethical issues are important to consider when conducting a research and Bryman and Bell (2015) mention four main principles that need to be considered. These are; lack of informed consent, invasion of privacy, deception, and harm to participants. These four main principles were considered throughout the thesis by the authors. The purpose of the study and what the research was to be used for were communicated to avoid lack of informed consent. To avoid invasion of privacy the interviewees could answer anonymously and they were also able to choose if they did not want to answer a question. As mentioned earlier the people participating in the research were informed of the purpose etc. to avoid deception. Finally, the authors tested all methods before conducting them to avoid harming the participants. This was done by sending the interview questions to a third-party to get feedback.

3. Theoretical framework

This section will discuss relevant and closely connected theory of kitting and its placement. The target is to give general knowledge that is appropriate to the matter so that further reading becomes facilitated. The theory will, firstly, describe a basic explanation of Lean philosophy and the different kinds of waste. Secondly it will focus on material feeding principles (i.e. kitting, continuous supply, batching and sequencing). It will also focus on the choice of location and its consequences. Thirdly, it will describe the replenishment system used in both cases which is a form of bin system. Finally, the theory section will describe the performance areas that are potentially affected by the choice of kit preparation location.

3.1 Lean Production System

As Lean has become a topical subject and a common production philosophy many companies try to adopt, it becomes natural to discuss theory connected to its concept, with focus on different kinds of waste that can be linked to kitting and the choice of its location. Kitting is commonly used within Lean to support an effective material supply, meaning eliminating waste. Furthermore, kitting enables for mixed model assembly which is in line with the Lean concept. These different kinds of waste can then be used for consideration, where pros and cons are placed against each other in regards to the kitting location. In that way, a comparison between different kitting locations can be described in the analysis or discussion viewed from a Lean perspective.

According to Liker (2013) Lean Production System is an ideology that is based on maximising the customer experience and at the same time eliminating waste. The terminology “Lean” was coined in the 90s, and was before recognised as Toyota Production System (TPS).

3.1.1 Lean Concept

The interpretation of TPS that Lean represented is described by Modig and Åhlström (2012). Their explanation of the Lean philosophy is described and deemed like a tree that has different levels. This tree consists of the following levels:

- Values - which stands for what the company want to be
- Principles - refers to how to think
- Methods - refers to how to act
- Tools - refers to what to use

In the same order as the levels are written, the abstraction level is the same (i.e. from higher to lower). The values are classified as the body of the tree in regards to the philosophy. The principles are however divided in two different orientations; Just-in-time (JIT) and Jidoka. The first orientation is about creating a flow, while Jidoka focuses on developing a visible organisation. This organisation is then intended to function as a way of reacting towards disturbances of the flow and develop preventive way of avoiding these by learning from past events. The focus should always be on the customer, through the whole value flow. This includes everybody in the value flow meaning that a customer does not necessarily have to be external, but can be internal as well (e.g. the next station/operator downstream in the value flow). Methods correspond to how an organisation should execute work tasks, while the tools instead refers to what to use to perform different activities, and thus can develop/create what the customer wants, as well as what they do not actually want.

The tree is like the “House of Lean” that is shown below (see Figure 2: *House of Lean Model*). According to Liker (2013), it shows the Lean production, where the customer focus is the highest priority (consisting of ensuring quality, and to be cost effective, as well as lowering the lead time by always eliminating waste). The two principles represent the House of Lean's pillars and the standardisation and stability both represents the foundation of the concept. Nevertheless, for the Lean concept to function properly the need of having every person's involvement is crucial from top management to floor-level.

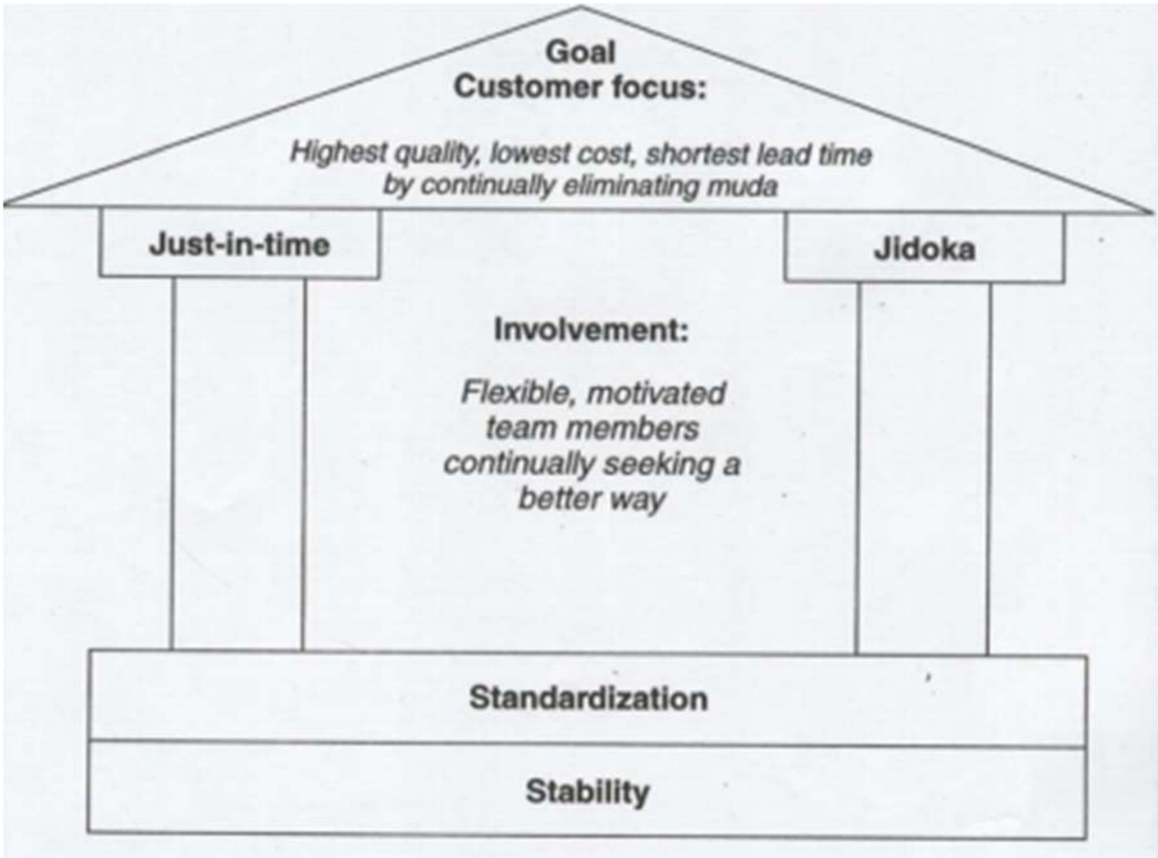

Figure 2: *House of Lean Model (Dennis, 2007)*

3.1.2 Eliminating waste

Eliminating waste is as mentioned top priority and included on the roof of the House of Lean under customer focus. According to Bicheno and Holweg (2009), the creator of TPS Taiichi Ohno identified different forms of wastes. He defined them as seven ones. However, there have been added and acknowledged an eighth one, as the Lean concept motivate creative thinking among the involved workers. These eight types of wastes are shown down below:

1. *Waste of overproduction:* It refers to producing too much seen from different scenarios, such as production to stock (i.e. producing without any insurance of the items being sold to an end-customer). This waste is considered by far the most crucial one.
2. *Waste of waiting:* This waste includes all unnecessary time that it takes in between different activities. Since this is not value adding to the end-product, it is potential time to be missed. The cause differs, as the one responsible can sometimes be the workers themselves, or caused by parts, as well as customers.
3. *Waste of unnecessary movement:* This waste includes all unnecessary motions that are creating non-value adding activities. E.g. motions such as walking between different processes or by just searching for parts are some activities that are classified as unnecessary.
4. *Waste of transporting:* All types of transportation that is not transported in an efficient way (e.g. half empty transportations of materials and the like, or transportation to and from storage are not value-adding).

5. *Waste of overprocessing/incorrect processing:* This includes all processes that are classified as either unnecessary or not efficient. Thus, bringing undesirable motions and sometimes even defects on the material or end-product.
6. *Waste of unnecessary inventory:* unscheduled deliveries, deteriorated/damaged material are some potential consequences of having too much inventory. It also ties-up capital that can be better spent through other investments. By reducing the inventory, the previous problems will easier be exposed.
7. *Waste if defects:* Defect parts cost as well as it takes time to fix or redo. The sooner it gets detected, the more economical it will be to fix the error. The aim is therefore to develop a preventive approach instead of increasing the inspections.
8. *Waste of untapped human potential:* As the Lean philosophy stands for respecting people it is highly motivated and encouraged to listen to each other, no matter what working position a person has. Every worker is seen as an expertise, within their working area, as they are the one performing their tasks day in and day out. To overlook that fact is considered as a crucial waste.

As Modig and Åhlström (2012) are mentioning in their literature, the Lean concept should not be classified as a toolbox for every organisation from different industries to copy. Since every company is unique, it should also be treated in its own way. Therefore, it is important to not copy the whole Lean concept, and instead seek for inspiration of its philosophy and later adapt it to each company.

3.2 Material feeding principles

An important decision that needs to be made is regarding the choice of material feeding system, meaning the way materials are supplied to the operators. This is an important decision since it affects the assembly lines performance as well as other factors. Johansson (1991) defines three main material feeding principles in his model (seen in Figure 3). These are; batch supply, continuous supply and kitting. The three principles are separated by whether a selection or all the part numbers are displayed at the assembly station, and by the way components are sorted at the assembly stations.

Continuous supply sorts material by part number and all part numbers are presented at the assembly line. Batch supply is also sorted by part number but only a selection of part numbers is presented at the assembly station. The part numbers presented are for a number of specific assembly objects. Kitting is sorted by assembly object and a selection of part numbers is presented at the assembly station. This means that kits contain a set of part numbers for one assembly object and are according to Hanson (2009) delivered in the order that they will be assembled.

Johansson and Johansson (2006) define a fourth principle called sequencing which Hanson (2009) means to say is similar to kitting and sorts part numbers by assembly object and only presents a selection of parts to the assembly. All principles will be described further in this chapter.

	Selection of part numbers	All part numbers
Sorted by part number	**BATCH**	**CONTINUOUS**
Sorted by assembly object	**KITTING**	

Source : Johansson, 1991

Figure 3: *Categorisation of materials feeding principles (Johansson, 1991)*

3.2.1 Continuous supply

Continuous supply is also common to be referred as "line stocking" and is when material is presented to the assembly direct from the supplier without assortment. According to Johansson (1991), continuous supply is the place that the material is being delivered to at the assembly areas. The material is normally supposed to be delivered in units that are adapted for usage/handling. As they run out they are supposed to later be replaced. Moreover, it is basically a system that provides a wider number of parts for an assembly, since no material is being prepared in a previous stage and delivered as kits. Hence, it requires a higher number of items that will be presented on the material rack that surrounds the assembly plant, (Hanson and Brolin, 2013). What distinguishes this material feeding process from other systems, is that the operator is supposed to pick all available parts by themselves. According to Bozer and McGinnis (1992) and Hua and Johnson (2010), a comparison between continuous supply and the kitting system both affect some performance areas differently. As stated in Hanson and Brolin (2013), the choice needs to therefore be well thought out, and pros and cons should be reviewed. Nevertheless, each assembly plant is unique, and therefore should be treated separately. Regardless, it is important to first understand how the strengths and weaknesses emerge.

3.2.2 Kitting

Johansson (1991) describes kitting as a set of parts consisted in one kit to be used for one assembly object. A kit is further defined as *"a specific collection of components and/or subassemblies that together (i.e. in the same container) support one or more assembly operations for a given product or shop order"* by Bozer and McGinnis (1992). This means that only the parts required are presented to the assembly operator which in its turn reduces the manufacturing floor space and increases the control of work-in-progress, according to Bozer and McGinnis (1992). Furthermore, kitting requires extra handling compared to continuous supply since someone must prepare the kits. However, kitting is considered more flexible to change in the assembly line since all material is presented in the kits, meaning there is no need for material racks beside the assembly line as there is when having continuous supply.

Johansson and Johansson (2006) mean to say that kitting is preferable when there are a lot of different parts, components and variants to be assembled. They also state that when there are serial lines with few components to be assembled then kitting is less preferable.
A company can work with several kinds of material feeding principles to the various assembly stations and Bozer and McGinnis (1992) talk about considering product complexity and product size when choosing a material feeding principle. These are also mentioned as motives for not choosing kitting. Furthermore, Bozer and McGinnis (1992) and Baudin (2004) discuss how some components, such as washers and fasteners, are usually excluded from kits because of their frequent use and small size.

Brynzér and Johansson (1995) discuss different design options regarding kitting in their report. One of the things discussed is who should be responsible for preparing the kits and the options mentioned are that either an assembler or a picker (i.e. a specialised operator) does it. They continue by saying that higher picking accuracy can occur when the picking is done by assemblers since these have a better understanding of the parts used in the assembly. Furthermore, they discuss the location of the kitting activities saying that these can be done either in a central picking area or in decentralised areas close to the assembly stations.

One pure kitting system design has been difficult to identify since organisations use different solutions in regards to kitting meaning that the literature studied varied a lot. However, regarding the kit, Bozer and McGinnis (1992) describe two types; stationary and traveling kits. Stationary kits are delivered and used at one station meaning that they remain at the one station until fully consumed. Traveling kits are delivered to one station but can travel along with the product being assembled meaning that they can be used on several assembly stations before fully consumed.

Moreover, Brynzér and Johansson (1995) explain some concepts that were noticed in their study, in regards to when picking kits. These are; *batching policy, zone picking, picking information and design of picking package*. Batching policy is reducing the walking distance and picking times by picking for several kits simultaneously instead of picking one at a time. Zone picking is when picking zones are created by dividing the picking order to enable simultaneous picking of the order. Picking information is about how the operator gets the information of what needs to be picked. This can be done in various ways such as having a picking, display showing what to pick etc. Having a display in the storage showing what to pick is considered to enable more accurate picking than having a list. Finally, design of picking package explains the importance of the functionality of the picking package in both the picking process and the assembly. The packages can either be standardised or non-standardised. Non-standardised packages present the parts freely while standardised packages present the parts in specific places. Having standardised packages increases the safety and the control while it can reduce the flexibility.

3.2.3 Batching

According to Johansson (1991), batching refers to a system that has a certain selection of part numbers, as well as it is sorted by part numbers which can be seen in Figure 3. The material is, therefore, only given to certain assembly objects. The batching supply system has some similarities with continuous supply, as the material feeding principle is also sorted by part numbers. However, batching supply only presents a specific number of details/parts for a certain order. This means that the company decides an amount of products that will be produced and then prepares material for that specific batch.

3.2.4 Sequencing

Sequencing is a material feeding principle mainly used by companies in the automotive industry. As Svensson (2006) explains it, most companies in that industry are working with just-in-time principles meaning that parts are delivered just in time and in a predetermined sequence.

Baudin (2004) means to say that sequencing is when materials are delivered to a determined location at the time they are needed. The materials are delivered in racks and to do this the sequence of the final assembly line is communicated to the supplier for them to deliver parts in the same sequence. The supplier does not have to be an external part as sequencing can also be done internally. Sequencing is further defined as displayed and sorted by object part numbers at the assembly stations by Johansson and Johansson (2006). Sequencing is preferable when there are few components being assembled and it can be done inside or outside the assembly plant (Johansson and Mathisson-Öjmertz, 2000). Baudin (2004) says that sequencing requires a lot of information exchange which in its turn requires better connection and communication between supplier and customer.

Johansson and Medbo (2004) mean to say that instead of displaying several packages at the assembly station companies can display one package when using sequencing. The package then contains various specific part numbers belonging to the same component group.

Sequencing has many similarities to kitting but there are also differences. What is similar is that both material feeding principles are sorted by assembly object meaning that only specific selections of part numbers are presented to the assembly stations. A difference is that one kit container with several different articles is presented in kitting, while in sequencing material is delivered in racks that contain different types of one article sorted by assembly object.

3.3 Two-bin system

Two-bin is one type of a bin system but it does not have to be just bins. The two-bin system works as a principle for when to replenish material. According to Ortiz (2015), the two-bin system can be represented by an operator that has two bins at his or her station. When one of these bins is empty, it is placed on some form of replenishment area. This area is supposed to indicate for the material handlers that the empty bin needs to be replaced with new material. When one of these bins is empty, the system has reached the minimum level of material and vice versa when new material has arrived and there are two full bins available for the operator. A common solution to facilitate the indication for the material handlers is by using some form of light that turns on as the empty bin has been placed on the replenishment area. Until the material handler reacts to this indication, or meanwhile the material handler is about to replenish the bin, the operator continues working as there is one filled bin left. That is supposed to be sufficient until the operator receives the newly replenished bin from the material handler. Ortiz (2015) further explains that the two-bin replenishment system is a form of Kanban system. The difference is that the two-bin system does not have Kanban cards, as empty bins represent the necessary information (through labels containing all necessary information that is needed) for material handlers when these are to be replaced by filled ones. As with the Kanban system, the two-bin system can also be used with more than two bins.

3.4 Third-party logistics (3PL)

More and more organisations are starting to outsource activities to specialised companies to focus on their core competences (Skjott-Larsen et al., 2007). Moreover, companies can choose to outsource due to other reasons such as lack of space in the plant. Transport and logistics are among the things outsourced and (Aronsson et al., 2004) mean to say that companies can, inter alia, outsource their logistics to third-party logistics (3PL). A 3PL is defined as a closer relationship between a shipper and a third part compared to a regular relationship by Murphy and Poist (2000). They continue by saying that a 3PL offers more customisation, embraces more functions and has usually a longer-term, mutually beneficial relationship. The customisation can, although, differ depending on the various relationships between shipper and service provider. If there exists a simple relationship then the degree of customisation is low, treating simple market exchanges and the competence exchange is also small. However, if the relationship is integrated then customisation is high, treating in-house logistics solutions and much exchange of competence. (Skjott-Larsen et al., 2007)

Skjott-Larsen et al. (2007) describe three types of services that a 3PL can offer, which are; asset-based logistics providers, network logistics providers, and skill- based logistics providers. Asset-baset logistics providers offer 3PL as an extension of their core business and they own assets such as terminals, airplanes, trucks and warehouses. Network logistics providers are specialised in fast and reliable shipments since they have a strong global transportation and communication network. Lastly, skill-based logistics providers offer financial services, managerial skills, information technology and consultancy since these do not own any physical assets.

Vaidyanathan (2005) has identified warehousing as one of the functions that is usually outsourced to a 3PL for a company to be able to focus on its core competence. He also mentions that kitting is a part of the warehousing functions, meaning that a 3PL can be responsible for kitting. Having kitting done in a logistics centre which is managed by a 3PL is common and 3PL claim that kitting is then performed better since focus is within one area.

Skjott-Larsen et al. (2007) mean that outsourcing allows for fixed costs to become variable costs meaning that costs such as trucks and warehousing are handled by 3PL and that the company can chose among different providers. 3PL have these kind of tasks as their core competence and can therefore handle these better. By streamlining operations, the shipper can create a leaner and more flexible organisation. (Skjott-Larsen et al., 2007) The difference in price is mentioned as a motive for outsourcing activities to 3PL by Baudin (2004). He means to say that the automotive industry has higher wages than a 3PL and that instead of having employees in the automotive industry handle the product it would be cheaper to have material handlers at a 3PL handling it. Lack of space in the factory is also a reason behind using a 3PL.

3.5 Location of kit preparation

According to Brynzér and Johansson (1995), a kitting process can be done in different places. It can for instance be done in a central picking store, or in a decentralised place. In the first one mentioned, the kitting processes are performed in an area that gathers every kitting process into one common central location (e.g. a main storage facility). The decentralised area stands for the opposite meaning that kitting processes are performed spread around a company. The latter, can for instance be placed next to an assembly line, as well as other decentralised locations nearby the assembly (usually called material markets). Each one of them carries both pros and cons as seen in Table 1. The decentralised picking store could for example develop a possible risk that could disrupt the balancing among the team if stations have more operators than needed (e.g. if a station requires 1,5 workers and is provided with 2 then there is a loss of 0,5). In a centralised picking store, it is easier to move around personnel enabling more balance among the stations. However, in some cases it is preferable to integrate the kitting processes into the work tasks of the assemblers. One reason is an increased picking accuracy that could be affected in a good way because of having assemblers responsible for both tasks. Another reason is that the integration can have an impact on the productivity. It also makes it possible for the design to be adjusted in a beneficial way for the operators in terms of ergonomics and quality. Furthermore, Brynzér and Johansson (1995), claim that the administrative work can tend to reduce as well.

Moreover, Brynzér and Johansson (1995) are categorising the order picking systems in two categories. One way is by having the material arrived to the kit picker (part-to-picker), and the other way is by having the kit picker walking towards the kitting location (picker-to-part). In this report the last-mentioned category is the one that has been used as a method by the companies that have been studied. The choice of system influences the organisations material feeding principle and picker-to-part is the system that is most commonly used.

The travelling time and distances are directly connected to the choice of location. According to Frazelle (1990), the travelling time measured up to 60% of the time used by the order picker when picking parts (i.e. in a picker-to-part system, as will be focused in this thesis). With kitting, the assembly line gets less material surrounding the area, since the material is moved to the kitting area instead, which frees up space and reduces the assemblers traveling time. Thus, less travelling is necessary for the assemblers. However, this means of course more travelling for the kit pickers. The traveling is furthermore affected by the location of the kitting. In a decentralised kitting area pickers usually have determined stations that they prepare kits for, leading to shorter traveling distances. In a centralised kitting area, the kit pickers have longer traveling distances, due to the larger area, but this can be reduced by dividing the area into different stations.

Hanson et al. (2011) noticed differences in regards to the ability to respond to quality deficiencies and replace faulty parts depending on the location of the kit preparation. They mean to say that if the kit preparation is close to the assembly, the response time to detect and replace faulty parts is much quicker than if the preparation is done further away. Hanson et al. (2011) in their study on kit preparation location within the plant, concluded that there were no significant differences on the overall inventory levels depending on where kit preparation was done. This was, however, considered a subject for further research. The authors also noticed that less transportation was needed when the kit preparation area was close to the assembly. This means that the lead time is reduced the closer the preparation is to the assembly. Furthermore, the authors noticed that no extra space beside the assembly line was needed when the kit preparation was done in storage. Finally, Hanson et al. (2011) found that centralised areas, separate from storage and production, had a higher flexibility regarding expansion of the kit preparation area.

	Pros	Cons
Centralised	High level of utilisation of pickers (Brynzer & Johansson, 1995) Higher flexibility for expanding the area used for kit preparation (Hanson et al.,2011) Reduction of storage quantities, inventory cost, and space requirements (Battini et al.,2009)	Reduced communication between assemblers and kit pickers (Brynzer & Johansson, 1995) Decreased integration between assemblers and kit pickers (Brynzer & Johansson, 1995) The ability to respond to quality deficiencies and replace defect parts (Hanson et al.,2011) Sub-optimisation in regard to continuous improvements (Hanson et al.,2011)
Decentralised	Increased picking accuracy when the operators are responsible for both kit preparation and assembly (Brynzer & Johansson, 1995) Improved quality in kits (Brynzer & Johansson, 1995; Hansson, 2009) Less transportation (Hanson et al.,2011) Ability for visual control (Hanson et al.,2011) Shorter lead time (Hanson et al.,2011)	Requires an area in addition to the main storage (Hanson et al.,2011)

Table 1: *Pros and cons of centralised and decentralised kitting location*

Since previous studies have not focused much on the location of the kit preparation and what effects this has, literature has also been gathered from related subjects, such as location of parts storage and order picking.

Koster et al. (2007) discuss the location of picking processes and mean to say that this has a significant effect on the traveling distances within a facility. Tompkins et al. (2010) in their study regarding location of storage inside a warehouse, mention that placement of items by the departure point of the storage, instead of the entrance point, should be done when items have a higher frequency of deliveries from the storage than to it. They also mention that items with low frequency of deliveries should be placed near the entrance point. Furthermore, Hales and Andersen (2001) mention, that visual control over the inventory levels is enabled when storage location is nearby the consuming operations. They mean to say that with the help of visual control costs such as information systems can be eliminated. However, reduction of storage quantities, inventory costs and space requirements by the assembly line can be enabled by centralised storage according to Battini et al. (2009).

The distance between the assembly and the kit preparation area is also an aspect that can affect the quality of the kit preparation, since it affects whether the assemblers have the possibility to prepare kits. Brynzér and Johansson (1995) and Baudin (2004) mean to say that if the pickers are acquainted with the assembly operations, then the picking accuracy is probably going to be higher.

Continuous improvements are of great importance and often highlighted when describing lean production (Liker, 2004). Having assemblers perform kit preparation allows for improved feedback regarding continuous improvements since the assemblers have a better understanding of both work tasks, leading to reduced risk of sub optimisation.

Tompkins et al. (2010) mean to say that the picking operations location can affect the way a picking area is arranged and mention the amount of available space as an example. Furthermore, it is mentioned that restrictions regarding the amount of freedom to design the kit preparation area can arise when kit preparation is done in locations that are used for other purposes as well. An example described is if the preparation is done in a main storage facility or at an assembly line, meaning both centralised and decentralised locations.

When discussing order picking, Jane (2000) mentions that achieving and maintaining high level of the pickers' utilisation in situations of variety in production volumes is associated to the efficiency of kit preparation. Jane and Laih (2005) mean that if pickers are working in connected picking zones, one has the flexibility to move tasks between pickers and thus enable better handling of changes in order volumes.

High level of utilisation of the pickers can be difficult to achieve when having decentralised kit preparation areas, because of the long distance between the kit preparation areas. However, high utilisation can be achieved but it would require long traveling distances. When investigating parts presentation in component racks at assembly stations, Wänström and Medbo (2009) found that flexibility to handle changes in production volumes, new product introductions, product modifications, and changes in product mix increased when the available space for presenting parts increased. This could mean that the flexibility of a kit preparation area is also related to the amount of free space available since the component racks used to pick from and prepare kits are like the ones used in assembly stations.

There have not been many studies regarding the effects of kitting on ergonomics. However, Limére et al. (2012) state that ergonomics is benefited by kitting. This is confirmed by Finnsgård et al (2011) who to say that ergonomics is benefited since material can be placed in smaller containers when having kitting and thus reduce space in the material facade, which is a direct effect of kitting, according to Bozer and McGinnis (1992), Medbo (2003) and Caputo and Pelagagge (2011). This means that both the assembler and the kit picker benefit, in regards to ergonomics, from having kitting.

On the other hand, Sellers and Nof (1986) and Bozer and McGinnis (1992) mean to say that ergonomic risks can be connected to kitting since it is required to have extra handling, from other personnel, to prepare kits. Finally, Matt et al. (2011) say that the risk is higher the greater the size and weight of parts is.

3.5.1 Kit location performance areas

Due to the literature mentioned above the report focused on the following areas; amount of transportation, inventory levels and space requirements, potential for visual control, flexibility, efficiency of kit preparation, quality in the kit preparation and ability of continuous improvement. These performance areas have been investigated in a research made by Hanson et al. (2011) and they mean to say that the location of kit preparation affects the different factors. Since these performance areas have not been studied in a large scale, it was of interest to see whether the outcome would become similar in this report. The main reason of choosing them was, however, the fact that they covered different aspects in regards to kitting location. Besides them, other performance areas that have not been studied widely within this subject were the ergonomics and ownership that might be affected depending on the choice of kitting location. The performance areas are all connected to the location and are shortly described below:

- *Amount of transportation*: It includes every transportation that is connected to and from the kitting processes. The kitting location has a great significance, as it directly affects the amount of transportations and their lengths.
- *Inventory levels and space requirements*: It refers to the levels as well as the kits in process. Along with this it also includes the space requirements that are directly connected to the inventory levels. Even in this performance area, it regards every inventory that is connected in some way or another with the kitting processes and their location.
- *Potential for visual control*: How easy it is for the concerned kit pickers to detect an error on the material before it arrives to the assembly line. It can also be affected by whether the kit picker has any experience of assembling as well as the distance between the pickers and the assemblers.
- *Flexibility*: This performance area refers to how flexible a company is towards being able to change their kitting process, or readjust any part/system of the kitting depending on where kit preparation is located.
- *Efficiency of kit preparation*: The level of freedom to design or redesign the kitting processes. This can vary depending on the amount of space for the kitting area which in its turn can vary depending on the area's location.
- *Quality in the kit preparation*: This performance area refers to how the quality is being affected depending on where the kitting processes are in relation to the assembly line, and the extent.
- *Ability of continuous improvement*: This performance area seeks to investigate how much a company is striving for continuous improvement. This applies to all levels within the company. How able a company is to strive towards continuous improvement, or is the kitting process seen as locked in some way which complicates eventual changes? The distance between the assembly and the kitting processes is affecting the communication and could therefore affect the ability for the operators to contribute with feedback.
- *Ergonomics*: This area seeks to find out how much the current state of the kitting processes that a company has is affecting the ergonomics of the employees and if this is affected by the location.
- *Ownership*: This factor is about the ownership of the parts used to prepare kits and the ownership of the kits. It seeks to find out if there is a difference of ownership regarding parts/kits depending on where the kit preparation is done.

4. Current state description

The following section will describe the findings from the two case studies that were carried out. The cases had different setups regarding kit preparation location and will be investigated concerning some performance areas.

4.1 Case 1

Case 1 was from an engine assembly plant for mainly trucks but also construction equipment. The company had approximately 3000 employees and was based in Sweden. The preparation of kits was performed in connection to the assembly line and operators were working both with assembly and with kit preparation, as can be seen in Figure 4. The operators varied between the different work tasks daily.

The company was working with Pick By Light (PBL) meaning that every part in the kit area had a light button assigned to it. The operators started the picking process by pressing a (green) start button which led to all buttons needed to be picked lighting up. The operators then picked the different parts from various containers and pressed each containers light to turn it off when the part had been picked. Some containers had a display showing how many needed to be picked (if more than one was needed). Once all parts had been picked and all lights had been turned off a (red) finish button turned on. The operators pressed this and they either delivered the kit to the assembly line or continued picking for more stations and then delivered. The operators usually picked parts and prepared kits for more than one station (i.e. traveling kits). When the finish button for the specific product was pressed the start button lit up again for the operator to continue with the next product in line.

There were different kit carts at the various stations and some carts were standardised for the specific station, although most carts were not. Standardised kit carts meant that they were designed to carry parts used for that station, and that each part had a determined place in the cart. All carts had wheels and could easily be moved around. The kits usually contained 20 to 60 parts and there were two different kinds of kits; stationary and traveling. The traveling kits were “hooked” on the product being manufactured and travelled along the various stations. The stationary kits were placed on a specific place, marked with a square on the floor, next to the assembly line, where the operator fetched them. Each station usually had one or two prepared kits in buffer.

When a material container was empty, it was put on a “refill rack”, and a forklift driver that drove around the factory was responsible of checking the refill racks and scanning empty containers. When the container was scanned, a signal was sent to the warehouse area where they send a new one. The employee driving “the train” (i.e. a tugger carrying parts) was then responsible of delivering material containers to the different stations. The kitting stations also contained pallets with parts. These were refilled by forklift drivers when the kit pickers scanned empty ones. All roads in the factory were one way and some were just for forklifts while others were just for the train.

The company had an area in the plant that was called “the sequence” which was sequencing parts to the assembly line. This station contained parts that were low runners, as well as larger part sizes that took too much space at kitting areas located next to the assembly line. The sequence was, therefore, located further away from the assembly line. The operator working in the sequence could sometimes go to help other operators with kit preparation.

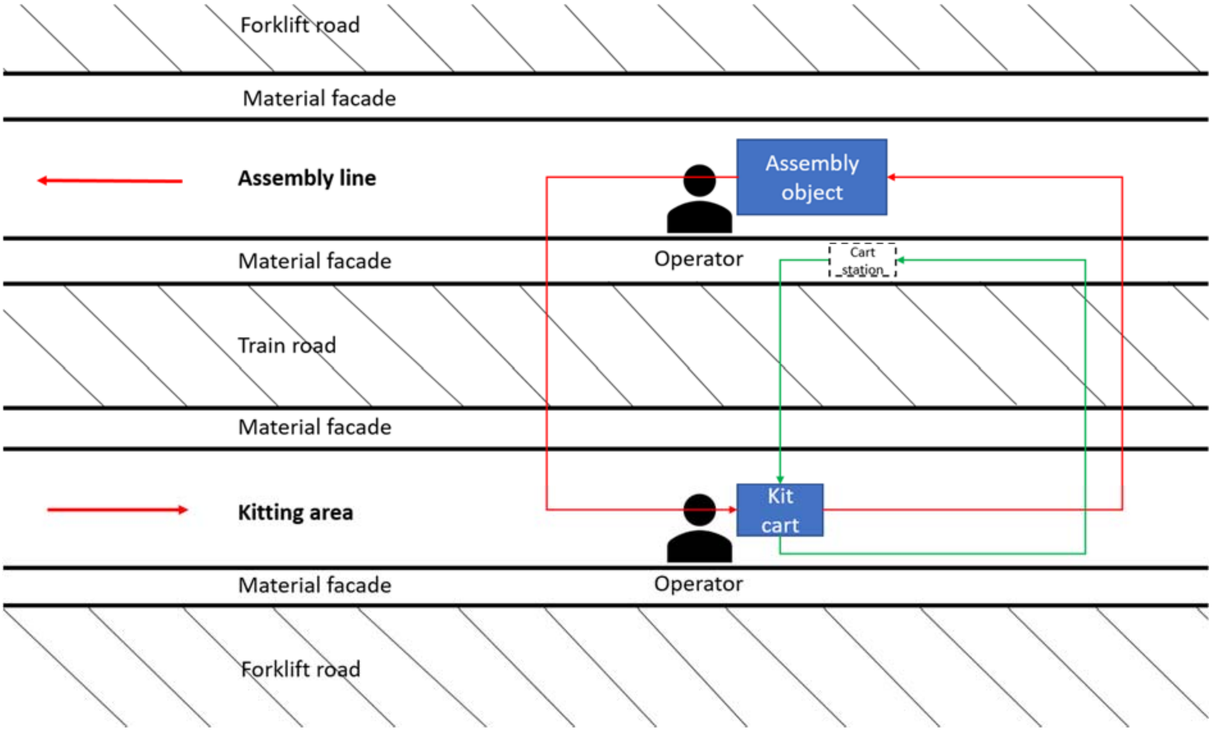

Figure 4: *Layout of the assembly and kitting location in case 1*

4.1.1 Amount of transportation in case 1

The transportation to and from the kitting area was mostly based on a two-bin system. However, the order was made either by the kit picker when the containers had reached a certain level, or by the material handlers when the material containers were on the refill rack. In either way, this triggered an order upwards to the high bay warehouse. The delivery time was varied, depending on the material and its consumption, but also the time it took for the kit picker to react until scanning had been done. There were different reasons why the kit pickers were scanning instead of the material handlers. Some of them were whether it was new material or not, the size, how much load capacity a certain container could manage, whether it was a euro pallet (due to the difficulty for the kit pickers to move them without equipment etc.), and how frequent a material was consumed.

With the current replenishment system, the deliveries were varied. They did, however, take between 30-40 minutes most of the times for both pallets and containers. The current routes for the material handlers divided the routes to strictly be trafficked by certain types of transporting. There were for instance roads that were specifically for forklifts, and others for the trains, as can be seen in Figure 4. The difference of these two was mostly that the trains were transporting smaller containers, while the forklifts could transport one euro pallet at the most. Nevertheless, it should be mentioned that there was a certain train that could carry three euro pallets as well.

It rarely occurred that parts were missing from the racks but one reason that could lead to this was that the kit picker forgot and ordered material late which lead to waiting times. Another reason was that the kit picker threw away the cardboard container without scanning it. This happened very seldom but if it did then the two-bin system for that station did not work. The kit picker could get the material from other stations but this did not solve the problem and would furthermore cause problems with the material delivery since each container was synched to a station.

4.1.2 Inventory levels and space requirements in case 1

The kitting areas were being refilled with material by the train-drivers as mentioned earlier and the company had approximately 5500 to 6000 different parts in inventories and there were approximately 100 to 200 different article numbers per kit station. There were no finished kits in inventories as kits were being picked when needed. Furthermore, there was only one kit per engine meaning that there were no "back-up" kits for the engines if something were to happen. The in-plant material handling did not affect the company's inventory levels since these were based on other aspects, such as frequency of use, delivery time etc.
However, when asked if the inventory levels would have been affected if the kit preparation was done in another location the answer was yes since the kit preparation would have had to be done much earlier. This would mean that the inventories would be higher due to the longer distance between the kitting area and assembly line.

4.1.3 Potential for visual control in case 1

The operators working with kitting could easily communicate with the operators in the assembly line since the kit preparation was done in connection to the assembly line. The kit pickers could see the line and if one part were to be missing/lacking in quality, the line operators could easily call for a new part. Furthermore, seeing the line enabled for the kit pickers to control the pace of the kitting processes, as preparation of kits could be initiated on demand.

4.1.4 Flexibility in case 1

The kit cart was designed with the help of operators and changes could be done to improve the design. Furthermore, the operators could help with design and changes of the materials facade to enable better picking. A typical change in the materials facade was to switch the containers place considering ergonomics and frequency of the containers usage which was done with the help of the kit technicians. The kitting operators did not have to consider changed orders since the structure was fixed once it entered the system, meaning that once a product started being manufactured no changes could be done, from the customer, to the order. The company's kit technicians were responsible for changes regarding rebalancing which was considered easy to change if needed.

Changes in the kitting process could be done but with some limitations. The material facade in the kiting area was fixed and thus difficult to move but the containers on the facade could easily change place to enable improved picking. Changes regarding relocation of kitting processes, meaning where a part would be kitted, could be done without difficulties since kitting was connected to the assembly and changes in the assembly were easily done. However, the company had lack of space since the kitting areas were fixed. This meant that problems could arise if parts were to be added to the kitting area and the company must then consider packaging, placement of materials etc. Rebalancing could also be done easily since the kit preparation areas were linked to each other.

4.1.5 Efficiency of kit preparation in case 1

In the factory, there was some level of freedom to design the area for the kit preparation. The company had a team that worked specifically with designing the area, when a change was needed. Since the kitting area was next to the assembly line it was considered easy to make changes in the kitting process. However, there were some aspects that were essential to consider during changes. One was that the kitting area was fixed parallel to the assembly line and even if it was possible to move around the material facade, it was quite difficult and created some form of hindrances to do major changes due to its size and the lack of space. There were also other aspects that needed to be considered within this, such as the "golden zone" (i.e. an optimal ergonomic zone) described by Saccomano (1996).

Furthermore, since the company had a limited and fixed area there were problems regarding lack of space. Some changes were difficult to make because of this and the company tried to move seldom used parts out from the kitting areas to the sequence area.

Since the company had their kitting processes parallel to their assembly lines, changes became visible for all concerned working roles that were in direct contact to the processes. Also, since the assemblers and kit pickers shifted roles on daily basis they also became aware of eventual changes.

4.1.6 Quality in the kit preparation in case 1

The plant had focused a lot on preventive work so that right items were being picked etc. by for instance having PBL. Normally it did not occur that wrong parts were being picked in the kitting processes, due to the PBL system. It worked as a solution to avoid wrong parts from being picked. However, if there was a situation where it occurred, one probable reason may have been because wrong parts were placed at the wrong chute and vice versa. Another probable reason may have been if wrong material were being picked from wrong containers, even though the PBL indicated which container to pick from. If that happened, it was very likely that the assemblers reacted by telling the kit pickers across the road to bring the correct part instead. Thus, the kit picker realised and could reflect upon why the wrong part was picked etc. The company did not measure the amount of wrong parts picked since the communication was strong between the kit preparation area and the assembly line due to the short distance between these.

Further, there were some parts that required a barcode to be scanned before they were picked. This facilitated for the kit pickers since it indicated if a wrong item had been picked. Hence, assembly errors could be avoided in greater occurrence, which thus led to less number of reclamations/returns.

Furthermore, it sometimes occurred that parts were damaged. A probable cause could develop as a result from avoiding the use of lifting tools which could then result in parts that fall off and being damaged, as an example. Another was that the material handlers damaged the parts during transportation. However, it was not very common and if it occurred, the kit pickers reacted most of the time. Nevertheless, if it turned out that the kit pickers missed it anyway, the chance of noticing the damages became higher when it was time for the assemblers to mount the damaged parts, either by inspection or failure during assembly. As mentioned before, since the kit pickers were close to the assembly line, the feedback back and forth could be received quite fast as well as response was being shared. The company did not measure the amount of wrong parts picked due to the small distance between assemblers and kit pickers. Remarkably, the operators were rotating on daily basis, which implied more gained knowledge regarding both the assembly and the kit preparation working stations and how the parts should properly look like and vice versa.

4.1.7 Ability of continuous improvement in case 1

The company worked with continuous improvements and tried to get the opinion of the operators by having meetings where anyone who wanted could join and give ideas on how to improve the kitting process etc. Common improvements were regarding the materials being used and their placement. Furthermore, if material should be moved to “the sequence” since there was lack of space in the kitting areas. A potential action that the factory intended to take was to implement a PBL system in the sequence area as well as other kitting areas.

4.1.8 Ergonomics in case 1

The company had some heavy parts thus assembly stations and kitting areas had lifting aid equipment to help with heavy lifts. However, these were rarely used because the equipment was considered, by the operators, to be more suited for the kitting areas rather than the assembly. It was mentioned that the equipment helped with lifting the parts onto the kit cart but was not helpful when lifting the parts from the kit cart and onto the product being assembled. Even though the aid equipment were considered more suited for the kitting areas, they were still not being used since it was considered time consuming. This meant that the operator did so manually and some considered this an opportunity to work out while others thought it was not ergonomic. Lifting these kinds of parts manually was not supposed to be done by the operators and by doing this the operators deviated from the method which was developed for an ergonomic way of working. The operators kitting had to walk a lot but this was not considered bad. Some operators had complained about the height of the material racks meaning that some parts were low down while other high up causing the operators to stretch to pick them.

4.1.9 Ownership in case 1

The parts used to prepare kits and the kits were owned by the company.

4.2 Case 2

Case 2 was also from the automotive industry and was a company that manufactured truck cabs. The company had 3000 employees in total and 300 of them were working in the logistics centre. The preparation of kits was done in the logistics centre (seen in Figure 5), which is a main storage facility approximately three kilometres outside the assembly plant (seen in Figure 6), and it was done by specialised personnel.

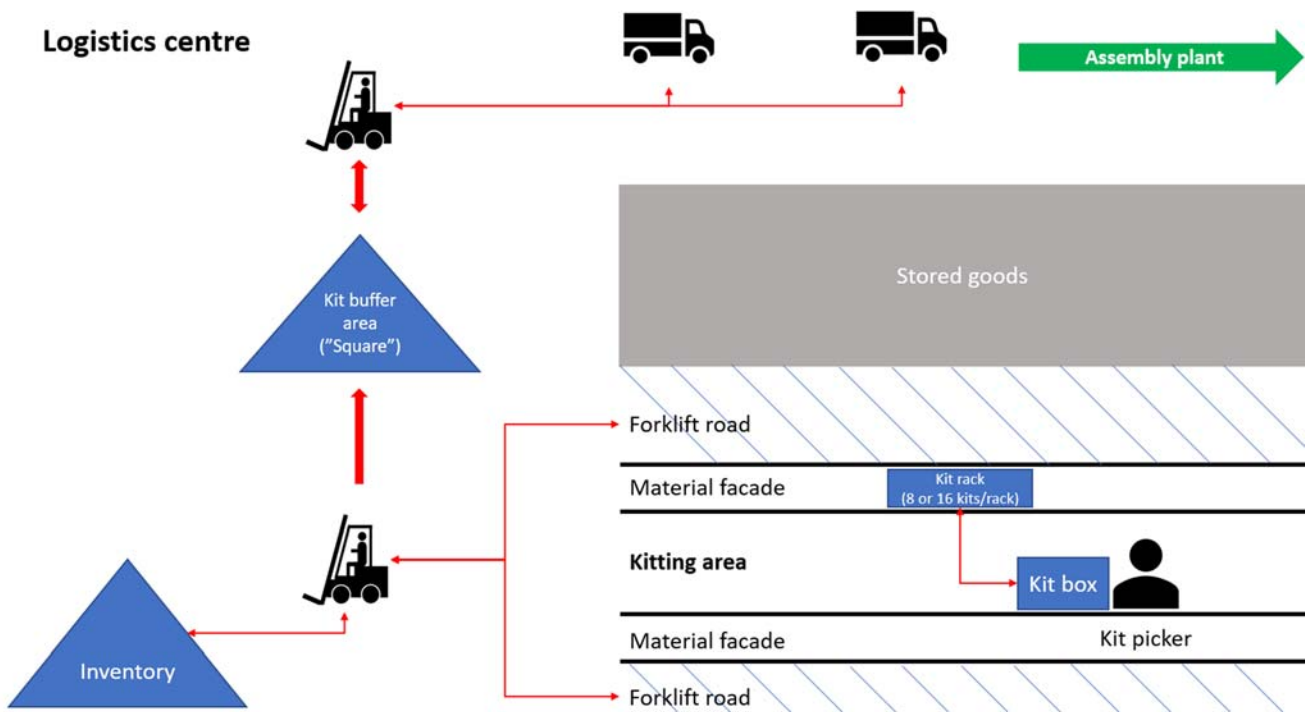

Figure 5: *Layout of the logistics centre in case 2*

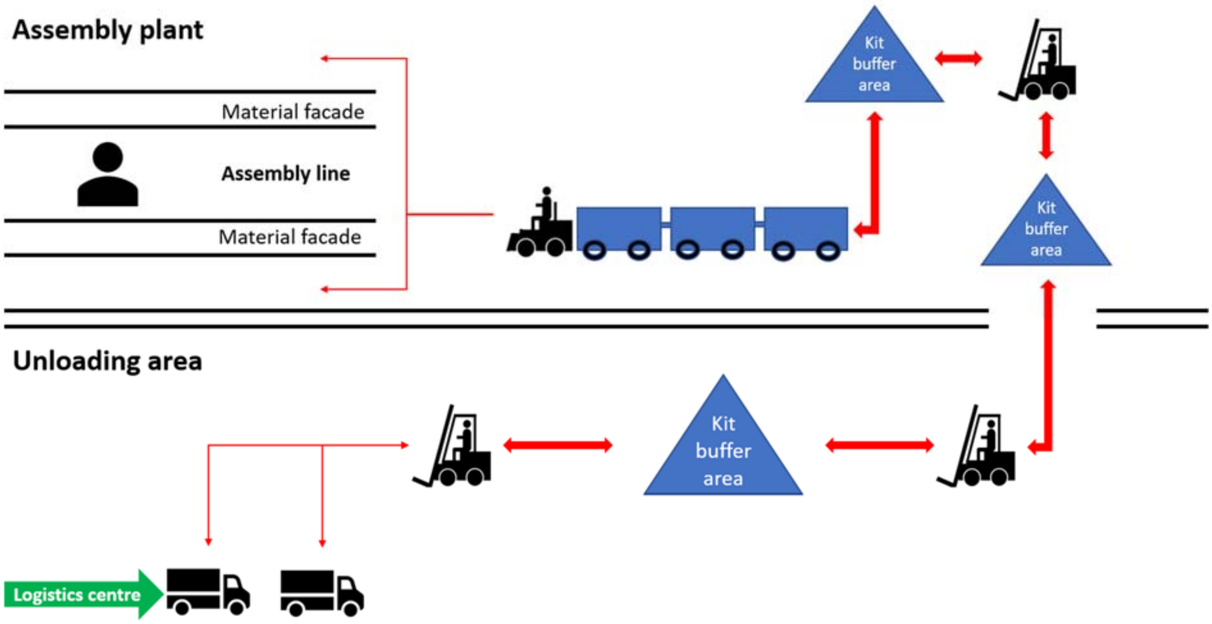

Figure 6: *Layout of the assembly plant in case 2*

As in case 1 the kitting areas were equipped with a similar PBL system to help the kit pickers. The PBL had sensors that detected motion and when kit pickers took a part from a container the light of that container was turned off. Moreover, some stations had a Pick To Voice (PTV) system which was also a way of increasing the picking accuracy compared to PBL. The way PTV worked was that the kit picker put a headset on and said a keyword to the microphone on the headset. The system then told the picker what part to pick and from where. When a part had been picked, the picker replied another keyword that was written on a label hanging over the part for the system to know that the right part had been picked. The picker then got new instructions on what part needed to be picked next.

Every time a cab passed a trigger point in the assembly line a label was printed in the various kitting stations in the logistics centre simultaneously. Each label represented a cab and these were also used as picking information for the kit pickers. The kit pickers picked for eight cabs at a time meaning that they waited until there were eight labels. They then scanned the first out of the eight and then the pick by light system showed what parts needed to be picked. When the picker had picked all parts for the first cab the system automatically moved on to the next. There was a change in the colour of the lights on the material racks for the picker to know that the system had moved on to the next kit. Besides a barcode the labels contained the article numbers that needed to be picked in case of there being a problem with the PBL.

The kits were standardised meaning that they had a specific place for each part and they usually contained three to four parts. In addition to material racks, case 2 had kit racks in the stations, which were racks that contained full or empty kits. The kit racks usually contained 8 or 16 kits. As mentioned earlier the operators picked for eight kits at a time and each kit had a number (from one to eight) on it. When picked, the kits were placed in a specific order, using the numbers, in the rack to be in the correct order when they were to be used in the assembly. Moreover, the company did not have any traveling kits.

Kit pickers also drove forklifts for variation but they only drove the forklifts that were responsible for transportation of kit racks. This meant that the kit pickers only had experience of driving kit racks to and from the kitting stations and no experience of refilling the stations with needed material.

The material emergency department (MED) was a part of the company that was responsible for mainly one area, which was; provide the assembly with material in case of emergency, meaning if a part was defect or missing. Employees of the MED were in both plants and communicated with each other in case of emergency. If a part (in a kit) was to be missing or be defect in the assembly line the assembler would contact the team leader who would then contact the MED in the assembly plant. The person working for MED in the assembly plant would then contact a person from the logistics centres' MED who would send someone to pick the part missing and drive it to the assembly as soon as possible in a, so called, "ambulance". Furthermore, the MED was working together with the team leaders and production leader to prevent such emergencies.

The company was manufacturing two versions of the cab model, meaning that they had introduced a new model but were still manufacturing both. This caused some problems regarding the space but was believed to be solved in approximately a year as the company would then only manufacture one of the models.

4.2.1 Amount of transportation in case 2

The transportation of racks to and from the kitting area was handled mostly by forklifts, however the transportation from the logistics centre to the assembly plant was handled by trucks. Furthermore, the logistics centre had recently added a, so called, train that provided material to the kitting stations by restocking the material racks. The train had a specific pick list that was created when empty material containers, in the various stations, were scanned by the train driver. This was done when the train driver was refilling the stations with material from the previous pick list. The train was following specific stops when refilling the stations.

In the logistics centre, frequently used material was being refilled four to five times per hour. The company also had material that was exposed in pallets instead of material racks. This material was being refilled, one pallet at a time, by forklifts and operators working in the stations had to place an order of new material. This was done by scanning a barcode when there were two parts left in the pallet. A forklift driver then got a notification, on a screen attached to the forklift, and refilled the station with the required material. It usually took 20 minutes for material handlers to arrive, thus stations had more than one pallet of each article number available to avoid waiting times. The kit pickers had to also scan the kit rack when it was full for the forklift to move it and bring an empty one.

When a kit had been picked, it was put in a kit rack which usually had place for eight kits. The kit rack, when full, was transported by a forklift to a square in the logistics centre and then loaded by another forklift onto a truck, as can be seen on Figure 5. There were four trucks (through an external haulier hired for one task) that transported material to and from the assembly plant and every eleven minutes a truck left the logistics centre to keep up with the assembly plants takt time. When a truck reached the assembly plant full racks were unloaded by forklifts and empty racks were loaded on it. The full racks were transported first to a square and then to a platform where the kits were unloaded from the rack onto a train to then reach the assembly line. Empty racks took the opposite way back to the logistics centre (i.e. platform→ square in assembly plant→ truck→ square in logistics centre→ kit station).

4.2.2 Inventory levels and space requirements in case 2

There were about 111 article numbers in inventory, aimed for kitting, in the logistics centre. However, there were approximately 140 articles that were being transported to the kitting areas, since some parts came from other areas, such as the assembly plant. The kit stations studied had approximately 30 to 60 different article numbers per station. The company did not think that the inventory levels would have differed if the kit preparation was done closer to the assembly, since material was ordered after demand etc.

However, due to the distance between the logistics centre and the assembly plant the company was forced to have two racks, each containing eight kits in process, placed in the assembly line, and two other racks placed in the “platform logistic” area, and finally one in the assembly square (as seen in Figure 6). Meaning five racks of eight kits each in the flow. These were used as protection against unforeseen events, and to be able to keep up with the takt time.

4.2.3 Potential for visual control in case 2

The operators working with kits did not have the ability to communicate with operators in the assembly line since they were located in a different plant. Furthermore, the kit operators had no experience of the assembly line. Communication between the two was handled by the team leaders through the MED, meaning that they communicated mostly in cases of emergency but also about improvements and changes.

4.2.4 Flexibility in case 2

The kit technicians were the ones that were responsible for the design and changes that were made regarding the kitting processes. It could be work related to changed orders, rebalancing, and changing the pace etc. Requests from the assembly regarding the design of the kit containers were usually shared in meetings, and eventually investigated by team leaders and kit technicians for further potential development. Ultimately, the changes were depended on various factors that needed to be considered before implementing them, such as updating the warehouse system etc. Changes could sometimes be made quite easily while other times more difficult depending on what was to change. The company had for instance no problems at all with changing the articles, and moving around containers within a material rack. However, the company was facing more difficulties of being able to move the containers to other racks, since it required more work (e.g. update warehouse workers, ensure that the engineering department had addressed new locations etc.).

4.2.5 Efficiency of kit preparation in case 2

The level of freedom to design the kitting area was limited since the area used for kit preparation was fixed. However, the kitting stations were constantly changed to enable better picking and a usual change was to move containers within the material racks. Changes were lead with the help of the operators working in the stations where meetings were held to get feedback. The company was facing problems with space requirement since they were kitting and had material for both their new and old model. However, new article numbers were still being added to the logistics centre. Changes could also be done in the kits if it favoured both the operators kitting and assembling.

4.2.6 Quality in the kit preparation in case 2

It was common that wrong parts were being picked in the kitting processes. The amount of wrong parts picked was measured and it was approximately 13.5 wrong parts picked per month. There were various causes behind this, such as operating errors, wrong material was either picked or placed at the wrong place, and by kit pickers that were being confused as some article numbers were almost identical. It occurred often that parts were damaged, meaning they had scratches etc., but this got noticed in different places at the company, such as in the logistics centre in conjunction with the kitting processes. Most of time deviation, meaning damage or lack of quality, was detected by the kit pickers, however detection was also sometimes made in the assembly plant. The reasons differ, but it oftentimes led to quality issues caused in an earlier stage (i.e. from the supplier). In either way, the quality department took on the case, which also was responsible for the communication between the company and the suppliers concerning quality related issues. When damaged parts had been detected, they needed to be replaced as quickly as possible. As mentioned before, the MED took on these cases normally. Yet, there could be common situations that the company was aware of in the assembly plant (e.g. a certain part that was frequently lacking of quality), and had therefore prepared/protected the work flow through extra material available in the assembly plant. In those cases, the MED was not needed. Otherwise, they were contacting the same department that was located and responsible for the logistics centre, which in turn contacted responsible workers such as team leaders or production management so that the feedback could be shared. Thus, the ones concerned in the kitting processes could obtain the feedback and improve the daily work from a quality perspective. Meanwhile, the MED were focusing on transporting the new part that will replace the damaged one. Moreover, if it turned out that the root cause was outside the plant, the MED dropped the case so that the quality department could take over from there by contacting the supplier responsible.

Due to a recent period of employment, the logistics centre had recruited people that lacked experience in assembling kits. In this way, the kit pickers' lack of knowledge could for instance lead to not noticing defective parts in the material racks etc. Even though the defect parts had been detected in a later stage in the assembly plant, the possibility of extra control was something the company was missing out on.

According to the logistics centre, it did not occur very often that the material racks lacked parts. However, if it occurred the common cause was due to operating errors, meaning that the kit pickers forgot to order new material. When refilling material to the kitting areas, the material handlers usually double checked by scanning twice to ensure that nothing was missing in the racks.

4.2.7 Ability of continuous improvement in case 2

Continuous improvements were considered important and the company had its own production system driving improvements. Furthermore, the company measured its performance based on the amount of deviations and at the start of every shift a meeting was held where the operators discussed if any deviations (e.g. damaged parts) had occurred. Any occurred deviation was noted on a whiteboard to later be discussed in the control board meeting. When a deviation occurred, it was first fixed short term to "stop the bleeding" and if this did not help it was later discussed in the control board meeting to find a long-term solution.

Furthermore, meetings with the operators regarding different kind of improvements were held regularly and feedback from the operators was considered important. Improvements were continuously happening and the company had recently made a change regarding the kitting location where the kit preparation area was moved from one place in the plant to another.

4.2.8 Ergonomics in case 2

According to the kit pickers they did not make any heavy lifts at all in the logistics centre. Therefore, no lifting aid equipment were necessary since most of the parts were lightweight. Besides a lot of movement back and forth that occurred on some kitting areas, the kit pickers found the work tasks to include some repetitive movements. Concerning the material handlers working conditions, the ergonomic aspect was something that they had been given the opportunity to design. In that way, they could for instance adjust the location for some racks to strive towards more ergonomic working conditions.

4.2.9 Ownership in case 2

The parts used to prepare kits and the kits were owned by the company.

5. Analysis

The following section will analyse the selected performance areas by comparing the findings from the cases to the theoretical framework.

5.1 Amount of transportation

Both cases had some form of bin-system in their kitting processes, with two or more bins. Hence, their kitting processes were secured for a while until the material handlers delivered the new material. There was no significant difference between the cases regarding the kit pickers traveling distance. However, the number of problems that were in connection to the kitting processes being placed outside the plant became high as it demanded mainly a more complicated logistics planning. The amount of middlemen differed a lot between the two cases, which had, inter alia, a significant impact on the amount of transportation. In case 2 it was required to have more middlemen such as forklifts, trains, and trucks. This meant more inventory in between each middleman, as seen in Figure 5 and Figure 6. This meant automatically more loading and unloading processes for case 2. Besides the ones mentioned, they also had the emergency department that had to be responsible for emergency transportations when needed, since the kitting processes were in the logistics centre. Unlike case 2, case 1 could avoid these extra stops, as their company delivered directly to the kitting areas located along the assembly line (see Figure 4). Moreover, the findings in both cases agrees upon the theoretical framework, i.e. that the amount of transportation and or traveling distances becomes less by having the kitting processes nearby the assembly operations. Since the theoretical framework also mentions “Waste of transporting” as one of the crucial areas within the Lean concepts definition of waste, case 2 should consider reviewing their situation, as case 1 has fewer transports.

5.2 Inventory levels and space requirements

As mentioned in the theory sections the overall inventory levels are marginally affected by the kit preparation location. This seemed to be true even for these cases. In both cases the inventory levels were based on aspects such as; demand, frequency of use etc. and not on the location of kit preparation. The location could have an impact on the levels but this was not considered significant. The main difference between the cases was that case 2 needed to have larger buffers before and at the assembly line in to be able to keep up with the takt time (as seen in Figure 5 and Figure 6). Furthermore, none of cases had any finished kits in inventory since they produced on demand. As mentioned in the theoretical framework by not having unnecessary inventory the company reduces the tied-up capital and can chose to invest in something else if wanted.

Another difference noticed was that in case 1 operators prepared one kit at a time and sent it to the assembly while in case 2 operators usually prepared 8 or 16 kits which were sent in batches to the assembly. This meant that case 2 had more kits in process which led to more inventories.

5.3 Potential for visual control

Case 1 differed a lot compared to case 2 in terms of potential for visual control. The main reason was due to the fact case 1 had the kitting processes parallel to the assembly line. This enabled for the operators to communicate in an easier way across the train road (see Figure 4) regarding issues connected to quality, missing parts in the kits etc. The theoretical framework agrees upon this, as it confirms that communication and potential for visual control is enhanced when having the kitting processes closer to the assembly area.

Moreover, in case 1 the kit pickers could see when there was a demand for a kit in the assembly and could then start preparing one. However, in case 2 there was no visual control of the assembly meaning that the operators were more depended on the trigger system in the stations.

5.4 Flexibility

According to the theory, the location of the picking operations has an impact on how the picking area is arranged. The theoretical framework also claims that when kit preparation is done in a location that serves other purposes as well then the freedom to design the area can be restricted.

Both cases had the kit preparation done in locations that served other purposes. As mentioned earlier, kit preparation in case 1 was located beside the assembly while in case 2 it was located outside the plant in a main storage facility. Even though the kit preparation was done in different locations the picking area of both cases was very similar. Both cases could easily make changes regarding the location of containers within the material facade, but both considered it to be more difficult to move containers from one material facade to another. Furthermore, rebalancing and relocation of kitting processes was considered easier in case 1 since the kit preparation areas were close to the assembly and linked to each other. Finally, a restriction for the cases was the lack of space since both cases had a fixed place, in respective location, available for kit preparation. This has an impact on the flexibility in terms of variations in production volumes and product mix, as mentioned in the theory.

5.5 Efficiency of kit preparation

The location of the kit preparation did not directly affect the efficiency of the kit preparation, as the efficiency is depended on other aspects. However, an aspect that was found to have a certain impact on the efficiency was the amount of freedom to design the kitting area. Both cases had a limited area available for kit preparation which affected the level of freedom to design the area.

As mentioned in the theoretical framework, there can be some form of balancing problem by having the kitting processes decentralised. This issue could easier be managed in a kitting process that is centralised. In the sequencing area in case 1, this was identified as one operator went to another kitting station to help other operators with the kit preparations. Thus, it could be confirmed that some form of utilisation issues existed in case 1, while case 2 has better conditions to deal with balancing. Based on the condition, partly confirmed in case 1, it has of course a negative impact on the efficiency of the kit preparation. However, as mentioned in Hanson et al. (2011), they identified that lack of utilisation for a decentralised kitting process that is located nearby an assembly area could be beneficial. It could become more efficient during circumstances where changes in production volumes changes. Hence, the available operators can more easily move some tasks temporary to the kitting processes, as subassemblies instead.

5.6 Quality in the kit preparation

Both cases had PBL to facilitate the kit pickers and obtain high quality in the kit preparation. The quality of the kit preparation is depended on a lot of different factors besides the location and is thus difficult to compare between the cases. However, the main difference noticed was, as mentioned in the theory, the response time to quality deficiencies and replacement of faulty parts. Case 1 had kit preparation next to the assembly, thus if a part was defective the assembler could just call for the kit picker to bring a new one and fix the problem immediately.

However, in case 2 where the kit preparation was done in a separate plant, the company was required to have a buffer of frequently defective parts in the assembly plant and moreover have the MED that was responsible for providing parts from the logistics centre. This meant that case 2 needed to have extra personnel to be able to handle “quality errors”.

Another difference noticed was that case 1, unlike case 2, did not measure the amount of wrong parts picked since the kit preparation was located in connection with the assembly. This could possibly have a negative effect on the quality since data is needed to know what to improve.

Furthermore, in case 1 the operators preparing kits were also working in the assembly. This was not done in case 2 and according to the theoretical framework, if operators are working with and have experience of both kitting and assembling it helps improve the quality in the kit preparation.

5.7 Ability of continuous improvement

Both cases seemed to be able to promote continuous improvement and thinking among their employees which is of great importance according to the Lean philosophy. The ability, however, to measure it became difficult. It was mentioned in both cases that the workers could and have been involved in many recent changes so far. This indicated that it did not seem to be any problem at all regarding the ability of continuous improvement in conjunction with the kitting location. Nevertheless, the theoretical framework points to the fact that depended on whether a company has the same operators responsible for both the kitting processes as well as the assembly operations, it becomes easier to introduce continuous improvements regarding both the kitting process and the kits design. Case 1 had a rotating work system between assemblers and kit pickers, thus feedback regarding the assembly line but especially the kitting area could be adapted to what was perceived as effectiveness, and ergonomics etc. (for instance in terms of placement of material).

5.8 Ergonomics

Both cases emphasised the ergonomics in the kit preparation stations, and feedback from the employees was taken into consideration. The theoretical framework mentions that ergonomics can be affected by the type of material feeding principle, meaning that kitting can be more ergonomic than continuous supply. However, the authors of this study believe that ergonomics is not influenced by the location of the kit preparation since the kitting stations were very similar in both cases.

A difference noticed, was that case 1 had lifting aid equipment which case 2 did not have but this was considered, by the authors, to not be related to the location of the kit preparation but rather the size and weight of the parts being kitted.

5.9 Ownership

Both cases owned the kits and the parts used to prepare them. However, this can vary regarding who is responsible for preparing kits (e.g. if a 3PL does it).

6. Discussion

This chapter discusses the main performance areas affected by the choice of location. As has been studied and analysed, it has shown that most of the performance areas can be affected based on the choice of having the kitting location centralised or decentralised. The two case studies that have been done should however be examples, since their kitting processes are only a part of a larger system.

The performance areas, that have been studied, showed similar effects to previous studies mentioned in the theoretical framework. These performance areas have, however, showed different levels of severities in both cases. The performance areas that have been considered as more crucial, meaning having significant difference between the two cases, are the amount of transportation, quality in the kit preparation, and the potential for visual control. The amount of transportation turned out to have a huge difference between the two case studies with different locations. In a centralised kitting location, vastly many middlemen are required to transport the kits or other inventories within the logistics centre, as well as transportation of the kits from the logistics centre to the assembly plant. From an economic perspective, the transportations become more expensive the more transports a company has. These costs can potentially be reduced by outsourcing the kitting processes to a 3PL, as mentioned in the theoretical framework. However, it needs to be put against an economic study that compares the costs and profits of both cases. The focus of this economical comparison should then, of course, cover a larger part of the chain to find a more truthful and realistic result, rather than only focusing on the kitting processes since a chain is no stronger than its weakest link (i.e. small processes in a value chain). Another aspect that is linked to the centralised kitting processes outside the assembly plant, is that the transportations companies may have an environmental impact that needs to be considered. These can be avoided by having a decentralised kitting location nearby the assembly line instead. Thus, having less transportations becomes an advantage for the environmental aspects as well as reducing transportation costs. However, again, account should be taken on the overall view.

In terms of quality in the kit preparation, it could have a great impact on the quality of the end-product. It should be mentioned that quality in the kit and quality in the end-product are not the same. However, wrongly picked kits can lead to disruptions in the production which can sometimes lead to problems in the quality of the end-product. This means that there is a connection between the two. Picking wrong parts for the kit can occur if there is a long distance between the assembly and the kit preparation area. This is because there is a longer lead time which can lead to operators borrowing parts from other kits to cover for missing or lacking parts. Yet, again, this speaks in favour for a decentralised kitting location. The long distance between the kitting location and the assembly plant in the decentralised kitting location was also affecting the communication badly.

Moreover, in a centralised location, since the kit pickers lacked of experience in regards to assembling, the chances for them to identify defect parts in the kitting phase became less, as well as picking correct items. These hindrances that the distance brings could, of course, become less of a problem with today's technology (i.e. in particular communication opportunities). Technologies can help with showing the operator where and what to pick but it cannot replace the knowledge of being able to make a judgement of whether a part is lacking in quality or not. Another additional approach for the setup in the centralised kitting location, could be to create a cross-functional team which target is to strengthen the communication between the assembly plant and the external location so that misunderstandings can be avoided, thus improve quality in the extension. Although case 2 had some form of cross-functional team (i.e. the MED), it certainly did not gather representatives from every concerned department.

Regarding the potential for visual control, it goes partly hand in hand with the quality in the kit preparation since the visual control enhances the closer it is between the kitting processes and the assembly operations.

Table 2 below, shows a summary of what has been discussed in this section. In the column to the left the crucial performance areas are presented, while the other columns present the centralised and decentralised option to have a kitting process. The summary that Table 2 is presenting, views the pros and cons of each performance area, in respect of the kitting location. As mentioned earlier, the performance areas presented are the ones with the biggest difference between the two cases, which explains why some have no pros or cons regarding the choice of location.

	Located externally (Centralised)	**Located internally** (decentralised, in connection to the assembly)
Amount of transportation	Pros: • Transportation costs can be reduced by outsourcing Cons: • More middlemen between assembly and kitting location	Pros: • Less transportations • More environmentally friendly Cons:
Quality in kit preparation	Pros: Cons: • Negative impact on the end-product • Impaired communication between kit pickers and assemblers	Pros: • Better at identifying defect parts • Increased knowledge regarding parts Cons:
Potential for visual control	Pros: Cons: • Limited visual control	Pros: • Increased visual control Cons:

Table 2: *Summary of pros and cons regarding the main performance areas affected, connected to centralised and decentralised kitting location*

The effects, found in this study, of having the kit preparation outside the plant were that it freed up space in the assembly plant. However, it required more middlemen between the assembly line and the kitting area, as well as longer transportations between the two. More middlemen can therefore be linked to more costs, as it requires more man hour throughout the processes, and longer lead time from preparation to delivery of kits. Furthermore, it was needed to have buffers to be able to keep up with the pace and secure the production flow. Other effects were that the kits were sent in batches to the assembly and that there was no direct communication between assemblers and kit pickers.

The main reasons found to have kitting outside the plant were; lack of space, and if the company wanted to outsource it to a third part so that the company can focus on their core competence. Another reason for outsourcing was to reduce costs, however these seemed to increase when having preparation at an external location. In the cases studied, the design of the kitting process did not vary a lot. The picking process and areas were similar although differences were found on the kits design.

7. Conclusions

The aim of this thesis was to investigate how the choice of location effects the kit preparation process. This was done in regards to different performance areas and two case studies were conducted. From the results obtained in the case studies it can be concluded that the location of kit preparation influences various performance areas. The main differences were the amount of transportation, quality in the kit preparation and the potential for visual control.

The conclusion that can be drawn from this thesis is that it is more advantageous to have the kitting processes located nearby the assembly. The advantages weigh over the disadvantages, especially regarding the crucial performance areas that have been discussed.

This thesis has contributed to the knowledge regarding the choice of location for kit preparation by investigating an area that had not been studied yet. The thesis has also compared existing theories with cases. The authors conducted only two case studies thus the results might not be enough input to sufficiently motivate the conclusions mentioned.

For future research, it would be interesting to conduct more case studies and investigate a centralised location outside the plant that is solely used for kit preparation. It would also be interesting to see how the ownership is handled in a setup where kit preparation is managed by a 3PL. Finally, the literature is mostly about small and medium sized parts thus it would be interesting to study kitting of larger parts.

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Appendix A – Interview questions

A - Assembler/Kit picker
L - Team leader
M - Material handler
T - Technician/Responsible for the kitting processes

Current state description [T]

What does the company work with?
What is the end-product?
Who is the costumer?
How many employees does the company have?
How many of the employees are working with kitting?
How many operators are kitting per day?
How many kitting areas does the company have?
Can you explain briefly how the kitting processes in your organisation works?
How long have you kitted this “current” way?
What are the latest changes in the kitting process?
How many shifts do you have?
What is the takt time per shift?
How many kits do you prepare per time unit (day/hour)? [A]
How many picks do you make per time unit (day/hour)? [A]
For how many stations do you usually kit? [A]

Context

Which parts of the assembly process are kitted and why? [T]
What kind of system do you have? (assembly to order, make to order etc.) [T]
Does the size of the parts in the kit affect the choice of kit preparation location? [T]
Where are the company's inventories? [T]
Is the company working with JIT or something similar? [T]

What is the size of the end-product/the parts kitted? [T, A]
How many parts are there in the kits? [T, A]
How many article numbers are there per kit? [T, A]
How many exposed article numbers are there per kit-area? [T, A]
What factors do you consider are the conditions to have kitting processes? [T, A, L]
What factors do you think are restricting having a kitting processes? [T, A, L]
How many article numbers (different kind of parts) are there per kit? [T, A, L]
How many details (amount of parts) are there per kit? [T, A, L]

Design

Where is the kit preparation done? [T]
How do kits reach the assembly line? [T]
How are the parts included in the kits delivered to the kit preparation area? [T]
What happens if a part breaks during assembly? Is there a back-up part/kit somewhere? [T, A, L]
Can you easily make changes in the kit if so needed? [T, A, L]
Who is responsible for the kit preparation? [T]

Performance

How do you measure performance? [T]

<u>What are your experience of following factors in conjunction with the kitting:</u>

- **Amount of transportation** [T, A, L, M]

How does the transportation to and from the kitting area look like?
How often and how does material arrive to the area? And, how often do kits transport out from the area?
Is there a replenishment system? How does it work?

- **Inventory levels and space requirements** [T, A, L, M]

Does it occur that the racks lack parts?
How is material being refilled?
How many parts and kits do you have in inventories?
Do you have a buffer of kits for the stations? If so, how many kits?
Do you think that the inventory levels would have been affected if the kit preparation was done in another location? (further away/closer to the assembly line)

- **Potential for visual control** [T, A, L, M]

Can the person kitting easily communicate with the operators in the assembly line?
Can the person kitting see the assembly line?

- **Flexibility** [T, A, L, M]

Who/how designs the kit and makes changes? (e.g. changed orders, rebalancing, new pace)
Can you easily make a change in the kitting process?

- **Efficiency of kit preparation** [T, L]

How does the freedom to design the kit preparation area look like?
Can you easily make changes?

- **Quality in the kit preparation** [T, A, L, M]

Does it occur that wrong parts are being picked? If so, what happens in this case?
Does it also occur that the parts are damaged in some way?
Do the workers preparing the kits have experience of the assembly as well?

- **Ability of continuous improvement** [T, A, L, M]

Do you work with continuous improvement? If so, how?
Do you feel that your experience is being considered as input when improving the kitting system?
Do you have any coming changes?

- **Ergonomics** [A, L, M]

Do you have many heavy lifts?
Do you use lifting equipment?
Do you have to walk a lot when kitting?
Do you think the current kitting stations are ergonomic? Why/why not? [T]

Problems [T, A, L, M]
What problems do you experience with the current design?

Good things [T, A, L, M]
What do you experience as positive with the current design?