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Parts feeding of low-volume parts to assembly lines in the automotive industry

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ABSTRACT

Parts feeding to mixed-model assembly lines in the automotive industry is a large challenge, since diverse customer demands have increased the amount of parts handled within the production facilities; hence a large amount of parts can be categorized as low-volume parts. Existing theory states that the design of the parts feeding system impacts the performance of the production system, however, there is a gap in existing literature regarding research focusing on parts feeding policies appropriate for low-volume parts. The aim of this study is therefore to develop guidelines for when different parts feeding policies are suitable to apply for LVPs and highlight the effects of design options related to the parts feeding system. The aim has been broken down into three research questions which the study should answer:

1. *How can low-volume parts be defined for parts feeding in the automotive industry?*
2. *Which parts feeding policies are suitable to use for low-volume parts, and for what part characteristics does each policy fit best?*
3. *How should the parts feeding system related to each parts feeding policy for low-volume parts be designed?*

A multiple case study of four companies within the automotive industry has been performed in order to fulfill the aim. The study has been qualitative and data has been collected through direct observations, semi-structured interviews and internal documents.

It was identified that companies within the automotive industry can benefit from categorizing their parts based on consumption volume, where low-volume parts could be grouped into a separate segment. This allows for reduced complexity in the assignment of parts feeding policies. This study has concluded that it is less beneficial to use continuous supply for low-volume parts compared with other parts feeding policies. The assignment of parts feeding policies for low-volume parts can be performed based on part characteristics, where the part size and amount of part variants within the part family have been identified as most relevant to consider. Findings related to the design of the parts feeding system include that space limitations near the assembly line has a large influence on design choices. Furthermore, it is beneficial to consolidate parts when transporting them to the lineside presentation. In addition, the picking accuracy has been identified as more important for low-volume parts than picking efficiency, and picking information such as pick-by-voice can be helpful to enable increased accuracy of picking operations.

Keywords: parts feeding policy, parts feeding system, low-volume parts, automotive industry, continuous supply, kanban-based continuous supply, kitting, sequencing

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1 INTRODUCTION

This chapter will begin with a description of the constituents of a production system, which will then be narrowed down to explain the importance of parts feeding in the automotive industry, which will form a basis for the purpose of this study. The aim of the study as well as research questions are presented and the scope and limitations of the study are motivated. In the end of the chapter, an outline of the report is presented.

1.1 Problem background

According to Finnsgård (2013), a production system in an assembly environment consists of a parts feeding system and an assembly system, see Figure 1. The parts feeding system supplies parts to the lineside presentation, which is the border to the assembly system. The delivered parts are within the assembly system assembled to an object and the output is end products (Finnsgård, 2013). These relations are presented in Figure 1 below.

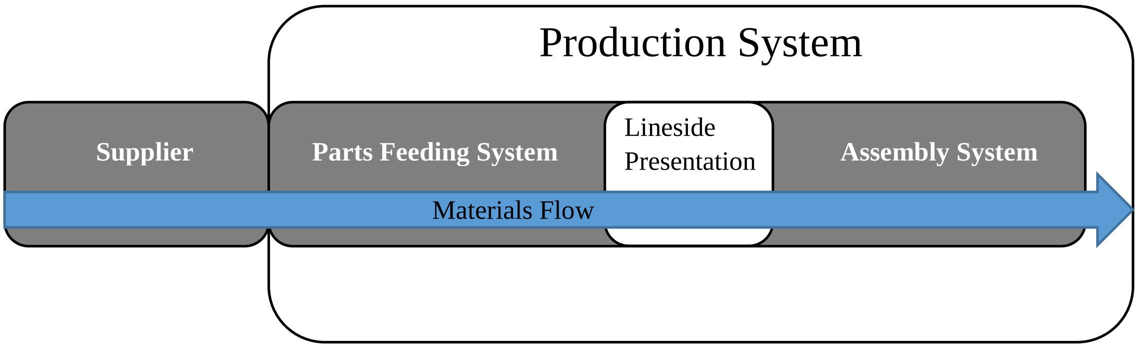

Figure 1. The production system and its constituents - Adapted from Finnsgård (2013)

Studies show that some companies within the automotive industry offer up to billions of different product variants (Pil & Holweg, 2004). This is a consequence of the diverse customer demands that exist in the automotive industry. The high number of product variants impacts both the parts feeding system and the assembly system. The latter needs to maintain high efficiency while being capable of handling a high degree of flexibility. This is enabled by designing the assembly system into a mixed-model assembly line as it allows multiple products to be manufactured efficiently (Boysen, et al., 2009). However, as an increased number of parts needs to be handled, the complexity of the parts feeding system increases which could have a negative impact on the efficiency of the assembly system (Emde & Boysen, 2012). It is therefore important for a company to have a suitable design on their parts feeding system since it impacts the performance of the production system (Kilic & Durmusoglu, 2015).

The parts feeding system can be divided into several constituents which all contribute to the performance of the system. According to Kilic & Durmusoglu (2015), the parts feeding system could be categorized into transport of parts, storage of parts, and parts feeding policy. However, previous studies highlight additional constituents which also could have an impact on the performance. An argumentation about the constituents of the parts feeding system will be further elaborated in the theoretical framework. This study will explore the constituent denoted as parts feeding policy in detail, due to its great influence on the entire parts feeding system. The parts feeding policy can be described as the method of delivering parts to the point-of-use (Kilic & Durmusoglu, 2015). However, as the constituents are interdependent it is necessary to consider the whole parts feeding system (Kilic & Durmusoglu, 2015).

Emde & Boysen (2012) highlight the parts feeding to the mixed-model assembly line as a large challenge since a high amount of parts need to be handled. Caputo & Pelagagge (2011) state that an appropriate and cost efficient way of choosing among parts feeding policies is to use several different policies for different parts depending on their characteristics. Hua & Johnson (2010) concluded that part characteristics such as consumption volume, part size and variety within part family impact the design of the parts feeding system, meaning for example that the design for parts used in low volumes would differ from that of parts consumed in higher volumes. Furthermore, economic value of the part has also been identified as relevant to consider (Caputo & Pelagagge, 2011; Schwind, 1992). It has also been concluded that the design often is based on qualitative judgement where contextual factors such as company-specific practices, tradition, product structure and operational constraints impact the decision (Carlsson & Hensvold, 2008). Moreover, Carlsson & Hensvold (2008) concluded in their study of a production facility at Caterpillar that the organizational needs have a significant impact on the decision. For instance, the most appropriate design of the parts feeding policy depends on how the firm evaluates the importance of criteria such as lineside space reductions, operator walking time, and kitting time.

Traditionally, continuous supply has been a common parts feeding policy to apply, where large quantities of all components are stored near the assembly line (Faccio, 2014). However, Caputo & Pelagagge (2011) state that continuous supply is not appropriate to use when there is a high amount of part variants, since it could cause high inventory costs and problems related to space limitations at the lineside presentation. As stated above, high amounts of part variants could often be seen in the automotive industry. Furthermore, the amount of non-value adding time for the operator can increase since excessive time is spent on fetching material due to longer walking distances (Medbo & Wänström, 2009).

In order to handle these issues that could arise when using continuous supply, alternative parts feeding policies have been developed. Kitting, kanban-based continuous supply, and sequencing are some of the parts feeding policies that can be found in existing literature (Faccio, 2014; Sali, et al., 2015). Several comparisons between kitting and continuous supply can be found in previous research while there is a limited amount of studies regarding the other policies.

As companies within the automotive industry experience more diverse customer demands, an increasing amount of parts needs to be handled by their parts feeding systems. Therefore, it is reasonable to argue that a large amount of parts could be categorized as low-volume parts (LVPs) today. While existing literature has not provided a definition for LVPs, the authors of this thesis refer to them as parts that are used to a low extent compared to other parts within the production system. Furthermore, to provide a definition of LVPs is one of the research questions that this thesis will treat. As the amount of LVPs increase, the importance of having an appropriate design of the parts feeding system becomes even more critical in order to reduce complexity, inventory costs, and issues related to space restrictions. However, even though several studies exist where parts feeding policies have been compared, literature focusing on policies that are appropriate to use for LVPs have not been found. As a consequence, companies cannot receive support from the academia about guidelines for how to choose the most suitable parts feeding policies for LVPs that fit their needs. Therefore, this study is focusing on filling this gap in the academia through a multiple case study.

1.2 Aim

The aim of this study is to develop guidelines for when different parts feeding policies are suitable to apply for LVPs and highlight the effects of design options related to the parts feeding system. Since existing literature has identified that contextual factors impact the performance of the parts feeding system, the study will also highlight which factors that are most important for companies to take into consideration. In addition, the guidelines will be developed for the automotive industry, based on the fact that the automotive industry handles a large amount of parts in order to meet the diverse customer demands. The findings for LVPs based on contextual factors and part characteristics would be applicable for companies within the automotive industry to use as support when designing their parts feeding systems in order to choose the most appropriate policy, thus enhancing the performance of their production system.

1.3 Research questions

In order to develop these guidelines for designing the parts feeding policies for LVPs in the automotive industry, three research questions have been developed. The first research question relates to the lack of definition for LVPs in existing literature. It is considered relevant to have a definition for LVPs, which should be adapted for the automotive industry and answer which parts the guidelines are applicable for.

Research question 1: How can LVPs be defined for parts feeding in the automotive industry?

The second research question is related to the various parts feeding policies that can be found in existing literature and to highlight the advantages and disadvantages with each policy. The parts feeding policies' suitability for LVPs should also be answered with this research question. To further be able to give recommendations about what parts feeding policy to use for parts within the LVP scope, the different policies' suitability based on part characteristics - such as consumption volume, size and variety within the part family - will be examined. This is relevant to evaluate since it has been stated in previous literature that it is beneficial to assign different policies based on part characteristics (Caputo & Pelagagge, 2011). Contextual factors influencing the choice of parts feeding policy will also be addressed.

Research question 2: Which parts feeding policies are suitable to use for LVPs, and for what part characteristics does each policy fit best?

As mentioned in the previous section, there are several constituents within the parts feeding system that impact the performance, thus it is not possible to isolate this study to only consider the design of the parts feeding policy. The third research question should therefore cover how design choices within the other constituents in the parts feeding system could impact the performance of the parts feeding system, as well as how contextual factors influence the design.

Research question 3: How should the parts feeding system related to each parts feeding policy for LVPs be designed?

1.4 Scope and limitations

The scope of this study is to investigate parts feeding policies and design options related to the parts feeding system that can be found in existing literature and that are applied by the studied companies. The reason is that the guidelines should be based on both theoretical knowledge and take into consideration practical issues, such as contextual factors. Furthermore, parts feeding policies relevant for LVPs are in focus, and therefore the various policies and design of the parts feeding systems will be evaluated accordingly. The scope of this study has also been further narrowed down to solely include companies within the automotive industry, since the importance of parts feeding within this industry has been identified as critical. Moreover, the multiple case study is constituted of Swedish manufacturers. It could be argued that a mix of facilities located in different countries would increase the generalization of the recommendations from this study. This will therefore be further treated in the discussion chapter.

Due to limited time and resources, at most one visit to each company's production facility has been conducted. However, it is believed that the time was sufficient to identify and analyze the various parts feeding policies applied at the companies as well as relevant contextual factors. Furthermore, several of the companies participating in the study have multiple production facilities in Sweden and it is possible that different parts feeding policies are used at the various sites. However, one facility per company has been studied, which could lead to that we miss out on valuable information. In order to visit the most appropriate sites, it was decided in accordance with contact persons at each company regarding which facility that was most relevant to study. It is therefore believed that sufficient information was gathered during the visits in order to develop the guidelines. In addition, the companies participating in the study are considered to contribute with a good mix since they manufacture different types of products, with various production volumes as well as differences in design of their production systems. It is believed to be a requirement to have this mix of companies in the automotive industry since it increases the possibilities to capture a larger amount of different parts feeding policies. In addition, a higher degree of relevant contextual factors existing among the studied companies could be examined.

1.5 Thesis outline

The overall structure of the report starts in Chapter 2 with a theoretical framework introducing concepts that will be used throughout the report, mainly covering the different constituents of the parts feeding system. Chapter 3 describes the methodology used in the study for the reader to get a clear picture of how the study has been conducted. Chapter 4 covers the empirical studies, treating the four case companies that were studied for this report, how they have designed their parts feeding systems and how they currently handle LVPs in this aspect. Chapter 5 connects the theory with the empirical findings into an analysis, where arguments will be put forward to be able to answer the research questions about how companies should define LVPs, what policies that are suitable for these parts, as well as what a company should think of when designing a parts feeding system for LVPs. In Chapter 6, the most important findings from the analysis will be presented. A discussion of the results is held in Chapter 7, treating reflections of the findings, contributions to the industry, generalizability and trustworthiness of the study, as well as input for further research that could be needed to provide further insight in the area of LVPs and parts feeding. The conclusions are presented in Chapter 8, and the report ends with references and appendices.

2 THEORETICAL FRAMEWORK

The theoretical framework begins with describing methods for how classifications of parts can be carried out. This section should form a base for how the classification of LVPs can be performed within the parts feeding system, followed by a description of the parts feeding system and its constituents. The framework narrows down on theory related to parts feeding policies that will be used to evaluate when the policies are suitable for LVPs. In addition, contextual factors impacting the parts feeding system as well as relevant performance areas that the parts feeding system can be evaluated according to are presented.

2.1 Classification of LVPs

Within existing literature, there is no unanimous definition of what should be categorized as an LVP. However, van Kampen et al. (2012), state that it is common to perform a classification of a company's parts since it facilitates a systematic approach for decision-making based on part characteristics such as volume, value, and storage requirements. The usage of classifications could be found in many fields, for instance within the areas of production and operations management, and could be used for several different purposes (van Kampen, et al., 2012). The authors describe that it can be advantageous to use a part classification when deciding production and inventory policies since each class contains parts with similar characteristics, thus reducing the complexity of the control. Hence, LVPs could be grouped together in order to make the parts feeding of low-volume parts as efficient as possible. The ABC classification is a well-known method that is simple to apply since the parts are usually divided according to one criterion (Teunter, et al., 2010). For instance, demand value or consumption volume are measures which the division into groups could be based on (Teunter, et al., 2010; de Koster, et al., 2007). According to Caputo & Pelagagge (2011), a suitable criterion to perform an ABC classification for parts feeding takes volume and cost of the parts into consideration. However, van Kampen et al. (2012) state that the decision of which characteristic to base the ABC classification on depends on the purpose of the classification, but also contextual factors related to specific industries could have an impact.

2.2 The parts feeding system and its constituents

In any company, the management of parts plays a large role in how the whole production system operates, in for instance ensuring the optimal flexibility and efficiency for the assembly system (Battini, et al., 2009). Accordingly, Baudin (2002) states that the factor that impacts the productivity of assembly systems the most is parts feeding. Further important parameters that can be significantly impacted by how parts feeding is managed are the costs related to materials handling and inventory (Battini, et al., 2009).

The constituents of the parts feeding system differ between various studies. For instance, Sali et al. (2015) define parts feeding as an in-plant logistics process that involves preparation of parts at storage areas and transportation to the lineside presentation. Battini et al. (2009) also include the issue of how many storage areas that is optimal and where they should be placed. However, the theoretical framework treating parts feeding systems in this report is based on the framework presented by Kilic & Durmusoglu (2015), although with some modifications. Kilic & Durmusoglu (2015) have divided the parts feeding system into three constituents, namely storage of parts, transport of parts, and parts feeding policy. This framework has been modified in this thesis by breaking out picking of parts as a separate constituent, which in the framework from Kilic & Durmusoglu (2015) is included in storage of parts, and with the addition of packaging of parts as a constituent, since this has been identified as an important factor impacting the parts feeding system. An illustration of the framework adapted for this study is presented in Figure 2 below.

The choice of adding packaging to our description of the parts feeding system is due to the big impact that choosing the correct packaging size can have on both the parts feeding system, as well as on the assembly system. Medbo & Wänström (2009) express that choosing a smaller packaging size fitting the assembly context for the part could significantly improve flexibility and efficiency in the system. Picking of parts is described as a separate constituent due to its importance especially for the parts feeding policies of kitting and sequencing that will be presented in the following sections. Brynzér & Johansson (1995) state that picking of parts accounts for a large share of the time that operators spend to prepare the material, and therefore is important to consider when designing the parts feeding system. All these five constituents are intertwined and affect each other as well as the performance of the total parts feeding system and production system. Therefore, it is necessary to address all constituents of the parts feeding system when choosing and designing parts feeding policies for LVPs.

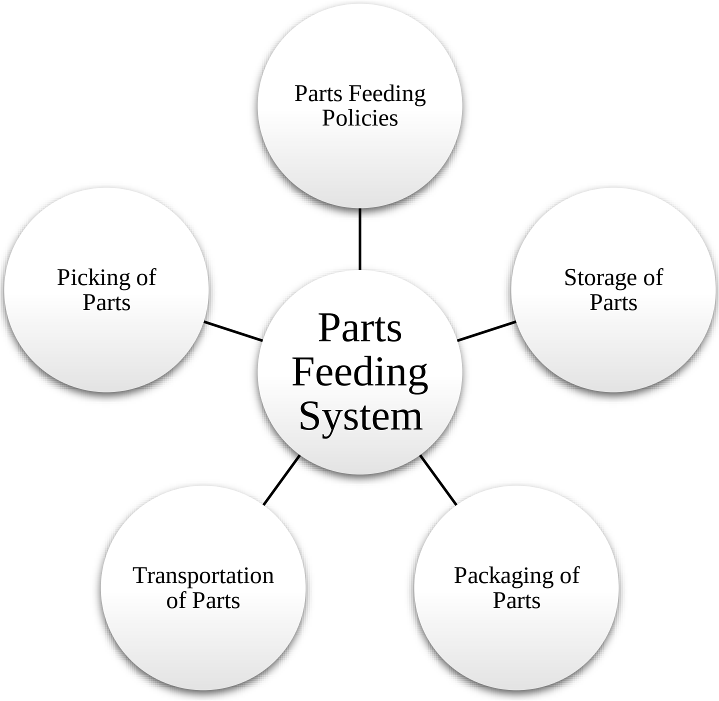

Figure 2. The parts feeding system and its constituents – Adapted from Kilic & Durmusoglu (2015)

2.2.1 Parts feeding policies

This chapter will treat the focus area of this study, namely different parts feeding policies. According to Kilic & Durmusoglu (2015), the parts feeding policy is defined as "the method of delivering parts to the usage points". By studying the existing literature, several parts feeding policies have been found that are used in industrial companies. Some of the parts feeding policies described below can certainly be used on their own as the only method for delivering parts to the lineside presentation, and many authors have treated their reviews and analyses on this premise. While this could probably work for some companies, a more appropriate and cost efficient way of choosing among parts feeding policies is to use several different policies for different products depending on the part characteristics, or by dividing the products through an ABC classification (Caputo & Pelagagge, 2011).

There are several part characteristics that have been mentioned in previous studies as relevant to consider when choosing the parts feeding policy. Some that have been identified are variety in part family (Caputo & Pelagagge, 2011; Hua & Johnson, 2010), part size (Caputo & Pelagagge, 2011; Ding, 1992; Hua & Johnson, 2010; Limère, et al., 2012), consumption volume (Caputo & Pelagagge, 2011; Hua & Johnson, 2010), and part value (Caputo & Pelagagge, 2011; Schwind, 1992).

In the following sections, the most commonly used parts feeding policies will be presented. They are, in order of appearance in the report, continuous supply, kanban-based continuous supply, kitting and sequencing. Each policy will be described with their characteristics as well as some advantages and disadvantages, and in what context and for what part characteristics the policy is most suitable to use. Since existing literature related to parts feeding policies lacks a focus on LVPs, the descriptions of the policies will mostly be on a general level. In the end of this section of the report, a table that summarizes the described policies' suitability based on the above-mentioned part characteristics is presented.

Continuous supply

Continuous supply, also called line stocking, is a very common parts feeding policy in companies (Limère, et al., 2012), and is often used in practice to feed parts to assembly lines (Sali, et al., 2015). Sali et al. (2015) explain continuous supply as that all parts are stored in both a central warehouse or a preparation area, as well as at the lineside presentation, and the parts are replenished at a given time interval corresponding to a certain amount of takts. The term also includes how material is presented at the assembly line, with the main feature that parts are stored according to their part numbers, and that all part numbers are always presented at the assembly line (Hanson, 2012; Johansson, 1991). Most often, parts fed by continuous supply are stored at the lineside presentation in their original packaging (Limère, et al., 2012). Parts that are needed for a specific assembly process are then picked by the assembly operators, directly from these unit loads (Johansson, 1991).

The downsides of continuous supply are mainly the space requirement for storing all parts at the assembly line and that some parts might need to be stored at multiple workstations at the assembly line, requiring even more space (Hua & Johnson, 2010). There will also be problems when there are increasing cycle times, due to more material having to be presented at each assembly workstation, making continuous supply a less useful parts feeding policy (Johansson & Johansson, 2006). Furthermore, this parts feeding policy often requires handling by forklift, which could be a risk in areas where there are many operators. Additionally, due to the nature of continuous supply where parts are presented in their original packaging and not suitably presented for the assembly operations, the picking time for operators could be long and the proportion of non-value adding work is at risk of becoming high, especially for parts in large packaging such as pallets (Medbo & Wänström, 2009; Finnsgård, et al., 2011). However, continuous supply is very efficient in terms of that the parts usually not needing any rework or repackaging from the supplier, but can be put in place directly at the lineside presentation (Hua & Johnson, 2010). Some work could be needed though, depending on how the material is received from the supplier and how it is wanted to be exposed at the assembly line. For example, parts being received in pallets but presented in smaller boxes at the assembly line need to be repackaged, a procedure that is called downsizing (Sali, et al., 2015; Johansson, 1991).

According to Sali et al. (2015) continuous supply fits best for supplying an assembly line with larger parts with low variety in part family. Hua & Johnson (2010) argue that continuous supply is more suitable for parts consumed in high volume. Furthermore, the policy is not recommended for high value goods since it increases the work-in-process at the assembly line (Caputo & Pelagagge, 2011).

Kanban-based continuous supply

Another variant, or further development, of continuous supply is the kanban-based continuous supply. In this policy, parts are fed in standardized storage containers, such as bins, from storage areas located close to the assembly line to the lineside presentation (Faccio, 2014). The replenishment can be triggered in many ways, for instance through empty bins or kanban cards, which could either be physical or electronic (Jonsson & Mattsson, 2009).

The greatest advantage of kanban-based continuous supply is that parts can be frequently delivered in small quantities from the storage areas located close to the assembly line, which makes it possible to reduce inventory at the lineside presentation by using smaller unit loads, and avoid long delivery distances from central warehouses (Faccio, 2014). Furthermore, is it a highly visible and reliable system, and cheap to implement (Kouri, et al., 2008). A downside for kanban-based continuous supply is the stock-out risk resulting from high variability in the consumption of parts, which further requires higher safety stock at the assembly stations, inducing higher costs (Faccio, 2014). Jonsson & Mattsson (2009) also argue that kanban should be used in a stable environment in terms of e.g. lead times and demand. Caputo & Pelagagge (2011) argue that kanban-based continuous supply would not be suitable in a mixed-model assembly system, where the variation of products is high and the demand is low. Additionally, the same authors state that kanban-based continuous supply enables reduced work-in-process compared with continuous supply, thus it can be argued that the policy is more appropriate for parts with higher value.

Kitting

The parts feeding policy referred to as kitting is rather different from the above-mentioned policies. Kitting treats parts feeding to assembly line by delivering a so called kit with parts corresponding to the exact requirement at one or several assembly stations or for a complete end product (Limère, et al., 2012). The kit is prepared by putting the required parts into a kit carrier through picking from storage in a decentralized storage area or other kitting area (Faccio, 2014). The kit is then delivered to the assembly line in the sequence the kits should be assembled.

There are two types of kits that can be used at the assembly lines, namely stationary kits and travelling kits. Kits are consumed in accordance to takt time, and for stationary kits one takt equals one kit. This makes it easy to forecast the consumption of parts and need for replenishment of kits (Limère, et al., 2012). A stationary kit is sent to a certain workstation after it has been put together and stays at the workstation until all parts have been used for the product, which then travels along to the next workstation where another kit awaits (Bozer & McGinnis, 1992). A travelling kit, however, follows the product through several workstations where parts are taken from the kit and put on the product in a certain sequence, until it is emptied (Limère, et al., 2012).

According to Bozer & McGinnis (1992), advantages with kitting is the increased visibility and control over work-in-process and the possibility to reduce storage space at the lineside presentation. Further advantages involve a possible increase in product quality and productivity at the workstation, since kits can present the parts in an effective way as an instruction, which induces learning for the assembly operators (Johansson, 1991). This also means that assembly operators could spend less time on fetching and searching for the required parts (Johansson, 1991; Medbo & Wänström, 2009). A main property of kitting is that it facilitates a wide variety of products, due to the ease of changing parts in every kit (Bozer & McGinnis, 1992), which also facilitates part introductions. Kitting is also advantageous to use when there are several workstations requiring the same parts, when the assembly system handles a large number of different parts, when the parts handled are of high economic value (Caputo & Pelagagge, 2011), and when the individual part volumes are low (Hua & Johnson, 2010).

The main disadvantage of kitting on the other hand is the required labor-intensive assembly of the kits before moving them to the assembly line (Bozer & McGinnis, 1992). The kit preparation may also require additional storage space (Bozer & McGinnis, 1992). Furthermore, problems in assembly could occur when the quality of the kit is not satisfactory, since kitting entails that a defect product is not easily replaced (Limère, et al., 2012). In addition, there are restrictions concerning weight, volume and size for the parts delivered through kits, so not all parts are able to be kitted (Limère, et al., 2012). However, this depends on what materials handling equipment and kit containers the companies are using, or are able to implement into their parts feeding system.

Sequencing

The last parts feeding policy that will be described in this study is sequencing, or sequential supply. This policy could be seen as a special kind of stationary kit, where each kit consists of only one part (Sali, et al., 2015). The parts needed for a determined number of products are presented in the correct order they should be assembled on the products (Johansson & Johansson, 2006). The sequenced parts are typically transported and displayed at the lineside presentation in specially adapted unit loads (Sali, et al., 2015).

Since sequencing can be seen as a certain kind of kitting, the policies share several benefits and drawbacks. For instance, sequencing is often preferred for parts that have a high number of varieties. However, in contrast to kitting, sequencing is more suitable for larger parts, which was shown in the study by Sali et al. (2015), where factors such as walking distances for assembly operators and preparation costs were considered. In addition, sequencing can be used if there are only a few components being assembled at every workstation (Johansson & Johansson, 2006). An advantage with sequencing compared to continuous supply, is that a higher space efficiency could be achieved at the lineside presentation for the sequenced parts (Hanson, 2012). Disadvantages with sequencing include the need for a specific preparation area as well as the requirement of specific operators for sequencing the parts into the transportation units. In addition, some sequentially fed parts might require special packaging solutions (Johansson & Johansson, 2006).

Summary of parts feeding policies' suitability based on part characteristics

Table 1 below summarizes the findings from previous studies regarding when the different parts feeding policies could be suitable to use based on part characteristics that have been identified in existing literature, namely variety in part family, part size, consumption volume and part value. It should be noted that the table is a simplified view of the reality, and should only be seen as a guideline, since contextual factors might influence the suitability of the parts feeding policies. Each part characteristic has been categorized into three segments. The table shows which segments of the part characteristics that each parts feeding policy is most suitable for according to findings from existing literature, which was mentioned within each section above. The grading has been performed by the authors in order to make the comparison more standardized, however, it should reflect the conclusions from previous findings. The evaluation of whether the policies are suitable for LVPs is mainly based on part volume, where continuous supply tends to be less preferable to use as parts feeding policy for LVPs, while kitting and sequencing and to some extent kanban-based continuous supply could be more suitable. This reasoning will be further developed in chapter 5.2 where empirical findings also are taken into consideration.

Table 1. Parts feeding policies' suitability based on part characteristics according to findings in existing theory

Parts feeding policy* / *Part characteristics	***Continuous supply***	***Kanban-based cont. supply***	***Kitting***	***Sequencing***
Variety in part family	Low	Low-Medium	High	High
Size	Medium-Large	Small-Medium	Small-Medium	Large
Consumption volume	High	Medium-High	Low	Low
Value	Low	Medium-High	High	High
Suitability for LVPs	Low	Medium	High	High

2.2.2 *Packaging of parts*

The second constituent in the framework related to parts feeding system is packaging. Hanson & Finnsgård (2014) mention that there is often thought to be a tradeoff between large unit loads, which enable a high efficiency in the parts feeding system versus smaller unit loads which enable a more efficient assembly system. Unit loads can for instance be containers or pallets. By having larger unit loads, the frequency of replenishment and thereby the number of transports of parts being made can be reduced (Hanson & Finnsgård, 2014). However, large unit loads will also lead to higher work-in-process and a requirement of more space being available at the point-of-use (Hales & Andersen, 2001). Most companies in Sweden mainly base their choice of packaging on cost and transportation efficiency, resulting in large unit loads (Medbo & Wänström, 2009).

On the other hand, Hanson & Finnsgård (2014) conclude that the efficiency of the parts feeding system doesn't necessarily depend on unit load size, since smaller unit loads also can provide a high efficiency of the parts feeding system. This is due to the possibility to transport a high number of different parts simultaneously with a tow train. The use of smaller containers further allows for easier and faster replenishment of unit loads, since it is easy to replace the containers at the lineside presentation. This is not possible when using pallets as unit loads, since the replacement has to be made with a forklift or other material handling equipment (Hanson & Finnsgård, 2014). Medbo & Wänström (2009) argue that another advantage with small unit loads is that a higher flexibility at the lineside presentation can be achieved, since a higher variety of material can be presented at the same time in close proximity to the assembly operators, allowing more efficient fetching of parts.

The process of repacking parts, mainly by downsizing to smaller unit loads, is a very inefficient activity that should be avoided (ten Hompel & Schmidt, 2007). It is therefore important that companies, together with the suppliers, strive towards choosing the proper packaging for parts in which they will be presented at their place of consumption. However, supplier contracts and fill-rates in the delivery trucks must also be considered, and might limit the choices of packaging solutions (Hanson & Finnsgård, 2014). Table 2 summarizes the relevant design options related to packaging.

Table 2. Description of design options related to the packaging constituent

Constituent	***Design area***	***Design option***
Packaging	Unit load size	Choosing an appropriate packaging size for the part. For instance, pallets, boxes or cartons.
	Repacking	Moving parts from one unit load to another. Inefficient process that should be avoided.

2.2.3 Storage of parts

The third constituent in the framework related to parts feeding system is storage of parts. Storage space at the assembly lines is mostly a great restriction for companies today as a consequence of the high variety of parts, and it is also the most expensive storage area (Emde & Boysen, 2012). There is a trade-off between having material available at the assembly stations when it is needed to avoid stoppages, versus keeping stock and traffic at the assembly line to a minimum level to avoid high material handling and holding cost (Emde & Boysen, 2012).

Storage of parts has traditionally been centralized in production facilities, and parts have been transported one unit load at a time when replenishment has been needed at the assembly stations (Emde & Boysen, 2012). For this to work and not to have excessive traffic in the facility, the parts have to be delivered in large lots, which increases work-in-process and takes up a lot of space at the assembly stations (Emde & Boysen, 2012). Battini et al. (2009) argue that the centralized storage configuration can reduce inventory cost by having most material in only a few places, but that material handling costs will increase due to a high amount of transport from the centralized storage area. This will also impact the flexibility at the assembly line negatively.

Another possibility is to instead have a decentralized storage configuration where parts are supplied from supermarkets to the assembly line. This entails shorter delivery times when material could be stored closer to the assembly line, consolidating material to match the need at the assembly line and at the correct time that it is needed (Emde & Boysen, 2012). By having a decentralized storage configuration, material can be presented in smaller unit loads, which will increase the accessibility for the assembly operators, as well as decrease picking time and improve ergonomics (Emde & Boysen, 2012). The downsides of supermarkets are mainly that they require space in the facility and that the material is stored in a less efficient manner than in a central storage area, due to that most material should be easily accessible for the operators (Emde & Boysen, 2012). As a contrast to the centralized storage configuration, decentralization leads to higher flexibility at the assembly line and less transportation, but higher inventory costs (Battini, et al., 2009).

There are several storage policies mentioned in existing literature for how parts should be stored in the different storage areas, where random storage, class-based storage and family grouping are three highlighted policies mentioned by de Koster et al. (2007). Random storage means that a unit load can be stored in any empty slot in the storage area, allowing for high space utilization but an increased travelling distance, when parts consumed in high volumes could be stored in less preferred storage locations. The class-based storage policy divides the parts into different categories based on for instance an ABC classification and assigns them to a dedicated storage area for each class. The parts that are picked most often could be stored closest to the depot in order to reduce travel distance, while LVPs could be placed in less easily accessible areas. When applying family grouping, parts that are often picked together are stored close to each other. This method could be related to Brynzér & Johansson's (1995) recommendation that the product structure could be used as support when assigning storage policies. Table 3 summarizes the design options related to storage of parts.

Table 3. Description of design options related to the storage constituent

Constituent	***Design area***	***Design option***
Storage	Storage configuration	Centralized or decentralized storage of parts
	Storage policy	Random, class-based or family grouping

2.2.4 Transportation of parts

The next constituent of the parts feeding system is transportation of parts. The transportation process is defined by Sali et al. (2015) as "collecting items prepared and delivering them to their point-of-use…". Baudin (2004) makes a distinction between in-plant transportation and inbound & outbound transportation regarding where the most improvement potential can be achieved. For in-plant transportation, which this study focuses on, Baudin (2004) states that it is of higher relevance to reduce the number of trips rather than reducing the distance travelled on the trips. Hence, it is beneficial to perform transports of multiple parts in the same delivery tour instead of having direct transports.

According to Baudin (2004), some common material handling equipment used in production facilities are forklifts, tow trains, push carts, and pallet jacks. The various handling equipment have their advantages and disadvantages and therefore the usage should reflect the requirements in terms of load size and frequency. According to Cottyn et al. (2008), the forklift has traditionally been the most common equipment used for in-plant transportation due to its flexibility. However, the forklift is adapted for carrying large and heavy parts in pallets directly from a storage area to the point-of-use, and is less appropriate to use for smaller unit loads (Baudin, 2004). In addition, the forklift is a safety risk for both employees and material causing many companies to evolve towards having a forklift free environment (Cottyn, et al., 2008).

In comparison with the forklift, the tow train has higher capacity and is adapted for smaller unit loads (Baudin, 2004). They are common to use for indirect transport routes called milk runs, where the tow train travels in a loop on a fixed route from a decentralized storage location to several workstations, transporting multiple parts on each trip. The tow train is operator driven and consists of a tractor and several wagons carrying the materials, arranged in the order of delivery and usage at the assembly line (Sali, et al., 2015).

The push cart is a low cost alternative that is adapted for transporting smaller unit loads such as bins (Baudin, 2004). The pallet jack is another equipment which is cheap compared to the traditional forklift. However, it is primarily designed for short movements and it cannot perform vertical lifts (Baudin, 2004). Table 4 summarizes the design options related to transportation of parts.

Table 4. Description of design options related to the transportation constituent

Constituent	***Design area***	***Design option***
Transportation	Material handling equipment	Forklift, tow train, push cart, pallet jack etc.
	Routing	Direct transport or indirect transport (milk-run) from storage area to lineside presentation

2.2.5 Picking of parts

The last constituent of the parts feeding system being presented in this report is picking of parts, which could be performed both in warehouses and in specific picking areas in assembly facilities. The picking process in warehouses is important to consider because it is an expensive process that is labor-intensive (de Koster, et al., 2007). In the context of parts feeding systems, picking is primarily related to the kitting and sequencing processes. According to Brynzér & Johansson (1995) the design of the picking system is an important factor that impacts the overall performance of a kitting system. Brynzér & Johansson (1995) evaluate the performance of the picking process in terms of picking productivity and picking accuracy. The study highlights that the industry has put more emphasis on improving the productivity aspect while the picking accuracy has had lower focus, even though it could cause more severe problems in the production process.

In the context of picking in warehouses, approximately half of the order picker's time in a manual picking system consists of travelling (de Koster, et al., 2007). A method to reduce the total travelling distance is to apply batching of orders. It aligns to some extent with Brynzér & Johansson's (1995) conclusions as they state that batching of multiple kits could improve the picking efficiency unless it does not increase the amount of sorting and administrative work. Another recommendation is to implement storage policies within the area where picking is performed. A few storage policies mentioned in the literature, and their advantages, have been presented in section 2.2.3.

Within the study performed by Brynzér & Johansson (1995), frequently occurring issues related to picking accuracy were reading mistakes, interruptions of the picker, and mixing of parts in the batch. Thus, batching could increase the picking productivity, while it decreases the picking accuracy. A method which could improve the picking accuracy is to manually count the picked parts after the picking tour, however, there are more appropriate arrangements for improving the quality, such as improved picking information (Brynzér & Johansson, 1995). This aligns with the conclusions of Fager et al. (2014), stating that the picking information impacts the picking quality for materials preparation for kitting and sequencing. Traditionally, the picking information has consisted of a pick list, which informs the picker which parts that should be collected (Brynzér & Johansson, 1995), but other information methods exist such as pick-by-voice and pick-by-light (Fager, et al., 2014). According to ten Hompel and Schmidt (2007), the pick-by-voice method is superior from a picking accuracy perspective, while the pick-by-light and pick list shows approximately similar accuracy levels. From a picking efficiency perspective, ten Hompel & Schmidt (2007) state that a disadvantage with the usage of pick list is the time needed to identify the next part to pick.

The picking of parts for kit preparation could be performed either by specific kitting personnel or by the assembly operators. Brynzér & Johansson (1995) argue that it is generally more beneficial to assign the kit preparation to the assembly operators if the process is located close to the assembly line since balancing problems can be reduced and higher picking accuracy can be obtained as the operators are responsible for the whole job. However, if the process is far away from the assembly line, cost could often be held to a minimum if specific kitting personnel have responsibility for the assembly of the kits, since assembly and administrative work could be bundled with other storage and material handling activities (Johansson, 1991). Table 5 summarizes the design options related to picking.

Table 5. Description of design options related to the picking constituent

Constituent	***Design area***	***Design option***
Picking	Picking quantity	Picking for one or several orders during one tour
	Picking information	Pick list, Pick-by-light, Pick-by-voice
	Picking location	Close to or far away from lineside presentation
	Responsible for picking	Specific department or assembly operators

2.3 Contextual factors impacting the design of the parts feeding system

Apart from what has been described in earlier sections as part characteristics, there are also further contextual factors affecting the design of parts feeding policies. These are all important to consider, as e.g. cost could differ much depending on in what context a certain policy is used (Sali, et al., 2015). In addition to the part characteristics, Hanson (2012) divides contextual factors into production-related factors and layout-related factors. A similar structure will be adapted in this section.

Limère et al. (2012) state that the parts feeding system should be adjusted to the assembly system in order to enhance the performance, making the design of the assembly system an important contextual factor to consider. One production-related factor is the assembly cycle time which can vary between assembly systems. According to Medbo (2003), a longer cycle time increases the space requirements if all parts are supplied with continuous supply. Another important factor that influences the choice of parts feeding policy is the use of a certain part at several different workstations and for several end products, and the deduced need of presenting parts at multiple workstations at the assembly line (Hua & Johnson, 2010). Furthermore, the fact that the companies are operating within the automotive industry is an important contextual factor in itself. As has been said before, customer demand in the automotive industry is highly variable which means that companies in this industry must be very flexible (Pil & Holweg, 2004). This influences how they design their assembly and parts feeding system, with for example mixed-model assembly lines and extensive customization choices.

Layout-related contextual factors can also impact the design of the parts feeding system where space restrictions could cause limitations in the facility (Hua & Johnson, 2010). Battini et al. (2009) mention distances between storage areas and the assembly line as another aspect which could be restricted by the production facility. The design of the assembly stations may impact the space restrictions for displaying all parts at the lineside presentation. For instance, if there is not sufficient space available at the lineside presentation to display all parts, it is not possible to use continuous supply consistently (Caputo & Pelagagge, 2011).

Additional factors that are not to forget, is firstly that the personnel might be resistant to change, and that they might have certain preconceptions about the different parts feeding policies (Hua & Johnson, 2010). Secondly, company goals may play a role, where for example wanting to reduce non-value adding tasks might lead to the company choosing a certain parts feeding policy (Hua & Johnson, 2010).

2.4 How to assess the performance of the parts feeding system for LVPs

Performance assessment is important for the evaluation of how the parts feeding system is working, as well as to be able to assess how changes in the system affect the performance, in order to be able to improve the system further (Hua & Johnson, 2010). To evaluate how well a parts feeding system operates, existing literature have several different suggestions on performance areas that can be used.

Space requirements and work-in-process in the facility are mentioned by several authors as relevant performance areas to evaluate since different parts feeding policies yield different advantages and disadvantages in these areas (Bozer & McGinnis, 1992; Field, 1997; Hanson & Brolin, 2013; Hua & Johnson, 2010; Limère, et al., 2012). Another performance area that can be assessed is the flexibility in the assembly system with regards to handling a wide variety of parts and fluctuating production volumes (Hanson & Brolin, 2013; Medbo & Wänström, 2009). According to Baudin (2002) an important factor to account for and measure, especially in mixed-model assembly systems, is picking errors, which could be seen as the most common source of defects in assembly operations. This is in line with Hua & Johnson's (2010) performance area of component selection error. Hua & Johnson (2010) also mention the amount of material handling required as a relevant performance area to assess. Hanson & Brolin (2013) also evaluate the man-hour consumption required between usage of different parts feeding policies.

3 METHODOLOGY

In this chapter of the report, theory about research methods and their application is going to be discussed, such as different approaches to theory creation, quantitative versus qualitative studies and different designs available to perform a research study. The chapter aims to investigate what different research methods there are and how they should be used as well as to, from this information, draw conclusions about the correct and fitting methods for this particular study and to give the full description of the methodology that has been used.

3.1 Research approach

The research approach used in a research study describes in what way the theory used has been created, collected or evolved. Holme et al. (1997) explain that theory could be seen in two ways; either the theory is very vague and it must be evolved throughout the study, or the theory might be very precise and treats exactly what is meant to be investigated in the study.

There are mainly two terms present to describe the creation of theory and its connection to empirical findings, called deductive method and inductive method respectively. In the deductive method, the theory lies as a basis for the empirical observations and findings (Bryman & Bell, 2011), and hypotheses are often made from theory in order to be proven by the empirical studies (Holme, et al., 1997). This also means that further studies and research could be made from the results. Borrego et al. (2009) put it that theory is meant to justify variables used in the study as well as the purpose statement and research questions, which should be narrowly specified.

In the other end of the spectrum, there is the inductive method, where the empirical data and findings mainly are the basis for the theoretical framework (Bryman & Bell, 2011). Here, it is important that the framework matches the specific empirical situation and context that has been studied (Holme, et al., 1997).

The deductive method is the more formalized theory of the two, and is easier to create specific guidelines for (Holme, et al., 1997). However, most studies are not exclusively following only one of the two methods, but instead there is often some interaction between the two, perhaps having the deductive method with influences from the inductive method as the most commonly used mix. Holme et al. (1997) express that the combination of the two methods is very important, and that it is when they meet that creativity is created. Bryman & Bell (2011) also mention a mix between deductive and inductive methods, where data and theory is weaved back and forth and simultaneously changing each other to create a better focus for the study. They call this method iterative, as theory and data are continuously revisited. A very similar approach, although with a different name, is proposed by Dubois & Gadde (2002). This approach, called systematic combining, is according to them mainly used in case studies, and they describe the approach as continuous movement between theory and empirical findings, together influencing the process of the research study. The method usually means a better understanding of both the theory and the empirical observations, which can be used for a higher level research study (Dubois & Gadde, 2002).

The method mainly used in this study is the deductive method, but with some influences from inductive method, which also is the most common approach in many other case studies. The study started with a literature review in order to enhance the knowledge within the research area, and to be able to develop the aim and the research questions. After this was done, data was collected from case companies to see whether the reality corresponded to theory. In addition, the process was then somewhat iterative, as findings in the case companies affected the formatting of the research questions, and further studies of literature.

3.2 Research strategy

Another expression in research methodology is research strategy, treating the distinction between quantitative and qualitative studies. The two strategies have the same purpose in a study, which is to propose a description of our society and how entities in the society affect and influence each other, but the way to fulfill this purpose is different (Holme, et al., 1997).

The overall definition of quantitative studies is that it involves measurement in one way or another (Bryman & Bell, 2011), and that information is converted into numbers in order to be able to make statistical analyses (Holme, et al., 1997). Borrego et al. (2009) express the purpose of a quantitative study to generalize findings in a sample over a larger area of research through statistical analysis. Holme et al. (1997) mean that a strength of the quantitative study is that the researcher is able to cover a large amount of subjects by having standardized questions. This is often required to increase the generalizability of the study, since research subjects are often chosen randomly in a quantitative study (Eisenhardt, 1989). Furthermore, a weakness with this kind of strategy is that the study won't give any data on the social processes in the studied units (Holme, et al., 1997). According to both Bryman & Bell (2011) and Borrego et al. (2009), the quantitative research strategy is usually a good fit for a strict deductive approach described above, where the theory through several hypotheses is tested with help from empirical data.

The qualitative research strategy, which is defined by Holme et al. (1997) as that information is interpreted by the researcher, that his/her apprehension of the studied subjects is in focus, and that this information cannot or should not be converted into numbers. According to Borrego et al. (2009), a qualitative study is characterized by the collection and analysis of mainly textual data, meaning activities such as conducting and analyzing surveys and interviews, and attending at and observing the research subjects. The authors further explain that qualitative studies also can be used to generalize findings, but that the descriptions are connected to specific contexts, and that the readers can make their own conclusions about how the findings can be applied in their situation. Strengths with qualitative studies are that they give the overall picture of the case and that they are flexible in their design (Holme, et al., 1997). A weakness, however, is that because case studies in a qualitative manner might be very time consuming, not as many units can be investigated as in a quantitative study (Holme, et al., 1997). Bryman & Bell (2011) mean that qualitative studies are mostly suited for an inductive approach, where theory is generated through the findings of the empirical data, but also say that there are several examples where qualitative studies have tested the theory rather than to generate it.

Borrego et al. (2009) mean that, in order to be able to completely and correctly answer the research questions in a qualitative case study, the data has to go through a so called thick description, meaning rich, contextual descriptions. Yin (2014) on the other hand, means that this does not have to be the case, because a case study might be in a mix of qualitative and quantitative strategy, each providing their explanations of the case.

The research strategy used in this study is mainly qualitative, where the researchers' interpretation and analysis stand as a basis for answering the research questions. The number of companies taking part in this study is set at four, which makes it hard to perform a quantitative study, where a high number of participants would be preferred in order to give a bigger data sample. Another reason to choose a qualitative strategy is that due to the nature of the research questions, it is hard to find specific quantitative measurements answering the question of what contextual factors influence the decision of what parts feeding policy to use. The study's aim is instead to through observation assess whether the right feeding policies are used or what feeding policy would fit best in the specific context. This is clearly a qualitative process, where interpretation and apprehension are in focus.

3.3 Research design

Moving further within research methods, there is the question of what research design to use in order to best answer the research questions. According to Bryman and Bell (2011), there are five different kinds of research designs, namely: experimental design; cross-sectional or social survey design; longitudinal design; case study design; and comparative design. All of these designs have their advantages and disadvantages and all fit in different situations and contexts. Since this study will treat four different cases, at four separate companies, the most suitable research designs for this specific study are case study design and comparative design. These will be described below.

A case study is a detailed and thorough analysis of a single case, such as an organization, a location, a person or an event, and case studies are extensively used in business research (Bryman & Bell, 2011). Eisenhardt (1989) describes a case study as focusing on understanding the dynamics of a specific context, and that they usually combine several data collection methods such as interviews and observations. Case studies could generate results that are both qualitative and quantitative, or a mix of both, and could be used to provide a description of the research subject, to test theory or to generate theory (Eisenhardt, 1989). A weakness with a case study could be that due to the specificity of this design, it does not give enough information for a generalization to be made to more than perhaps a specific situation (Dubois & Gadde, 2002; Yin, 2014).

Case studies can involve both a single case or multiple cases, and several levels of analysis (Yin, 2014). When multiple cases are involved in the study and the strategy is mainly qualitative it is called a multiple-case study (Bryman & Bell, 2011). This is an extension of the case study design, and could also be seen as a comparative design. The comparative design improves the creation of theory and makes it easier to see whether a theory holds or not. There could, however, be a weakness here resulting in that the researcher only focuses on the differences between the cases and does not see the specific contexts of each case (Bryman & Bell, 2011).

This study consists of, as mentioned before, four separate case studies, and is primarily of qualitative nature. Apart from studying each case for itself to evaluate every company in its own context, a comparative study has been performed to find similarities and differences among the companies as well as between the companies and the theory.

3.4 Work procedure

This section will describe general views of how a research work procedure is made, as well as how the specific work procedure of the case studies looked like. The different research methods used in this study will be treated and presented in the following order: firstly, the literature review and how current theory has been processed; secondly, data collection with information regarding the case companies and how this has been obtained; and lastly, data analysis concerning how the case companies have been analyzed and how the results have been connected to the current theory.

3.4.1 Literature review

To be able to make a thorough investigation of the situation regarding parts feeding policies, an extensive literature review has been made. It is, according to Eisenhardt (1989) important to process a wide range of literature to be able to build a theoretical framework and to compare to the empirical findings for an interesting analysis of the study. Literature with both similar and contradictory findings are important to include in the framework, in order for the researchers to draw their own conclusions about the situation in the specific case and to show the readers that all options have been considered, and to make the study more valid and easier to generalize (Eisenhardt, 1989).

A literature study has been performed in order to fully understand the theory related to parts feeding systems and what design options there are, especially for LVPs. The theoretical framework does also provide a greater knowledge of what conclusions that previously have been drawn regarding the existing parts feeding policies.

3.4.2 Data collection

According to Yin (2014) there are six sources of evidence for data collection: documentation, archival records, interviews, direct observations, participant observation, and physical artifacts. These sources give different kinds of information, and a good case study should use as many of them as possible (Yin, 2014). The sources relevant for this study will be discussed below.

In this study, an empirical study has been performed in order to build up the awareness of what kind of parts feeding policies that are applied for LVPs in companies today. Four Swedish companies within the automotive industry have been analyzed in the study.

Data from the involved companies has been gathered through semi-structured interviews, both via telephone and in person, and visits at three of the four companies' production facilities. In addition, follow-up questions were asked to the participating companies over telephone and email after the visits at the companies' production facilities. At each participating company, the interviewed employee has been considered to be well familiar with the current design of the respective parts feeding system. The data collection was also complemented by internal documents such as existing guidelines related to parts feeding. This data has given an insight in how the parts feeding is performed in the studied facilities, as well as the reasons behind their choices of the parts feeding policies and whether the current policies are actually suitable for their specific context. This data has also made it possible to draw conclusions about similarities and differences between the studied companies, conducted as a comparative study.

Interviews

The initial contact with the companies was made via e-mail and a first phone meeting was held with each company taking part in the study. During this meeting, the researchers introduced themselves and the project, and the company contact was given the chance to explain how they perceived the project, what results they were expecting and how they could support the researchers in the work of the study. This first phone meeting was mainly unstructured, with only some notes guiding the conversation. No real interview questions were asked, since the meeting was primarily for the researchers and the company contacts to get acquainted. During this phone meeting, the structure for future contact was discussed, where the researchers presented a request of having a phone interview within a couple of weeks, as well as a study visit at each company's production facility a few weeks after that.

The interviews were scheduled a few weeks in advance to give time for the researchers to make themselves acquainted with the current theory, to make sure that the correct questions would be asked. This aligns with Leech (2002), stating that what information you currently possess will decide what questions you will ask. Hence, starting with a wide knowledge base means that it will be easier to attain relevant and valid information from the interviewees, which will enable more thorough analysis and conclusions to be made.

Interviews conducted in case studies are often of the semi-structured type, as were the phone interviews in this study. Yin (2014) describes semi-structured interviews as guided conversations where the researchers both have to follow a question protocol and at the same time ask further questions to deepen the answers from the interviewee, and make sure that the conversation has a friendly tone. Semi-structured interviews are a mix between unstructured interviews (conversations) and structured interviews (surveys), and are helpful to provide detail, depth and a perspective from within the interviewee's situation (Leech, 2002). The questions were sent to the companies prior to the phone interviews for the interviewees to be able to prepare, and the questions for the semi-structured interviews can be found in Appendix II.

Direct observations

To better help the researchers understand the full picture of the parts feeding systems at the companies, and to be able to see what might not have been brought up or kept unsaid during interviews, direct observations were made in the form of study visits at three of the four companies. It was not possible to visit the facility of one company, later denoted as Company B, due to restrictions regarding visits for non-employees during the period this study was conducted. Direct observations carried out in proximity to the interviews are according to Yin (2014) useful to provide additional information about the studied topic, and to increase the reliability of the observations it is important that multiple researchers are present for the observations. During the study visits, both researchers were always present, in order to get the most from the visits, and to be able to discuss and analyze what had been observed.

During the study visits, the researchers followed the parts feeding process of primarily LVPs, and how the most important constituents of the parts feeding system were designed at each case company. The contact person at each studied company led the walking tour in the respective visited facilities, and as specific questions arose, personnel in the different areas of the facilities were asked in order to get the most qualitative data for the study.

Documentation

In order to get a better understanding of the companies as such, and specifically about the parts feeding system and the policies used for LVPs, the companies shared documents and presentations with the researchers during and after the study visits. This data was studied as a complement to the interviews and study visits in order to get more detailed knowledge of the companies and their processes.

Yin (2014) illuminates the importance of knowing that documents do not show all the truth, since they may have been edited or describe something a bit different from how the reality actually looks like. Company documentation should therefore be used carefully, and only as a support to other sources of evidence. These recommendations were followed by the researchers, as documents were only complements to the direct observations and semi-structured interviews, and were continuously discussed with the interviewees.

3.4.3 Data analysis

An analysis approach described by Eisenhardt (1989) for case studies explicitly is the so-called within-case analysis. It involves the detailed description of each case, which is very important to create insight, and to become very familiar with each case as its own unit. This is helpful for the researchers to see the contexts of each company and its situation, to compare between the cases, and later also to generalize patterns across the cases (Eisenhardt, 1989).

To help get the data sorted and to make the analysis easier and higher in quality, it could be a good idea to compare answers from interviewees, to put collected data into arrays and matrices, to create flowcharts and other graphics, and to sort data into chronological order to easier see contexts and sequences in events (Yin, 2014).

This study will, as described above, give a thorough description of each case company – how they work, how their parts feeding policies are designed, and which contextual factors that can be identified. Given this data from four different companies, the analysis will compare current theory from the theoretical framework with the reality in all the case companies, as well as a comparison between the four companies. The analysis will also treat what the most appropriate parts feeding policy would be, based on different part characteristics by connecting current theory with empirical findings and the interpretations and thoughts from the researchers.

3.5 Research quality

To make sure that the quality of the research study and report is at a high level and that the results could be trusted, it is important that the reliability and validity of the study are robust. The terms reliability and validity primarily concern quantitative studies, although it could be applied to qualitative studies through some re-work of the definitions (Bryman & Bell, 2011).

Reliability refers to if the results in the study are repeatable, if the measures are stable and if the results are consistent (Bryman & Bell, 2011). This is important in a quantitative study, but not as much in a qualitative study, since it’s not as important to get the statistical average as it is to understand the whole picture (Holme, et al., 1997).

Validity is according to Bryman & Bell (2011) the most important criterion, and refers to the level of integrity of the conclusions that are generated in the study. Also this criterion, however, primarily applies to quantitative studies, and it is not such a big problem to collect valid information in a qualitative study (Holme, et al., 1997). There may, however, be a problem that even if the information received and collected in the study might be valid, the researchers may interpret the information wrong, and the results will not mirror the reality (Holme, et al., 1997). Another problem may be that the studied subject, if it is a person, might behave in a different way when he/she is studied, according to what he/she thinks the observer want him/her to do. To make sure that the collected data is valid, it is important for the researchers to have a back-and-forth strategy with data collection, meaning that the information is processed several times by both the researchers and the studied subjects (Holme, et al., 1997).

To better apply these concepts to qualitative studies, some authors have adapted them into other concepts. Borrego et al. (2009) explain that the term trustworthiness is often used for qualitative studies instead of reliability and validity. For a study to be trustworthy some criteria are to be fulfilled, for example: a clear statement of the theoretical perspective; asking participants to review research findings; using multiple data sources; and providing thick description of the cases (Borrego, et al., 2009).

By making a comparative study with four different cases in which several different data collection methods are used, this study will provide a high trustworthiness, and the results will be easier to generalize than if only one company would have been studied. Furthermore, the theoretical framework was structured and literature was reviewed before starting to interview the companies. All study visits involved both researchers, and any questions that arose during data collection or analysis were revisited and checked with corresponding interviewee or company contact. All of these actions have made the study and the results more trustworthy.

4 EMPIRICAL FINDINGS

In this chapter, general descriptions of the studied facilities of the participating case companies will be presented. The companies' current view of LVPs will also be described, as well as a description of the parts feeding policies that are used for LVPs and which factors that impact the choice. Furthermore, the design of the parts feeding systems related to each parts feeding policy applied for LVPs will be presented. A short summary where key findings are presented can be found after each company description. Due to confidentiality agreements, the companies will be denoted as Company A through Company D.

4.1 Company A

Company A is a global company within the automotive industry that manufactures heavy-duty vehicles, such as articulated haulers, wheel loaders, road rollers, and excavation equipment. The facility that has been studied manufactures cabs to the vehicles as well as complete fuel tanks and hydraulic tanks for wheel loaders and articulated haulers. Within this study, however, only the parts feeding system related to the final assembly of cabs will be examined. The cabs are delivered to other production facilities within the same company, located in Sweden and Germany, for final assembly of the complete heavy-duty vehicles. Within the production facility that was studied, approximately 400 people are employed and 35 people work within the materials handling department.

4.1.1 LVPs at Company A

Company A offers a high degree of customer adaptation. For instance, the customers are able to choose from 350 different single options for the cab alone when purchasing a wheel loader, making almost every assembled cab unique. Hence, a high degree of flexibility is required in the production process in order to meet the customer requirements.

The interviewee indicated that a pareto relationship exists among the various product options that the customers can choose from, which means that there is a large variation in demand for the different parts managed in the facility. The diverse customer demands result in that many parts in the facility have low consumption volume and therefore can be considered as LVPs. Currently, the company does not have any general guidelines for deciding which material flow to apply for parts based on consumption volume or usage frequency. The LVPs are therefore handled with the same parts feeding policies as parts with higher consumption volume. This is seen as troublesome to the company, since LVPs take up a lot of space at the lineside presentation, even though they are not used that regularly, and prohibit efficient use of the more frequently used parts. Therefore, Company A is looking at how to improve parts feeding for LVPs, and one option is to categorize the parts in the near future. The interviewee expressed that the pareto relationship could be used to create classes based on consumption volume for the parts. The classes should then be treated differently regarding parts feeding, resulting in specific choices for parts feeding policies and the design of the parts feeding system for LVPs.

4.1.2 Factors influencing the choice of parts feeding policies at Company A

The parts feeding system at Company A primarily consists of two material flows that are used to feed parts to all three assembly lines within the facility. Both flows can be categorized as continuous supply, and the biggest reason for the company to be using this parts feeding policy for all parts is according to the interviewee mainly due to tradition, and that the current design of the parts feeding system has worked fairly well in the past. Furthermore, the use of three assembly lines reduces the part variety of each assembly line, making it feasible to display all parts at the lineside presentation. Fasteners and other components that are prepared in pre-assembly processes have different parts feeding policies. However, they are only a small share of the total amount of parts handled in the facility, and therefore, these flows will not be considered in this study nor described in this section.

The two flows in the assembly facility have different designs, and what flow a part is fed through depends on what packaging the part is presented in at the lineside presentations. One flow consists of parts feeding of pallets and the other of boxes and cartons. The majority of the parts are presented at the assembly lines in these standardized packages. More than 5,000 parts are handled within the facility and approximately 70% of them are being used at the final assembly lines, whereas the rest are used at the several pre-assembly workstations in the facility.

The decision of what packaging a part is presented in at the assembly lines is made specifically for each part. The unit load that the part is received in from the supplier, available space at the lineside presentation, as well as sufficient cover time of the part are factors which are taken into consideration when deciding which packaging that should be used at the lineside presentation. The interviewee described that Company A is a relatively small actor compared with many of its suppliers, leading to difficulties to receive the parts in the most appropriate unit load as it could impact the purchasing cost of the parts. As a consequence, a large share of parts is repacked internally before being presented at the lineside presentation. When new parts are introduced, and there is not sufficient space available at the lineside presentation, the unit load of another part could be reduced in order to access the needed space. The part that is repacked into a smaller packaging is often an LVP. As a result, the choice of unit load that parts are presented in at the lineside presentation is not performed in a structured way and it is possible that LVPs are presented in inappropriate packaging leading to excessive space usage and inventory costs.

4.1.3 Description of the parts feeding system at Company A

Cabs for different heavy-duty vehicles are manufactured on the three assembly lines. The cabs for wheel loaders and road rollers are assembled on a continuously moving assembly line while the cabs for haulers and excavation equipment are manufactured on two separate assembly lines, where the cabs are manually transferred between the workstations. The continuously moving assembly line is elevated approximately 1.5 meters from the floor and therefore the parts feeding becomes more complex since the replenishment of parts to the lineside presentation has to be managed with materials handling equipment that can perform vertical lifting. As a consequence, various variants of forklifts are used for parts feeding to the assembly lines. The high degree of forklift traffic in areas where people are operating is considered to be an issue since the safety of the operators is at risk. However, it is difficult to overcome with the current design of the assembly lines. A measurement used at Company A related to workplace safety is the number of risks and accidents identified in the facility, and according to the interviewee, the high degree of forklift traffic is considered to be a large issue for the improvements related to a safe workplace.

The elevated assembly line has 14 workstations, each at about 4 meters in length, and material is mainly presented on one side of the line. The lineside presentation on the other side contains parts needed for the pre-assembly operations that are located in parallel with the assembly line. The takt time is usually 17 minutes, which limits the maximum time allowed for replenishment of pallets to the lineside presentation. The two other assembly lines have similar designs but with fewer workstations and shorter takt times.

With regard to the quality aspect related to the large number of parts being stored at the lineside presentation, the company experiences a risk of picking errors at the assembly line, due to similar parts being stored close to each other. This could be seen as a large disadvantage, since the quality aspect of the offered products is considered to be of high importance for the customers. However, an advantage experienced at Company A regarding all parts being stored at the line is that everything is accessible when it is needed. A measurement that is used for materials handling related to this is internal delivery precision, which is evaluated in terms of how often the parts are available at the lineside presentation when there is a requirement for them. According to measurement data provided by Company A, only a limited amount of shortages is experienced at the lineside presentation, hence the target levels are reached for most months.

Factors that limit the complexity of the parts feeding system at Company A are the low degree of fragile components being used in the facility, and that only a small share of parts are used at multiple workstations. The two material flows in the parts feeding system existing at Company A are described below and an illustration of the material flows can be found in Appendix I.

Parts feeding of pallets

This parts feeding policy is used for parts that should be displayed in pallets at the lineside presentation, and will be described as Continuous Supply A. This material flow is generally applied if there is sufficient space available at the lineside presentation. Currently, around 1,300 parts are stored in pallets and since all parts are delivered in pallets from the suppliers, no repacking is needed. Hence, the parts are transported with forklift from the goods receiving area to buffer storage. The buffer storage is decentralized, located above and below the lineside presentations and has a capacity of 1,800 pallets. The pallets are assigned storage locations according to where the parts are used at the lineside presentation. Replenishment to the lineside presentation is initiated when an assembly operator takes the last component in the existing pallet and scans a barcode located below it. The pallet should be replenished by the material handlers within the takt time in order to avoid material shortages.

Parts feeding of boxes & cartons

The second material flow will be described as Continuous Supply B and involves pallets containing boxes and cartons which instead are transported to another goods receiving area where they are unpacked. This area is also dedicated for parts that should be downsized to another container size. Currently a large share of parts is repacked into other unit loads than they were delivered in. The interviewee estimated that approximately 15% of all parts delivered in pallets are repacked into boxes or cartons and that an even larger share of parts delivered in boxes are downsized to smaller boxes or cartons in order to reduce space requirements in the central storage area and at the lineside presentation.

Boxes are transported from the goods receiving area to a high rack storage with a high reaching order picking truck. Approximately 1,000 parts are stored in boxes at Company A. The storage policy in the high rack storage is generally random, but there is a possibility to restrict parts to specific zones. This restriction has to be done on part-level, thus it is complicated to perform it for all parts stored in the area. Buffer storage for cartons is instead held in two vertical lifts that have a total capacity of 4,500 cartons. Approximately 1,000 parts are stored in cartons, which are transported from the goods receiving to the vertical lifts on a push cart. The buffer storage for boxes and cartons are located in the same area of the facility and can be considered to be centralized since it is the only buffer storage for these parts, concentrated in one area.

A reorder point system controls the inventory levels at the lineside presentation and indicates when replenishment of parts in boxes and cartons is required. Both the picking from the high rack storage and the replenishment to the lineside presentation from both storage areas are performed with a high reaching order picking truck with a rack attached to it. All three assembly lines can be replenished during the same route and therefore, a need for equipment that can manage vertical lifts to the elevated assembly line is required. It is common that the material handler replenishes multiple part numbers during one milk run. Table 6 summarizes the design of the parts feeding systems for each policy used at Company A.

Table 6. Design of the parts feeding system for each parts feeding policy at Company A

Constituent	***Design area***	***Continuous supply A***	***Continuous supply B***
Packaging	Unit load size	Pallets	Boxes & cartons
	Repacking	No	Large share
Storage	Storage configuration	Decentralized	Centralized
	Storage policy	Near point-of-use	Random
Transportation	Material handling equipment	Forklift	Order picking truck
	Routing	Direct	Indirect

4.1.4 Future design of the production system

Company A is planning to redesign the production system within a few years in order to increase the productivity. The development of a mixed-model assembly line where all types of cabs can be assembled will limit the space available at the lineside presentation, thus the current parts feeding system will not be feasible to use. The future assembly line will approximately have the same length as one of the assembly lines in the current design, and therefore a larger amount of different parts has to be handled at the new assembly line. This will also entail that an even larger amount of LVPs will be used at the assembly line due to more products being assembled at the same line. According to the interviewee, the new mixed-model assembly line will not be elevated, thus allowing more efficient parts feeding. Furthermore, it is estimated to take up less space than the current three lines and therefore areas in other parts of the facility will be made available for other activities.

The company is considering to use the freed-up area for a supermarket, kitting area or a sequencing area, but a final decision of the future design is yet to be decided. The design change will enable the company to apply alternative feeding policies, thus reducing the usage of continuous supply, and the direct delivery of pallets using forklifts. This would mean that the company could handle LVPs in a more efficient way when different parts feeding policies can be assigned to parts with different part characteristics, such as consumption volume. Moreover, according to the interviewee, the company is aiming towards eliminating the buffer storage of pallets near the lineside presentation and instead implement a centralized storage area. It would restrict the usage of forklifts to a specific area, leading to a safer workplace environment near the assembly line.

4.1.5 Summary of Company A

To summarize the parts feeding system at Company A, all parts are stored at the lineside presentation in order to enable high efficiency of the assembly system. The company is aware of the significant share of parts that can be considered as LVPs, but no classification is currently used to separate the parts feeding according to consumption volume, thus LVPs can be fed to the lineside presentation in various packaging sizes. As a consequence, the company experiences space restrictions at the lineside presentation with parts stored in larger packaging sizes than necessary. A large share of the parts is downsized in order to reduce the space limitations but the company lacks clear guidelines for which parts to repack. The replenishment of multiple parts in boxes and cartons on the same trip entails efficient parts feeding. However, the efficiency of the parts feeding system is reduced due to the current facility layout with an elevated assembly line, which constrains the company to use material handling equipment that can perform vertical lifts.

4.2 Company B

Company B is a car manufacturer that has production sites in multiple locations around the world. However, the Swedish final assembly facility was the focus for this study, where the parts feeding system related to the main assembly line was analyzed. Within the facility, a wide range of different car models are manufactured.

The variation in customer requirements causes a high number of parts to be handled within the facility and it is common that trends influence the demand for specific end-products and configurations. In addition, there are frequent introductions of new parts, causing an increased amount of parts handled in the facility. The manufacturing strategy is build-to-order and the end-products are manufactured on a mixed-model assembly line, leading to a wide range of parts required for assembly at the right time. The high amount of parts required at the assembly line causes space requirements in the facility which has a layout that, according to the interviewees, is not optimal for the current production system.

4.2.1 LVPs at Company B

Due to the high variety in customer demand, the company manages a high amount of parts within the production facility that have low consumption volumes. However, the company does not have a distinct definition nor classification for LVPs related to parts feeding. The volume of a part is, however, one parameter which is considered when deciding which unit load that a part should be handled in within the facility, and this impacts which parts feeding policy that is selected to use for a part. The company currently has no summarized chart or compilation of the total demand for all of their parts, and therefore has no clear view of what parts could be seen as LVPs. However, one of the interviewees expressed that such a chart could be a guide to find LVPs and perhaps assign a certain parts feeding policy for these parts.

4.2.2 Factors influencing the choice of parts feeding policies at Company B

There are several parts feeding policies used at the studied production facility at Company B. The company has guidelines that express how the policies impact the logistics cost to help prioritize between them. Continuous supply, kanban-based continuous supply, downsizing, minomi, batch supply, internal sequencing, external sequencing and kitting are the used policies, listed in accordance to how the policies increase the logistics cost. A first priority at Company B is to feed the parts directly to the assembly line workstations in their received packaging, resulting in the use of continuous supply or kanban-based continuous supply, depending on packaging. Parts delivered in pallets are fed with continuous supply, while parts in boxes are fed with kanban-based continuous supply. Due to that packaging size is chosen according to consumption volume, it is not common that LVPs are fed with continuous supply.

According to the interviewee, the policies used to the largest extent for LVPs are kanban-based continuous supply, downsizing, and internal sequencing, thus the description of Company B will be limited to cover these policies. Since the parts feeding system of downsizing is designed in a similar way as the parts feeding system of kanban-based continuous supply, with the exception that parts are repacked when fed through downsizing, these policies will be treated as the same parts feeding policy in this report, referred to as kanban-based continuous supply. Internal sequencing will hereby be referred to simply as sequencing.

The choice of policy is made partly based on the logistics costs, but also with an aim to reduce the non-value adding time for the assembly operator. It is therefore important to avoid excessive fetching of material. Part characteristics influence to some extent with which policy a part should be fed to the lineside presentation. These characteristics are the number of variants in a part family, size of the parts, and consumption volume, where a cover time of two hours for the unit loads is preferred. Kanban-based continuous supply is applicable when the variety of parts within a part family is limited since all parts are displayed in boxes at the lineside presentation. A large amount of parts within a part family causes extensive space requirements at the lineside presentation. In this case, sequencing is recommended since the needed parts for the assembly objects are supplied when needed from a sequencing area, thus less space is required at the lineside presentation. The size of a part also influences when the policies are used. Since parts are stored in boxes with kanban-based continuous supply, the parts need to fit into the boxes making it less appropriate for large parts. On the other hand, sequencing is more beneficial for large parts since it can reduce the space requirements at the lineside presentation. Both policies are used for LVPs, but can also be applied for parts with higher volumes, especially if the previously mentioned criteria related to part characteristics are fulfilled. The value of the parts is of less importance compared with the other characteristics according to one of the interviewees. Table 7 illustrates the findings from Company B.

Table 7. Part characteristics influencing choice of parts feeding policy at Company B

Parts feeding policy / ***Part characteristics***	***Kanban-based cont. supply***	***Sequencing***
Variety in part family	Low-Medium	High
Size	Small-Medium	Medium-Large
Consumption volume	Low-Medium-High	Low-Medium-High
Value	Limited impact	Limited impact

4.2.3 Description of the parts feeding system at Company B

The design of the parts feeding system for both policies will in this section be presented, according to the design options that were highlighted in the theoretical framework. A summary of the design options for each policy at Company B can be found in Table 8 in the end of the section. Furthermore, an illustration of the material flows can be found in Appendix I.

Kanban-based continuous supply

Parts fed through kanban-based continuous supply are transported from the goods receiving area to a marketplace by tow train. The marketplace is a storage area dedicated for boxes, causing parts received in pallets to be repacked. This operation is performed in the marketplace and approximately a third of the parts stored here have been repacked. The marketplace is located in another building than the final assembly line and is the only storage location for boxes, thus it can be considered to be centralized. The storage and retrieval is performed manually by operators and the parts consumed in the highest volumes have storage locations on the floor in the marketplace, while the other parts are stored in chutes. Replenishment is initiated when there are empty boxes at the lineside presentation and it is performed with tow trains which have fixed routes, allowing multiple parts to be replenished during one trip. Kanban-based continuous supply is considered to be relatively efficient in terms of logistics costs since only a low degree of preparation is needed in order to feed the parts to the lineside presentation.

Sequencing

Parts that are sequenced to the lineside presentation are received from suppliers in pallets or boxes. Depending on the packaging, the parts are transported with forklift or tow train to the sequencing areas where the buffer storage of parts is located above the picking area. Furthermore, no repacking is performed. There are three different sequencing areas at Company B and the largest is located in another building than the final assembly line. The storage and retrieval of parts are performed manually by the operators. The sequencing area is designed as a corridor with materials facades on the two sides that are opposing each other. The most commonly used parts are located in the middle while LVPs are located further out in the materials facades.

The parts are picked and placed in sequencing racks where each rack consists of a number of compartments. Each compartment is specific to one assembly object, and a rack feeds a specific workstation at the assembly line with a minimum of 20 minutes' up to an hour's production. Due to the takt time being one minute, each rack carries a large number of parts. It is possible, and commonly occurring, that more than one part is picked for each assembly object and put into one compartment in the rack. This means that many of the sequenced parts could be seen to be part of a kit, however Company B does not entitle this set-up as kitting. A specific department is responsible for picking the parts into the sequencing racks using pick-by-voice and barcode scanning. During one picking tour, the picking quantity varies depending on whether the parts are small or large. Large parts are commonly picked one-by-one, while smaller parts are picked in multiple quantities. Also, depending on size and quantity of the parts, the sequencing racks could either be stationary or moved along with the picker. When the sequencing rack has been prepared, it gets transported to the workstation at the assembly line with a tow train. Company B considers the sequencing to be expensive for the logistics department due to the high amount of labor required for the preparation. In addition, the racks need to be delivered to the workstations every 20 to 60 minutes, causing many trips for the materials handling department to perform.

According to the interviewees, about 800,000 picking operations are performed during an average week. The picking accuracy in the sequencing process is of high importance at Company B and is considered to be world class, according to the interviewee, who states that it has been enabled through pick-by-voice support. Historically, pick lists and pick-by-light have been used, but the picking accuracy has improved through the current design. In addition, picking accuracy can be kept high, even though no quality control is performed during the preparation of sequenced parts. However, problems can occur when a faulty part is delivered to the final assembly line. Since there is no buffer storage for sequenced parts at the lineside presentation, it could cause a production stop. The most common way of solving this is to borrow a similar part from another compartment in the sequencing rack if available.

Table 8. Design of the parts feeding system for each parts feeding policy at Company B

Constituent	***Design area***	***Kanban-based cont. supply***	***Sequencing***
Packaging	Unit load size	Boxes	Pallets & boxes
	Repacking	Commonly occurring	No
Storage	Storage configuration	Centralized	Decentralized
	Storage policy	Random	Class-based (volume)
Transportation	Material handling equipment	Tow train	Tow train
	Routing	Indirect	Indirect
Picking	Picking quantity	-	Varies
	Picking information	-	Pick-by-voice & barcode scanning
	Picking location	-	Far away from lineside presentation
	Responsible for picking	-	Specific department

4.2.4 Summary of Company B

To summarize the case description of Company B, there is no distinct definition for LVPs even though the high amount of parts in the facility causes many parts to be used to a low extent. The company has guidelines for when each parts feeding policy is recommended to use. These guidelines aim at reducing the logistical work for the parts feeding and enable a high degree of value adding time for the operators at the assembly line due to the short takt time. A limited amount of parts is fed with continuous supply. The guidelines recommend downsizing and feeding through kanban-based continuous supply as a first alternative to overcome the space limitations, however, sequencing is preferable when further space reductions are needed or if the parts are large. The reason for this is that kanban-based continuous supply is considered to require less logistical work than sequencing. Sequencing is performed with pick-by-voice and the quality of the picking operations is expressed to be world class.

4.3 Company C

The third studied facility belongs to a global company within the automotive industry that primarily manufactures trucks and buses. The final assembly of trucks has been studied since it accounts for approximately 90% of the manufactured units in the Swedish facility. Company C has a build-to-order strategy for their manufacturing process of trucks where a high number of different end products can be configured. All trucks are assembled on the main line; thus it is considered to be a mixed-model assembly line.

The main line at Company C has a seven minute takt time. It consists of about 40 workstations, each with an approximate length of 10 meters, and about 21,000 unique parts are being handled. The company perceives a relatively stable demand and are not affected by seasonal fluctuations. A small fraction of the parts is used at multiple workstations, although this primarily applies for fasteners. A majority of the parts can be stored in the standard containers that are used at the company. This includes pallets as well as several boxes in various sizes. In addition, only a limited amount of parts is fragile and has to be handled with care.

4.3.1 LVPs at Company C

The parts feeding system at Company C consists of multiple feeding policies that are combined with the aim of supplying parts to the assembly line at the lowest cost. The company has guidelines for when each feeding policy is most preferable and aims to reduce the logistical work content per part number. The logistical work content is perceived to be lowest when storing the parts at the lineside presentation, however, due to the space limitations at the lineside presentation at Company C, this is not feasible for all parts. In order to identify what amount of logistical effort that should be allowed for the different parts, the company uses an ABC-classification, where the categorization of parts is based on consumption volume per shift. The classification follows a pareto-shaped distribution where the parts that account for 80% of the picks are considered as A-parts, 15% as B-parts and the remaining 5% as C-parts. Since the scope of this study is on LVPs, more emphasis will be put on the C-parts. The consumption volume for parts within the C-category is aimed at a maximum of three parts per shift due to space limitations. With the current classification, about 5,500 SKUs are categorized as C-parts which is equivalent to approximately 25% of the total amount of parts handled in the facility.

The company currently lacks a systematic approach for revising the parts feeding policies assigned to the different parts, thus changes are primarily made in a reactive manner when problems occur. For instance, every day approximately two parts are revised for parts feeding policy changes, which could be derived to either shortages or excessive stock. This is an effect of fluctuations in consumption of existing parts as well as introductions of new parts. A general strive is to revise the parts feeding policies proactively, to avoid shortages and issues with space restrictions both at the lineside presentation and at the platforms, which can be described as supermarkets.

4.3.2 Factors influencing the choice of parts feeding policies at Company C

The parts feeding system at Company C can be divided into four categories of parts feeding policies, with a total of nine unique designs. The ABC classification stands as a basis for choosing an appropriate parts feeding policy for a part. C-parts are restricted to be fed with the low volume kit and partly sequence policies and therefore this study is limited to include these two policies, and they will be referred to simply as kitting and sequencing from now on. However, other factors which impact the choice of policy include space available at the lineside presentation as well as part characteristics which will be further described below.

With regard to part characteristics, as can be seen in Table 9, both policies used for LVPs are suitable to use for parts with a high amount of variants within its part family. However, kitting applies for parts that are smaller, while sequencing is used for larger parts. In addition, both policies are restricted to parts which have a consumption less than 3 units per shift. The value of the parts does also to some extent impact the choice of policy since low value parts, such as fasteners, are fed with continuous supply. Therefore, it is more common that parts that are fed through kitting and sequencing have a relatively high economic value.

Table 9. Part characteristics influencing choice of parts feeding policy at Company C

Parts feeding policy / ***Part characteristics***	***Kitting***	***Sequencing***
Variety in part family	High	High
Size	Small-Medium	Large
Consumption volume	Low	Low
Value	Medium	High

4.3.3 Description of the parts feeding system at Company C

The company experiences space restrictions in the facility due to increased production volumes and number of parts. As a consequence, a logistics center (LC) located next to the main facility has been implemented for buffer storage of parts and several materials handling operations. The goods receiving and storage of all LVPs are located in the LC. Approximately 150 employees within the main facility perform tasks related to materials handling while there are 100 employees within the LC. The design of the parts feeding systems related to kitting and sequencing will be described below and is summarized in Table 10. Additionally, the material flows are illustrated in Appendix I.

Kitting

A specific department is responsible for kit preparation, which is performed in the LC. Approximately 1,200 picks are performed per day and the department responsible for kit preparation and replenishment to the storage areas consists of eight employees plus a team leader per shift. Picking of parts to the kits is performed directly from the parts storage locations, divided into one section for pallets and another for boxes. The storage policy for parts in pallets is random while boxes have fixed storage locations for the most frequently picked parts and random for parts with lower consumption.

Picking in the two storage areas is performed in separate routes and different types of order picking trucks are used as materials handling equipment. The kits are prepared in batches consisting of kits for six vehicles manufactured in one section of the assembly line. The kit preparation process is performed by a picker who receives labels describing which parts to pick and where they are located. Due to lack of system support, methods such as pick-by-voice and pick-by-light are not currently used. The parts picked from the box storage are placed in boxes, where each box is dedicated for one kit and the parts located in the pallet storage are instead picked into a large box holding parts for several kits. When all parts have been picked, a quality check of the kits is performed by another employee in order to assure the quality of the kits. The quality assurance has been implemented since inaccurate kits are costly, causing missing parts to be transported directly to the workstation with emergency transports. These could be described as transports which were not planned for and according to the interviewee, 18 out of 500 emergency transports during a 20-day period derived from inaccurate kits. Common quality issues related to kit preparation concern placing parts into the wrong kits and missing parts in the kits.

After the quality check, the parts picked from the different storage sections are merged into a large container which is transported with a large wagon train to a platform area. The assembly line is divided into multiple sections; each being replenished with material from separate platforms. In the platform area, the large container is attached to a tow train, which performs the transport to the workstations requiring kits. At the workstation, the kits are put into a kit rack which is adapted to the design of the kits with one section for small parts delivered in kit boxes and a separate section for the larger parts.

The picking accuracy for the kit preparation is continuously monitored. It is measured by the amount of incorrect parts that have been detected by the operators at the assembly line. Thus, there is no measurement of how many incorrect parts that have been detected during the quality check. The current target for the picking accuracy is to have less than 300 ppm, which is a number that Company C aims to reduce. However, according to the interviewee, this is hard to achieve due to the current method for picking operations. For instance, the use of physical labels and separate picking routes for parts in pallets and boxes are aspects that are considered to limit the picking accuracy.

Sequencing

The other parts feeding policy for LVPs at Company C is sequencing, which is the most logistically demanding policy of all applied in the facility. Sequencing applies primarily for part families where a few variants account for a large share of the demand, while many variants have low consumption. In this scenario, the high consuming parts are fed to the assembly line with continuous supply. The LVPs are instead stored in the centralized LC in pallets. The parts required for six vehicles manufactured in one section of the assembly line are picked in the same batch directly from the storage locations. The picking is performed by a specific department using a pick list. The transportation to the assembly line follows the same procedure as for kits where they are transported via the platform area.

Table 10. Design of the parts feeding system for each parts feeding policy at Company C

Constituent	*Design area*	*Kitting*	*Sequencing*
Packaging	Unit load size	Pallets & boxes	Pallets
	Repacking	No	No
Storage	Storage configuration	Centralized	Centralized
	Storage policy	Pallets: Random Boxes: Class-based (volume)	Random
Transportation	Material handling equipm.	Tow train	Tow train
	Routing	Indirect	Indirect
Picking	Picking quantity	For several orders	For several orders
	Picking information	Labels	Pick list
	Picking location	Far away from lineside pres.	Far away from lineside pres.
	Responsible for picking	Specific department	Specific department

4.3.4 Summary of Company C

Company C handles a large number of parts within its production system and has developed guidelines for when each parts feeding policy is most suitable to apply. The aim is to reduce the total logistics cost while managing the trade-off with space limitations both at the lineside presentation and in the platform areas. All parts are classified according to an ABC classification based on usage per shift and approximately 25% of the parts are considered as LVPs. The LVPs are fed to the lineside presentation with kitting or sequencing, which are the most logistically demanding parts feeding policies used in the facility. However, the feeding policies reduce the space requirements both at the lineside presentation and in the platform areas since the parts do not have fixed storage locations in these areas and the material handling operations are performed in the LC. Kits and sequenced parts are prepared by specific departments and are transported to the lineside presentation via the platform area, thus allowing consolidation with other parts that should be replenished to the lineside presentation. High quality of the kits is perceived to be important, however the current kit preparation process constrains the quality of the kits to some extent. As a consequence, a quality inspection is performed before the kits are delivered to the lineside presentation.

4.4 Company D

The production facility of Company D that has been studied carries out assembly of heavy-duty engines, and is located in Sweden. The customers require a large variety of engines, causing Company D to have many part varieties in their assortment. There are approximately 800 employees working in the final assembly facility and 120-140 have tasks related to materials handling. The total amount of parts in the production facility is around 6,000, where the majority is used in final assembly of the engines.

There are three assembly lines within the facility, one main line and two variant lines. The production volume is higher at the main line and fewer product variants are manufactured compared with the two variant lines. As a consequence, the variant lines are fed with LVPs to a higher degree. The number of workstations are approximately 30 at the main line, 15 at one variant line and 20 at the other variant line, and the length of the workstations varies, albeit in terms of a few meters. The takt times for the assembly lines are 3, 10 and 12 minutes for the main line and variant lines respectively.

There are four major storage areas within the facility, consisting of an automated central storage, a supermarket, three materials facades and three sequencing areas. The automated central storage contains buffer storage for a large amount of parts, such as LVPs. The supermarket contains storage for parts in boxes and is also used for consolidation of LVPs that are fed with kanban-based continuous supply, which will be further described below. The sequencing areas are decentralized storage areas located close to the assembly lines, where parts that are sequenced to the materials facades are stored. The materials facades are decentralized storage areas located next to the assembly lines where all parts needed for assembly are kitted to the assembly lines.

4.4.1 LVPs at Company D

All parts that are fed through the supermarket are classified into low, medium or high volume flows based on consumption volume. An LVP is at Company D defined as a part with a consumption that does not exceed one unit load per day, i.e. at most one delivery per day is performed to the materials facades. In general, the company strives to use unit loads that equal a cover time of two hours in order to limit space requirements and make the parts presentation better. According to this definition, the interviewee estimated the share of LVPs to be approximately 10-13 % of the total amount of parts. A part can be used at all three assembly lines, and can be used in different volumes at each line. However, the highest volume decides how the parts should be classified, i.e. if a part is high volume at one line and low volume at the other two lines, the part will be classified as a high volume part. Company D experiences difficulties with LVPs today, mostly due to the wide assortment of parts that require storage in the facility as well as material handling. Additionally, continuous introductions of new product models require storage space for new parts, often demanded at low volumes in the beginning. Currently, no continuous revision of the categorization into low, medium or high flow through the supermarket is made for the parts. Therefore, consequences such as material shortages or excessive space requirements could occur if the demand for a part changes, while the categorization for the part is kept the same.

4.4.2 Factors influencing the choice of parts feeding policies at Company D

The parts feeding system has a similar design for all assembly lines at Company D, and the description will therefore be general but applicable to all assembly lines at the facility. The parts feeding system contains several different material flows but there are two policies that primarily apply for LVPs, namely kanban-based continuous supply and sequencing. There are three different designs of the kanban-based continuous supply, where the classification of parts into low, medium and high volume flows are separated. The flow for LVPs will primarily be described, however, since the design of their respective parts feeding system overlaps, the two other flows will be included to some extent.

There are three material flows at Company D which will not be considered in this study because they are either used for a limited amount of parts or primarily used for parts consumed in higher volume. The excluded material flows concern fasteners that are stored directly at the lineside presentation, pallets being transported directly to the materials facade from the automated central storage, as well as parts fed to the materials facade through minomi.

The largest problem experienced by Company D is the lack of space to store and present parts in all of the different areas of the facility, i.e. materials facades, the supermarket, the sequencing areas, and the automated central storage. The lack of space has influenced the design of the current parts feeding system, where all parts are kitted from the materials facades to the assembly lines. Another reason for the current design is that Company D aims for a focus on value-adding activities for the assembly operations, where activities such as fetching and unpacking of material should be reduced or avoided.

Parts fed through kanban-based continuous supply have fixed storage locations in the materials facades, while sequenced parts share dedicated storage locations in sequence racks. Therefore, part families with many varieties and large parts are preferred to feed through sequencing since it reduces the space requirements in the materials facades. It is also common that the sequenced parts have high economic value. Furthermore, the weight of the parts impacts the choice of feeding policy. For instance, kanban-based continuous supply is less favorable for heavy parts as they are presented in boxes and cartons which have weight restrictions of 12 kg for ergonomic reasons. Table 11 summarizes for which part characteristics kanban-based continuous supply and sequencing are generally applied.

Table 11. Part characteristics influencing the choice of parts feeding policy at Company D

Parts feeding policy / *Part characteristics*	*Kanban-based cont. supply*	*Sequencing*
Variety in part family	Low-Medium-High	High
Size	Small-Medium	Large
Consumption volume	Low-Medium-High	Low-Medium-High
Value	Limited impact	High

4.4.3 Description of the parts feeding system at Company D

The parts feeding systems related to kanban-based continuous supply and sequencing will be described in this section. The systems will be described separately, however, since all parts are fed with kitting from the materials facade to the assembly line, the design of the parts feeding system related to this policy will also be described. An illustration of the material flows at Company D can be found in Appendix I.

Kanban-based continuous supply

The goods receiving for LVPs is performed in connection to the automated central storage area, where the buffer storage of LVPs is located. From the goods receiving, the parts are transported to the automated central storage with an automated pallet transport, hence the parts are required to be stored on pallets in the buffer storage, although the pallets might contain boxes or cartons. The replenishment of LVPs to the materials facades is indicated through a kanban signal being the empty box or carton at the materials facades.

The parts are fetched from the automated central storage, and downsized if needed directly in the automated central storage before being transported to the supermarket with an order picking truck. The replenishment time from the automated central storage to the materials facade should be less than one hour. However, the retrieval from the automated central storage is currently an unstable process and is not working as well as it should, which leads to that fetching pallets could today vary between 20 minutes and over 3 hours.

At the supermarket, the LVPs are put in chutes in two reserved sections, and hence do not have fixed storage locations. Medium and high volume parts fed through kanban-based continuous supply have dedicated storage locations. The replenishment from the supermarket to the materials facades of all parts fed with kanban-based continuous supply is performed by tow trains that perform milk-runs. The tow trains can replenish both high, medium and low-volume parts on the same replenishment trip.

Sequencing

The second parts feeding policy used for LVPs is sequencing. There is one sequencing area for each assembly line, and these areas are supplied with pallets from the automated central storage via drop stations. The pallets are transported with the automated pallet transport to the drop station, where a forklift picks up the pallets and delivers them to the sequencing area. The preparation of the sequenced parts is performed directly from pallets that are assigned locations according to part family, and no repacking is performed. Operators at the specific department manually picks batches ranging from two to five parts to a specially built sequence rack with a pick list as picking information, and the sequenced parts are transported with a tow train to the materials facades. The interviewee expressed that the picking operations in the sequencing areas are not as efficient as in the kit preparation in the materials facades. It was also stated that the sequencing areas take up relatively large space since the parts are stored in pallets and some parts within the part family have low consumption.

From the materials facades to the assembly lines - Kitting

Every part that is taken from the materials facade to the assembly line is kitted by the operators themselves or by specific kitting personnel. The kits are prepared in the decentralized materials facades using pick-by-light, put on a push cart and then docked onto an AGV at the workstation. The kits are following the engines for up to three workstations, hence considered travelling kits.

When a quality problem related to a kit is detected at the assembly lines, for example with a missing part, it is common that the operator asks a person responsible for kitting preparation to fetch a new part, instead of making a formal documentation of the problem. This is a consequence of the proximity between the materials facades and the assembly lines. Table 12 summarizes the design of the parts feeding systems for parts fed with kanban-based continuous supply, sequencing and kitting.

Table 12. Design of the parts feeding system for each parts feeding policy at Company D

Constituent	*Design area*	*Kanban-based cont. supply*	*Sequencing*	*Kitting*
Packaging	Unit load size	Boxes & cartons	Pallets	Pallets, boxes & cartons
	Repacking	Large share	No	No
Storage	Storage configuration	Centralized	Decentralized	Decentralized
	Storage policy	Random	Family grouping	Class-based (volume)
Transportation	Material handling equipm.	Tow train	Tow train	Push cart
	Routing	Indirect	Indirect	Direct
Picking	Picking quantity	-	For several orders	For one order
	Picking information	-	Pick list	Pick-by-light
	Picking location	-	Close to lineside pres.	Close to lineside pres.
	Responsible for picking	-	Specific department	Assembly department

4.4.4 Summary of Company D

The parts feeding system at Company D is influenced by the space restrictions in the facility. As a consequence, all parts are kitted to the assembly lines from the materials facades located nearby. The company defines LVPs to be used less than one unit load per day. Approximately 10-13 % of the parts are considered as LVPs and are primarily fed to the materials facades through kanban-based continuous supply or sequencing. The buffer storage of LVPs is located in an automated central storage, with storage and retrieval operations that are perceived to be unstable. The replenishment of LVPs fed through kanban-based continuous supply is carried out via the supermarket, which allows consolidation with medium and high volume parts. The kit preparation in the materials facades is performed with pick-by-light, while pick lists are used in the sequencing areas.

5 ANALYSIS

In this chapter, the empirical findings from the multiple-case study described in the previous chapter will be connected with the theoretical framework. A comparison will be made between the case study companies, but also between them and the theoretical framework. The chapter is divided into three separate sections that each cover one of the three research questions that were formulated in the introduction.

5.1 Definition of LVPs

This section includes an analysis of how a definition for LVPs can be constructed for parts feeding in the automotive industry. From the multiple-case study, it was identified that all companies handle parts that are consumed in low volumes. Company A, which makes no distinction regarding parts feeding between LVPs and parts with higher consumption, expressed that the parts feeding of LVPs is problematic as it increases space requirements at the lineside presentation. The current set-up where decisions regarding parts feeding is performed individually for each part, can be considered to be a complex process and it is therefore possible that parts are fed and displayed in a suboptimal way. van Kampen et al. (2012) clearly state that the complexity could be reduced by performing a classification of the parts, allowing decisions to be made on an aggregate level.

The largest reason for Company A to use the same parts feeding policy for all parts in the facility is mainly due to tradition. However, the new design of the production system that will be implemented will require the company to categorize its parts when new policies such as kitting and sequencing could be used, in order to efficiently feed parts with different part characteristics with the most suitable parts feeding policy. Such classification could be made for example through the pareto relationship that exists among the options for the end products, expressed by the interviewee at Company A. In this distribution of options, a boundary could be drawn to differentiate the LVPs from the higher-volume parts. This goes in line with what theory states about ABC classification and that parts could be split into classes according to their consumption volume.

Company C & D have developed their own definitions for LVPs that impact how the parts should be fed to the lineside presentation. Company C categorizes LVPs as parts with a consumption volume less than 3 parts per shift, whereas Company D takes the packaging size into consideration, stating that LVPs are parts that are consumed in less than one unit load per day. A potential risk with the latter definition is that the number of unit loads can change by using another packaging size while consumption remains stable. Since it has been identified that repacking is used to a large extent by several companies in the study, the definition is not very robust, as a part can be considered out of scope of the LVP definition by downsizing to a smaller packaging size. In that sense, Company C has a more suitable approach since their definition categorizes the parts with the lowest consumption volumes as LVPs.

It could be concluded that it is important to have some sort of classification of the parts within a company. This is especially true within the automotive industry where customer demand is highly variable leading to a high amount of different parts, many of which are consumed in very low volumes. By efficiently feeding parts in different ways depending on their division into classes based on consumption volume, several advantages could be seen from both theory and empirical studies. Accordingly, the reduced complexity with a classification would make it less demanding to assign parts feeding policies to different classes, instead of making a separate decision for every part. By simplifying the choice of parts feeding policy for the parts, it would be easier for the companies to reduce space requirements in their facilities, which have been shown to be the most important criterion for the companies.

It is not possible to conclude that the distributions of parts at the case-study companies follow a similar pattern, regarding how large share that can be considered as LVPs. With their current definitions, Company C has approximately 25% of their parts within the LVP category, while Company D considers 10-13% to be LVPs. Additionally, Company A shows a clear pareto distribution for the consumption of the options for their end products, as a few configurations account for a large share of the total consumption, although an LVP definition does not exist. It can therefore be assumed that a large share of the parts handled in their facility has low consumption volume. Company B shows a similar distribution of their assortment where a high share of the parts accounts for a low degree of the total consumption. When comparing the distribution of parts consumed in low volumes at the four studied companies, it could be seen that the share of parts which should be considered as LVPs differs among the companies. It is therefore necessary for the companies to perform their own classification of LVPs that would be most suitable in their context.

Another aspect which is relevant to consider when classifying parts based on volume is the fluctuations in demand which could impact the demand distribution over time. The LVPs should over time consist of the parts with the lowest consumption volume, hence it is critical to revise the classification continuously in order to have the right parts within the LVP category. For instance, Company D expressed that introductions of new parts often leads to low volumes in the beginning, hence it is likely that the classification of these parts needs to be revised when the parts have become more mature. Company C and Company D, which have classified their parts, do not currently have processes for continuously revising their classifications. Instead, this is performed in a reactive manner which could cause part shortages or excessive stocks resulting in less efficient parts feeding.

5.2 Parts feeding policies’ suitability for LVPs

Within this study, four parts feeding policies have been included for comparison. It should be noted that additional parts feeding policies are used at the studied companies, but continuous supply, kanban-based continuous supply, kitting, and sequencing have been chosen to compare due to their frequent usage in practice as well as their coverage in existing literature. Therefore, it is important to clarify that this study does not cover all possible parts feeding policies that could be applied for LVPs in the automotive industry. However, it is believed that this study contributes with relevant insights in how the four covered policies could be applied for LVPs. Each policy will in this section be discussed separately and evaluated as to how suitable it is for parts feeding of LVPs.

5.2.1 Continuous supply

Previous findings conclude that an advantage with continuous supply is the limited logistics costs compared with other policies since the parts can be directly fed to the lineside presentation without any rework. This aligns with comments from Company A as well as existing guidelines at Company B and Company C. However, a trade-off with the policy is the excessive space requirements which the policy causes since each part is stored at the lineside presentation. All four studied companies experience space restrictions within their facilities, especially in the areas near the assembly line, making it unsuitable to feed all parts with continuous supply. Existing theory identified high consumption volume (Hua & Johnson, 2010) and low variety in part family (Sali, et al., 2015) as part characteristics suitable for continuous supply. With these characteristics, parts can efficiently be delivered to the lineside presentation without taking up too much space. However, since LVPs are consumed in low volumes, it could be concluded that continuous supply is less beneficial for this segment of parts.

Additional part characteristics that were mentioned in existing theory were the size and value of the parts. With regard to size, Sali et al. (2015) stated that continuous supply was preferable for larger parts. This study has not been able to confirm nor reject this statement, however, as the studied companies' experience space restrictions at the lineside presentation, companies should avoid feeding large parts consumed in low volumes with continuous supply since these parts take up much space. With regard to the value of the parts, Caputo & Pelagagge (2011) stated that parts with high value are less preferable to use continuous supply for since this policy has a higher impact on the work-in-process, increasing the inventory cost. However, a majority of the case study companies did not perceive the value of the parts as a prioritized criterion when deciding parts feeding policy.

Another objective which Company B, C and D highlighted as important was the reduction of non-value adding time for the assembly operators. Continuous supply is according to Medbo & Wänström (2009) less appropriate for this reduction due to, for instance, increased time needed to fetch parts compared with other parts feeding policies. The only studied company that used continuous supply extensively for LVPs was Company A, using this policy for feeding of all parts to the assembly line. The takt time at Company A was the longest among the studied companies and according to Johansson & Johansson (2006), this aspect would actually increase the amount of space needed at the assembly line, hence reducing the appropriateness of using continuous supply as parts feeding policy. On the other hand, Company A has three assembly lines manufacturing different vehicles, decreasing the number of variants at each line compared to if they were all going to be manufactured in a fully mixed-model assembly line. This makes the number of parts needed to be located at the lineside presentation less demanding, resulting in lower space requirements compared to the other facilities in the study and making it plausible to use continuous supply for all parts. Another aspect that was mentioned by Company A regarding continuous supply is the increased risk of picking errors for the assembly operators due to that all parts, many similar to each other, are located at the lineside presentation. As Baudin (2002) states that picking errors is the most common cause of defects in assembly operations, this could result in quality issues on the end products.

5.2.2 Kanban-based continuous supply

In contrast to traditional continuous supply, kanban-based continuous supply can reduce space requirements at the lineside presentation, mainly due to that parts could be stored in smaller containers and be fed more often to the line. The space issue has been seen to be very important at all studied companies, and this, together with the logistics cost, greatly influence how the priority of parts feeding policies is set at companies. Since kanban-based continuous supply is cheap to implement (Kouri, et al., 2008), and according to Company B is not particularly logistically demanding and does not induce more work than the occasional downsizing process, the policy often ranks high in how companies prioritize between policies. However, what is not taken into consideration at the companies, but that is highlighted by Caputo & Pelagagge (2011), is the fact that kanban-based continuous supply, due to the reduced work-in-process, is more suitable for parts of higher economic value than the traditional continuous supply.

However, there are restrictions with this policy that have to be considered at the companies. Firstly, if the parts are big and the variety within the part family is high, not much space is reduced compared to continuous supply, since all parts still have their fixed location at the lineside presentation. Limits concerning size and weight for parts fed with kanban-based continuous supply have been expressed by Company B and D since the parts should fit in smaller unit loads. This aligns with Faccio (2014), stating that kanban-based continuous supply is used to frequently replenish parts in small unit loads, hence not being suitable for larger parts. Furthermore, the companies have the criterion that the variety within part families should be low to medium, which can be seen in Table 13. A problem could also be seen if the parts are consumed infrequently and not used during a longer period of time, since they still take up space at the lineside presentation. The policy should therefore be used for parts with steady consumption, which is expressed by Jonsson & Mattsson (2009). Similarly, kanban-based continuous supply should be used when there are limited amounts of parts within parts families and for small or medium sized parts.

Table 13. Summary of parts fed with kanban-based continuous supply at case companies based on part characteristics, compared to findings from theory

Kanban-based cont. supply / *Part characteristics*	*Company B*	*Company D*	*Theory*
Variety in part family	Low-Medium	Low-Medium-High	Low-Medium
Size	Small-Medium	Small-Medium	Small-Medium
Consumption volume	Low-Medium-High	Low-Medium-High	Medium-High
Value	Limited Impact	Limited Impact	Medium-High

5.2.3 Kitting

Among the companies that have been studied, it is primarily Company C that applies kitting for LVPs. Company A does not currently use kitting in their facility. However, it was stated that the company is considering to implement it after they have changed their production system in order to overcome the increased space restrictions at the lineside presentation as well as to increase the productivity of the assembly system. Both these aspects align with existing theory, stating that space is freed up near the assembly line (Bozer & McGinnis, 1992) and that the assembly workers will spend less time on non-value adding tasks such as fetching of parts (Medbo & Wänström, 2009). Company D has a design of their parts feeding system that differs from Company C since all parts are kitted from the materials facades to the assembly lines. Hence it could be stated that LVPs with all different types of part characteristics are kitted in the facility, and a comparison of part characteristics is therefore not applicable. However, the design of the parts feeding system related to kitting at both Company C and Company D will be treated in section 5.3.2, treating the design of the parts feeding system related to kitting.

Company C, which specifically applies kitting for some LVPs, considers kitting to be one of the most logistically demanding policies applied in the facility. The advantages that the company can gain from applying the policy is reduced storage requirements at the lineside presentation since the kit preparation is performed in a centralized storage area. In Table 14, a summary is presented of which part characteristics that primarily are fed to the lineside presentation with kitting at Company C, as well as findings from existing literature of when the policy is suitable, which was described in section 2.2.1. As can be seen, Company C's usage of the policy aligns with the theory in most aspects. A high amount of varieties in the part family, small or medium sized parts and parts consumed in low volumes are recommended in theory and is applied by Company C. Lower emphasis was put on the impact of part value when assigning parts feeding policies at Company C. However, the company does not feed low value parts through kitting, hence aligning to some extent with the theory, stating that kitting is beneficial for high value parts (Caputo & Pelagagge, 2011).

Table 14. Summary of parts fed with kitting at Company C based on part characteristics, compared to findings from theory

Part characteristics / ***Kitting***	***Company C***	***Theory***
Variety in part family	High	High
Size	Small-Medium	Small-Medium
Consumption volume	Low	Low
Value	Medium	High

Since the largest difficulty related to parts feeding at Company C is the space restrictions at the lineside presentation, the use of kitting contributes with benefits in order to overcome this. On the other hand, the policy induces logistics costs. Since the studied policy is primarily used for LVPs at Company C, it could be concluded that the benefits gained in reduced requirement of space at the lineside presentation is greater than the increased logistics costs. This is a consequence of that logistics costs arise in kit preparation, which, due to the parts being consumed in small volumes, is performed to a low extent. Additionally, the feeding policy will save a great amount of space at the lineside presentation compared to if all parts would have had fixed locations. Hence, the kit preparation costs can be held at a relatively low level.

5.2.4 Sequencing

As has been highlighted, sequencing can be seen as a variant of kitting, where each kit consists of only one part. This entails that these two policies share many benefits and drawbacks, and are suitable for roughly the same parts. The biggest difference however, is that while kitting is mostly suitable for small to medium sized parts, sequencing reaps its most benefits when used for larger parts, which could be seen in theory and which has been expressed by all companies using the policy, namely Company B, C and D. The part characteristics used as guidelines for the companies to choose sequencing as a parts feeding policy, as well as what has been highlighted in theory, can be seen in Table 15.

Table 15. Summary of parts fed with sequencing at case companies based on part characteristics, compared to findings from theory

Sequencing / ***Part characteristics***	***Company B***	***Company C***	***Company D***	***Theory***
Variety in part family	High	High	High	High
Size	Medium-Large	Large	Large	Large
Consumption volume	Low-Medium-High	Low	Low-Medium-High	Low
Value	Limited Impact	High	High	High

All studied companies using sequencing have been observed to use the policy for parts with a high variety within their part families, which is also highlighted by theory. Only Company C goes in line with the theory by using sequencing solely for LVPs, while the other two companies mainly choose the policy based on high variety in part family, while the consumption volume is not considered. The reasons for these three companies to use sequencing in their parts feeding system is primarily to further save space at the assembly line compared to for example kanban-based continuous supply, as well as for reducing the non-value adding time for the assembly operators. The latter has been expressed especially at Company B and D, and it is important to consider that this would be put against the induced logistics cost, that is described for example in the guidelines at Company B and C. These companies put sequencing in the higher end of the spectrum concerning logistics cost, due to the extensive handling and transportation that is required. Due to that the logistics cost is high, and the consumption volume is low, the policy fits best for parts with a higher economic value since these will not be stored at the assembly line. The part value criterion is considered at Company D, and to some extent at Company C.

5.3 The design of the parts feeding system related to parts feeding policies

The design of the parts feeding system can differ in many aspects, which has been identified in the case studies. Constituents of the parts feeding system apart from parts feeding policies that have been highlighted in the theoretical framework, fall into the categories of packaging, storage, transportation and picking, where the latter primarily concerns kitting and sequencing. Some of the identified design areas within each constituent will in this section be evaluated according to how they affect the parts feeding system for LVPs. Since it was concluded in section 5.2.1 that continuous supply is a less suitable parts feeding policy for LVPs, it will not be included in this section. Hence, the design areas for kanban-based continuous supply, kitting and sequencing will be analyzed.

5.3.1 Kanban-based continuous supply

Company B and Company D use kanban-based continuous supply for feeding of a large share of the parts in their systems, including LVPs. In many aspects, the design of the parts feeding systems related to the policy are similar at the companies. However, a significant difference is that Company B uses the parts feeding policy to feed directly to the lineside presentation while Company D uses the policy to feed parts to the materials facades where the parts are kitted to the assembly line. Table 16 shows a comparison of the design of the parts feeding systems related to kanban-based continuous supply at Company B and Company D.

Table 16. Comparison of the design of the parts feeding systems for kanban-based continuous supply at Company B and D

Constituent	*Design area*	*Company B*	*Company D*
Packaging	Unit load size	Boxes	Boxes & cartons
	Repacking	Commonly occurring	Large share
Storage	Storage configuration	Centralized	Centralized
	Storage policy	Random	Random
Transportation	Material handling equipment	Tow train	Tow train
	Routing	Indirect	Indirect

The companies use the policy for relatively small parts, thus the size of the unit loads can also be kept small. Furthermore, the companies have guidelines expressing that each unit load should contain parts for approximately two hours of consumption at the lineside presentation or materials facades. Since the LVPs are consumed in low volumes, it should result in that the unit loads for these parts are kept at minimum size, hence aligning with Faccio's (2014) conclusions that the inventory levels at the lineside presentation can be kept low with the policy. As a consequence of the strive to present small unit loads, the companies perform a significant amount of repacking, which according to ten Hompel & Schmidt (2007) is a very inefficient process.

The buffer storage of all parts fed with kanban-based continuous supply at Company B is located at the centralized marketplace. At Company D, the LVPs fed with this policy have buffer storage in the automated central storage. According to Faccio (2014), supermarkets located close to the assembly lines could allow for reduced inventory levels at the lineside presentation or materials facade since faster replenishments can be performed. The current design at the companies depends to a great extent on contextual factors. At Company D, space restrictions in the facility in combination with that the location of the automated central storage is fixed makes it difficult to perform a design change in the near future. Furthermore, Company B experiences extensive space restrictions in the production facility making it difficult to locate the marketplace closer to the lineside presentation. It was highlighted that the time for retrieval of parts from the automated central storage at Company D currently is unstable, hence there is a risk of stock outs at the materials facades since the cover time there is two hours. Since it has not been possible to gather information for how often this occurs, it can only be stated that the current design can be considered risky.

The transportation from the buffer storages at both companies is performed with tow trains, allowing replenishment of multiple parts in the same trip. This aligns with Baudin's (2004) conclusion that it is of higher relevance to reduce the number of trips rather than reducing the distance of each trip. This conclusion entails that in order to overcome the previously mentioned problems with centralized storage areas located far away from the assembly line, it is beneficial to consolidate parts in order to reduce the logistics costs. This can clearly be seen at Company D where the LVPs are delivered to the supermarket for intermediate storage, where consolidation is performed together with parts with higher consumption.

5.3.2 Kitting

Kitting was observed at Company C and Company D and the designs of the parts feeding systems for the policy differ significantly between the companies. The studied kitting process at Company C is only used for LVPs, while all parts are kitted at Company D. However, other policies, such as kanban-based continuous supply and sequencing are used for delivering the parts to the materials facade prior to kitting at Company D. Since all parts are kitted at Company D, a larger amount of kits are prepared, and it could therefore be argued that the efficiency of the kit preparation is of higher importance than at Company C. Table 17 summarizes the design of the parts feeding system for kitting at Company C and Company D.

Table 17. Comparison of the design of the parts feeding systems for kitting at Company C and D

Constituent	*Design area*	*Company C*	*Company D*
Packaging	Unit load size	Pallets & boxes	Pallets, boxes & cartons
	Repacking	No	No
Storage	Storage configuration	Centralized	Decentralized
	Storage policy	Pallets: Random Boxes: Class-based (vol.)	Class-based (vol.)
Transportation	Material handling equipm.	Tow train	Push cart
	Routing	Indirect	Direct
Picking	Picking quantity	For several orders	For one order
	Picking information	Labels	Pick-by-light
	Picking location	Far away from lineside presentation	Close to lineside pres.
	Responsible for picking	Specific department	Assembly department

At Company C, kit preparation is performed directly from buffer storages in a centralized location, reducing the space needed for a kit preparation area. In addition, no repacking is performed at Company C since there are low space restrictions in the centralized storage areas. Company D is instead performing kitting operations in the materials facades. Space restrictions are experienced within these areas, hence a significant share of the parts have been downsized prior to delivery to the materials facades. The parts are stored according to their consumption volume, where LVPs are stored in the less preferable storage locations. When comparing the design of kit preparation at the two companies, it can be considered to be more efficient at Company D due to the use of pick-by-light, which according to ten Hompel and Schmidt (2007) has advantages compared to the use of pick list, which the picking information at Company C can be considered to be equivalent to. Furthermore, additional travel distance is needed to fetch the parts during the kit preparation at Company C. According to de Koster et al. (2007), a large share of the pickers' time accounts for travelling and therefore impacts the picking efficiency to a high degree.

Due to the location of the kit preparation, a specific department is responsible at Company C while the assembly department is responsible for the preparation at Company D. The approach at Company D aligns with Brynzér & Johansson's (1995) recommendation that the picking accuracy could be enhanced if the assembly operators perform the kitting preparation themselves. Furthermore, Brynzér & Johansson (1995) also recommended to have specific kitting personnel when the kit preparation is performed in an area located far away from the assembly line, similar to the design at Company C. An issue observed at Company D is that kits with quality issues, such as a faulty part, were not consistently reported since the same department is responsible for the final assembly and the kit preparation. This can be considered as an important issue since it could hinder the organization to continuously improve its performance. In contrast, this issue was not experienced at Company C with a separate department responsible for kit preparation.

Kit preparation for several orders during one picking tour is only performed by Company C, a process which could increase the picking productivity (Brynzér & Johansson, 1995). On the other hand, it could have a negative impact on the picking accuracy. Missing parts and placing of wrong parts in the kits were mentioned as occurring quality issues at Company C and could possibly be derived to the preparation of kits for multiple orders. Currently, a manual quality check is performed before the kits are delivered to the lineside presentation. However, Brynzér & Johansson (1995) state that there are more suitable approaches to increase the quality of the kits, such as picking information. According to ten Hompel & Schmidt (2007), a pick-by-voice system could increase the picking accuracy compared to the current picking information used at Company C, which previously was described as a form of pick list. Even though kitting operations have not been studied at Company B, many parts fed through sequencing could be considered belonging to kits, hence it is possible to include Company B in the comparison regarding picking accuracy for kit preparation. Company B uses a pick-by-voice system and the picking accuracy is perceived to be excellent, hence supporting the statement by ten Hompel & Schmidt (2007).

Another aspect regarding the quality of the kits is the difficulty to replace faulty parts since no buffer storage is located at the lineside presentation. Since Company C has a kit preparation area located far away from lineside presentation, it leads to lower responsiveness to quality deficiencies than a kitting area located close to the lineside presentation, since more time and effort will be needed to solve the issue. Therefore, it is of even higher importance to have high quality of the kits when the kit preparation area is far away from the lineside presentation in order to avoid excessive costs related to solving quality issues, such as express deliveries.

Different material handling equipment is used for transportation of the kits at Company C and D. Company C that has a centralized kitting area is delivering the kits via the platform area, enabling consolidated deliveries with other parts on tow trains. This method allows for high efficiency in the transportation since a reduced amount of transports can be made. Company D is instead using a push cart both for transportation to the lineside presentation and as kit container. It can be considered as a suitable alternative for the company since it is cheap, suitable for short transportations, and also facilitates for movement between the workstations. The latter aspect is important since the company uses travelling kits which contains parts for several workstations.

5.3.3 Sequencing

Sequencing activities are carried out at three of the studied companies, namely Company B, C and D. The policy is used at the companies to be able to reduce storage space at the lineside presentation as well as non-value adding work for assembly operators at the assembly line. However, the design of the parts feeding system in relation to this policy varies between the companies in some aspects, and the performance is experienced in different ways. Company D expressed problems with space requirements in the sequencing areas, and low picking efficiency due to the use of pick lists, while Company B are pleased with their sequencing operations, considering them to be world class in terms of picking accuracy, due to the use of pick-by-voice. The design of the parts feeding systems related to sequencing from some chosen factors, can be seen in Table 18.

Table 18. Comparison of the design of the parts feeding systems for sequencing at Company B, C and D

Constituent	***Design area***	***Company B***	***Company C***	***Company D***
Packaging	Unit load size	Pallets & boxes	Pallets	Pallets
	Repacking	No	No	No
Storage	Storage configuration	Decentralized	Centralized	Decentralized
	Storage policy	Class-based (vol.)	Random	Family grouping
Transportation	Material handling equipm.	Tow train	Tow train	Tow train
	Routing	Indirect	Indirect	Indirect
Picking	Picking quantity	Varies	For several orders	For several orders
	Picking information	Pick-by-voice & barcode scanning	Pick list	Pick list
	Picking location	Far away from lineside pres.	Far away from lineside pres.	Close to lineside pres.
	Responsible for picking	Specific department	Specific department	Specific department

The preparation area for sequenced parts differ between the companies. Company B has decentralized sequencing areas where most sequencing activities are performed rather far away from the assembly line, Company C has one centralized sequencing area located far away from the assembly line and Company D has three decentralized sequencing areas located close to each corresponding assembly line. An advantage with the sequencing areas at Company D, is that faulty or missing sequenced parts at the materials facades could be fixed rather quickly. However, an important disadvantage with this set-up was expressed by the interviewee at Company D, namely that the areas take up a lot of space close to the final assembly line for products that are consumed infrequently. With the companies having their sequencing areas located further away from the assembly lines, no issues with the transport distances have been expressed. Therefore, it can be argued that there could be an overall advantage in having a sequencing area located far away from the lineside presentation. However, in this case, the picking accuracy should be held to a maximum, to avoid express deliveries from the sequencing area.

According to ten Hompel & Schmidt (2007), to improve the accuracy of picking activities the best method to use is pick-by-voice. This method is used by Company B, which is one important reason for the company to consider their sequencing activities being world class, with very high picking accuracy. Company C and D, however, use pick lists as picking information, which is stated to be less accurate picking information (ten Hompel & Schmidt, 2007). Additionally, Company D has expressed problems with the pick lists at the sequencing areas, stating that it is not as well-working as the kitting operations where pick-by-light is used, mainly in the sense of efficiency.

The larger size of the sequenced parts makes the picking operation more time consuming than for kitting. For instance, the size of the parts could make it troublesome to take several parts at a time to put in the sequence rack, and the rack itself might be difficult to move. This has influenced the picking operations at Company B, where a large amount of different parts is picked into sequencing racks. The largest parts are picked one-by-one and transported to the sequencing rack, while smaller parts could be picked several at a time, and the sequencing rack could be moved along with the picker. The latter will decrease the distance that is needed to be walked for the order picker, increasing the efficiency of the picking operation. Further factors making the sequencing operations so well-functioning at Company B is their class-based storage policy according to consumption volume, making most of the picks being focused around the sequence rack in the middle of the picking area. At Company D, the storage policy in the sequencing areas is based on family grouping, also reducing travelling distance for the order picker, since each sequencing rack being sent to the materials facades contains parts within the same part family.

6 RESULTS

In this chapter, the most important findings from the study will be summarized and presented. This chapter follows the structure of the research questions and the analysis, where the first section presents the results regarding a definition of LVPs in the automotive industry, the second section covers parts feeding policies' suitability for LVPs, and the last section presents the findings regarding the design of the parts feeding system.

6.1.1 Definition of LVPs

It has been identified that two of the four studied companies within the automotive industry have definitions for LVPs related to parts feeding. The definitions for LVPs are used to an extent to decide which parts feeding policies that can be applied for these parts. Since it has been shown that companies within the automotive industry in general have a large number of parts that are handled within their facilities it becomes complex to assign a parts feeding policy for each individual part. By performing a part classification, the complexity of the control can be reduced, allowing for a more efficient assignment of parts feeding policies based on the classification.

The identified definitions for LVPs at the case study companies have been based on consumption volume and consumption of unit loads. Since it has been shown that repacking is a frequently occurring activity, the robustness of the definition based on unit loads is weaker, making it more appropriate to apply a definition which takes the consumption volume per part into consideration. Regarding which parts in the assortment that should be considered as LVPs, it has been concluded that the classification has to be made specifically for each company since the distribution differs between the companies in the amount of parts that are consumed in low volumes.

Furthermore, it has been concluded relevant to continuously update the classification in order to assure that the parts are categorized in the right segment, meaning that for instance the least consumed parts are classified as LVPs. This proactivity to continuously revise the classification assures that the company uses the parts feeding policies that are recommended for LVPs, enabling efficient parts feeding over time.

6.1.2 Parts feeding policies' suitability for LVPs

Among the four parts feeding policies that were studied, it can be concluded that continuous supply is not suitable to use for parts feeding of LVPs in the automotive industry. The primary reason is that the policy increases the space requirements at the lineside presentation, which is a large restriction at the studied companies, consisting of mixed-model assembly lines where a large amount of parts is needed.

The suitability of the parts feeding policies for different part characteristics have been identified and the study has shown that there are some characteristics that have larger impact. The results of the study show that the consumption volume of a part, the number of varieties within a part family as well as the part size have the most impact on the suitability. It can be noted that these part characteristics influence space restrictions in the facility. In contrast, it was identified that less consideration was taken to part value when assigning parts feeding policies.

The part characteristics that have been identified as most relevant can be used to categorize in what context the parts feeding policies are most suitable to use. This is illustrated in Table 19, creating four segments based on the part size and variety in part family. It should be noted that it shows a simplified view and deviations may occur when taking additional contextual factors into consideration. The consumption volume of the parts is considered to be low for all segments, since parts feeding of LVPs is in focus. Findings from case-study companies and theory have shown that kanban-based continuous supply is suitable for LVPs when the parts are small in size and the variety in part family is low, since limited logistics cost can be achieved while the space requirements can be kept down. However, it has not been possible to conclude which parts feeding policy fits best for large parts with low variety within the part family. For instance, kanban-based continuous supply has limitations regarding the part size since the policy favors the use of small unit loads, hence the policy is not suitable for large parts. Kitting and sequencing are instead more preferable when the number of parts within a part family is high, since the space requirements at the lineside presentation can be significantly reduced. It has also been concluded that sequencing reaps its benefits for larger parts while kitting is more beneficial for smaller parts.

Table 19. Most suitable parts feeding policies for LVPs based on relevant part characteristics

Variety in part family / ***Part size***	*Low*	*High*
Small	Kanban-based cont. supply	Kitting
Large	Not concluded	Sequencing

6.1.3 The design of the parts feeding system related to parts feeding policies

The main contextual factor that needs to be considered for parts feeding of LVPs is the space limitations in the facility, especially in areas near the assembly line. This can be seen regarding the amount of repacking that is made in relation to different parts feeding policies. It has been found to be more common to perform repacking for parts that are fed with kanban-based continuous supply than with kitting and sequencing. An explanation for this is that the size of the unit load impacts the space requirements at the lineside presentation to a higher degree when using kanban-based continuous supply.

It has also been highlighted that different storage policies are applied in the studied facilities in kitting and sequencing areas. For instance, class-based storage policies are applied, which causes the LVPs to have less favorable storage locations. Even if it may be less efficient picking for LVPs, it could reduce the picking time for parts consumed in higher volumes. As the LVPs only take up a limited share of the total picks, using a storage policy such as a class-based policy according to volume or family grouping, that will reduce the order picker’s transportation distance, would be beneficial from a total cost perspective.

It has been shown that the location of the storage area is impacted by contextual factors such as space limitations within the facility. A storage area that has been located further away from the lineside presentation does not necessarily cause increased logistics costs, if material handling equipment that facilitates consolidation is used. Additionally, an important advantage with this configuration would be the amount of space that could be saved close to the assembly lines.

Therefore, if extensive space limitations are experienced in the assembly facility, it could be beneficial to locate the storage area far away from the lineside presentation, while using material handling equipment that facilitates consolidation, reducing the total number of trips, and hence the logistics costs.

Picking, which concerns kitting and sequencing, can have many different configurations. Configurations that both separate and combine the picking of LVPs from high volume parts have been studied and it tends to be a higher focus on picking efficiency in the designs which combine LVPs and parts consumed in higher volume. However, it has not been possible to conclude if the picking of LVPs should be separated from high consuming parts. If the picking is separated and space restrictions are experienced near the lineside presentation, moving the picking operations of LVPs to a location far away from the lineside presentation would have low impact on the efficiency, while space could be saved near the assembly lines. Furthermore, it can be considered more beneficial to secure high picking accuracy than efficiency since the LVPs are consumed in low volumes and the consequences of inaccurate kits can be expensive. Both information from existing theory and the case study indicate that picking information can impact the picking accuracy, where the best-performing company in this aspect uses pick-by-voice. Picking of multiple parts in the same picking tour can improve the picking efficiency, but it is important to primarily assure high picking accuracy.

7 DISCUSSION

In this section of the report, reflections of the findings will be discussed, and contributions to academia and the industry will be covered. Furthermore, the generalizability of the report as well as the trustworthiness will be discussed, in relation to the methodology that has been used in the study. Last in this section, recommendations for further research on how to elaborate on the findings in this study will be discussed.

7.1 Reflections on the findings

An additional aspect of the report that could be interesting to take into consideration is whether all parts within a certain part family should be fed with the same parts feeding policy or not. As has been expressed in former sections of the report, if there is high variation within a part family where the parts all have low consumption volumes, the most suitable parts feeding policies to use would be kitting or sequencing, depending on size of the parts. However, if one or two parts of the part family stand for the majority of the consumption volume and several other parts within the same part family only stand for a small part of the consumption volume, a discussion about whether to differentiate these parts could arise. If simply looking at the recommended division into classes that was presented in the analysis, the parts that stand for the majority of the consumption volume within the part family should be fed through continuous supply or kanban-based continuous supply, which is the configuration that Company C has chosen. However, this could lead to confusion for the assembly operators, when similar parts from the same part family are not fed in the same way. Therefore, a choice could be made that for part families with a high variation of parts, where most of the parts have low consumption volumes, all parts are fed in the same way, consequently through kitting or sequencing. This configuration could be seen at Company D, where big and expensive parts belonging to part families with high variation are all sequenced to the materials facades. This will make it easier for the kit assemblers to find the right parts when preparing the kits.

This study has also concluded that contextual factors have an impact of how the findings from this study should be adapted by companies. For instance, the consumption volume distribution of parts was identified as a factor that should be reflected in the ABC classification performed by the company, hence it is difficult to give a clear recommendation for how the classification should be performed in a general manner. The space restrictions experienced within the facility have been identified as an important aspect which to a high degree impacts the design of the parts feeding system. However, if the space limitations within a facility are low, it would possibly be relevant to consider other parts feeding policies than the guidelines in the study have highlighted.

The argumentation in the paragraph above shows that the conclusions of this study are not absolute, but should instead be seen as recommendations for each company to apply in the most appropriate way in the context that they are operating in. Some part characteristics or company goals may be more important for a certain company, shifting the focus toward a certain factor, such as space requirements or value-adding time, leading to a prioritization of one or a few parts feeding policies and design options for the parts feeding system. Hence, companies should consider the conclusions in this study, and then form them to fit their specific contexts of operation.

7.2 Contributions to academia and industry

This master's thesis has the aim of filling a gap in academia, regarding parts feeding for parts that are consumed in low volume in mixed-model assembly lines, where the automotive industry has been chosen as a representative area of research in the subject. An explanation, or definition, of LVPs has not been found in existing literature, which is why the first focus of the study was to develop general guidelines for how LVPs should be interpreted and defined at companies, where a classification according to a pareto relationship of a company's parts based on consumption volume is recommended.

The study has treated suitability of parts feeding policies for LVPs based on several part characteristics, where focus was on qualitative findings in the automotive industry. It is possible that the same contextual factors could be found in other industries, which allows the findings of this master's thesis to serve as a basis for further research industries with similar context. Additionally, the study has treated design options regarding the parts feeding system in relation to the parts feeding policies, resulting in findings that could be further developed for an extensive framework regarding the design of the parts feeding system where parts feeding policies and several contextual factors stand as basis.

The contributions from this study to the industry include a recommendation for how companies can perform a classification of LVPs. The study also contributes with useful guidelines for when the covered parts feeding policies may be applicable to apply for LVPs and some findings regarding how the design of the different constituents of the parts feeding system could affect the performance of the production system.

7.3 Generalizability of the findings

The parts feeding of LVPs at four companies with different set-ups have been studied, and the report therefore describes a wide range of settings within the automotive industry. Hence, the findings could be applied to most companies within this context. Apart from the mixed-model assembly line, the most important factor impacting many of the findings in this study is the recurring problem of space limitations. Accordingly, companies operating in an environment with a mixed-model assembly line and experiences large issues with space limitations could benefit from the conclusions of this study, despite not operating in the automotive industry. As was expressed by Borrego et al. (2009), the findings of a qualitative study could be interpreted by the readers, for them to apply what is relevant onto their own situations.

Additionally, the study has been limited to be conducted only at Swedish final assembly facilities, and findings have been made only on this premise. However, the context that has been studied is not specific for the Swedish industry, since mixed-model assembly lines and diverse customer demand is common in the automotive industry all over the world (Pil & Holweg, 2004). Furthermore, all studied companies operate globally and have assembly facilities in several different countries. Hence, the findings could be applied in any country, where the company experiences the same difficulties as have been expressed by the companies in this study.

7.4 Trustworthiness of the study

Much has been made in order to make sure that the trustworthiness of the report has kept a high level, in accordance to what has been written in the methodology chapter. Trustworthiness is mainly about focusing on the correct subjects, asking the right questions and interpreting the data in a correct way (Borrego, et al., 2009). The research approach of the study has been mainly deductive, where theoretical findings have been collected before the empirical results (Bryman & Bell, 2011), to be able to create general knowledge about the subjects being observed. Research questions were made and later the observations and interviews were conducted. However, in order to increase the trustworthiness, the process of data gathering from theory has been iterative, where influences from an inductive approach can be seen. For instance, when new information was identified from the case studies that was not covered in the theoretical framework, further research of literature was made. Additionally, the research questions were continuously updated to match the findings and new thoughts that arose during the ongoing work with theoretical framework, empirical results and analysis.

The research strategy that was chosen for this study was qualitative, meaning that observations, thoughts and interpretations were in focus for the empirical results and the analysis (Borrego, et al., 2009; Holme, et al., 1997). An advantage with this strategy is that the researchers gain a holistic view of the studied environment, rather than focusing on single areas. However, a disadvantage in this context was that a clear evaluation of the performance of the different parts feeding systems was hard to make, for which another study with a different focus could be made, based mainly on quantitative measurements. In this study however, the researchers instead relied on qualitative assessments and interpretations of the performance, and expressed opinions from the interviewees.

This study was conducted as a case study, where four companies with different set-ups were analyzed according to current theory and their environments. This design was fitting for the type of study that was conducted, since the empirical results were very important to be able to draw conclusions about the parts feeding system (Eisenhardt, 1989). The design allowed for higher trustworthiness than if only one assembly facility would have been observed and analyzed, and also increased the generalizability of the study.

Regarding the work procedure, high trustworthiness of the study has been aimed for by thoroughly trying to understand the complex designs of the companies' parts feeding systems, which was expressed as important by Borrego et al. (2009). This has been made through gathering of data through several channels, for instance through interviews and direct observations, as well as studying company documentation. Furthermore, as the process of writing the report has moved on, questions that have arisen have been directed to the interviewees at the visited facilities, and the texts written about the empirical findings have been asked to be reviewed by the interviewees, to ensure good quality of the report.

Although much was done in order to keep the trustworthiness of the report at a high level, some flaws can be found, that, if avoided, could have given a better understanding of the companies' environments. Firstly, at three of the companies, one study visit was conducted, while at the fourth company no study visit was possible to carry out. It can be argued that to increase the trustworthiness of the case studies, several study visits could have been carried out to be sure that every aspect of the parts feeding system and related processes were perceived correctly. The reason for that a study visit was not carried out at one company was not in the hands of the researchers, and instead several interviews with three different people at the company were conducted, to be able to get as much information as possible from different sources. Secondly, at the three companies where study visits were conducted, one person was interviewed to get information about the parts feeding system. To be able to get an as high trustworthiness as possible, it could be argued that interviews should have been held with multiple employees with different backgrounds at the companies. However, the researchers believe that the study visits together with that the interviewees asked their co-workers for answers they did not have themselves, was enough to receive valid data.

7.5 Further research

The findings of this study could be used as a base for further research. This study has generated guidelines related to when parts feeding policies are suitable to use for LVPs based on part characteristics and design options related to the whole parts feeding system. The findings could be further developed into an extensive framework regarding the design of the parts feeding system where parts feeding policies and additional contextual factors stand as basis. To further elaborate on the findings and to develop a more in-depth analysis of how each parts feeding policy and corresponding design of the parts feeding system perform in different contexts, a quantitative study could be performed. In this study, observations over a longer time of all the policies could be made, as well as concrete measurements of how they perform. These measurements could for instance be time that is needed to feed parts with different policies, the quality of the policies for different parts, total cost for the policy or other parameters that could be found to be relevant to measure. Furthermore, a quantitative study could increase the generalizability by giving statistical and concrete conclusions that could be used without the need of interpretation from the reader, although the output of such a study would focus on performance, and contextual factors and the complexity of the production systems in the automotive industry would be lost. Hence, a quantitative study would not have been suitable for the research questions in this particular case study.

Another area that would be interesting to add into this research, is to increase the knowledge of different parts feeding policies, that have not been treated in this study. This could for example be an investigation in where for instance minomi and batch supply would fit in, or if there are other policies that could increase the performance of parts feeding for LVPs. It is important to understand that the findings in this study are based on the theory and empirical results that were able to be analyzed in relation to the four case study companies. Hence, other companies might use other policies or combinations of policies that could impact the performance of the parts feeding system in another way than what has been seen in this study.

8 CONCLUSIONS

This study has consisted of a multiple-case study including four Swedish companies within the automotive industry where parts feeding of LVPs has been analyzed. The study presents recommendations for how LVPs can be defined and examines the suitability to use four different parts feeding policies for feeding of LVPs in the studied context. It has been identified that space restrictions within the facilities have a large impact on the parts feeding, resulting in that three of the analyzed policies are more relevant to consider for parts feeding of LVPs.

The findings show that part characteristics can be used to decide which parts feeding policy that is most appropriate to use. The part characteristics that have the most influence impact the space restrictions in the facility, namely parts size and variety in the part family. However, it was identified that the part value has less importance in the choice of parts feeding policy. Guidelines for the design of the parts feeding system have also been presented with findings related to the packaging, transportation, storage, and picking constituents.

The findings of this study are not restricted to the Swedish automotive industry, but could be extended to other industries and countries, where companies face the same issues with diverse customer demand, a large number of low-volume parts and extensive space limitations in production facilities. This study could serve as a basis for further research, to develop a framework with concrete recommendations of how a parts feeding system should be designed in different production contexts. Such a study could also cover quantitative research to better answer how performance is affected by the different design choices that could be made for the parts feeding system.

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APPENDIX I. MATERIAL FLOWS

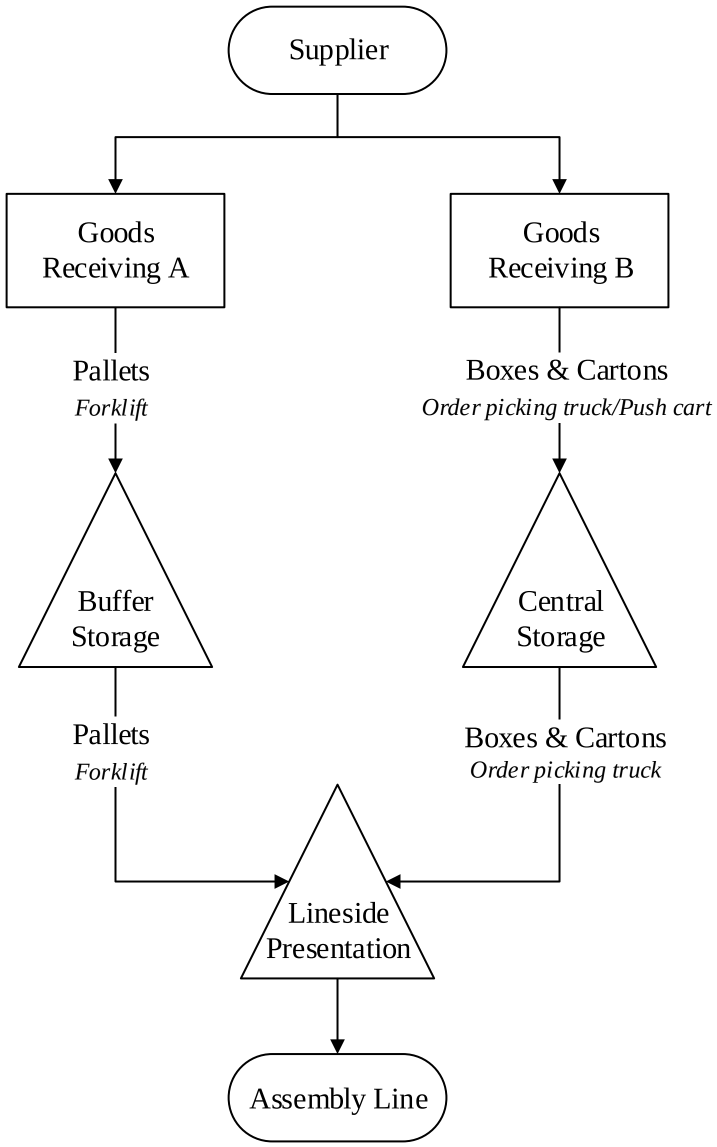

Figure 3. Illustration of the parts feeding system at Company A

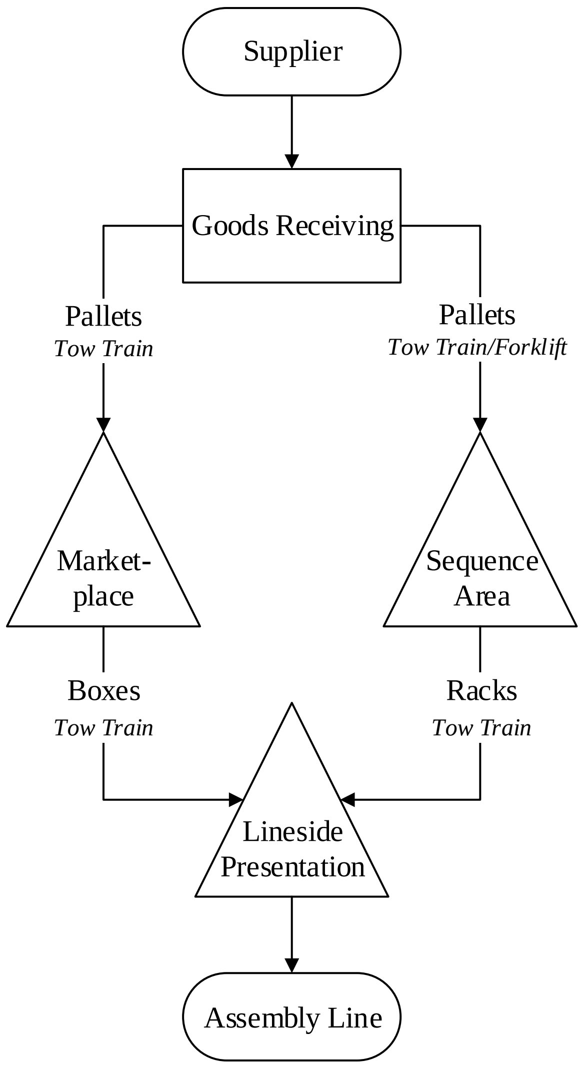

Figure 4. Illustration of the LVP parts feeding system at Company B

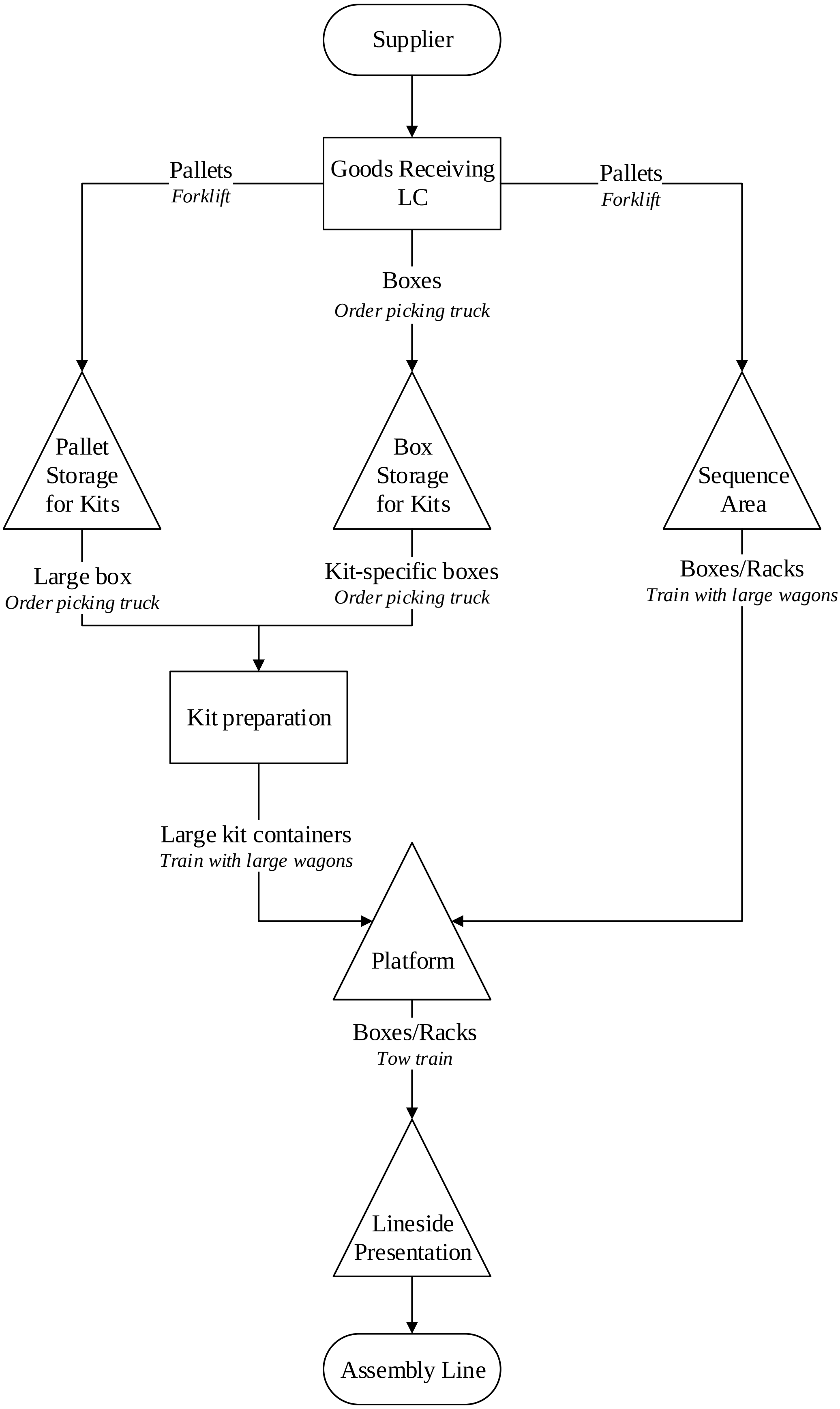

Figure 5. Illustration of the LVP parts feeding system at Company C

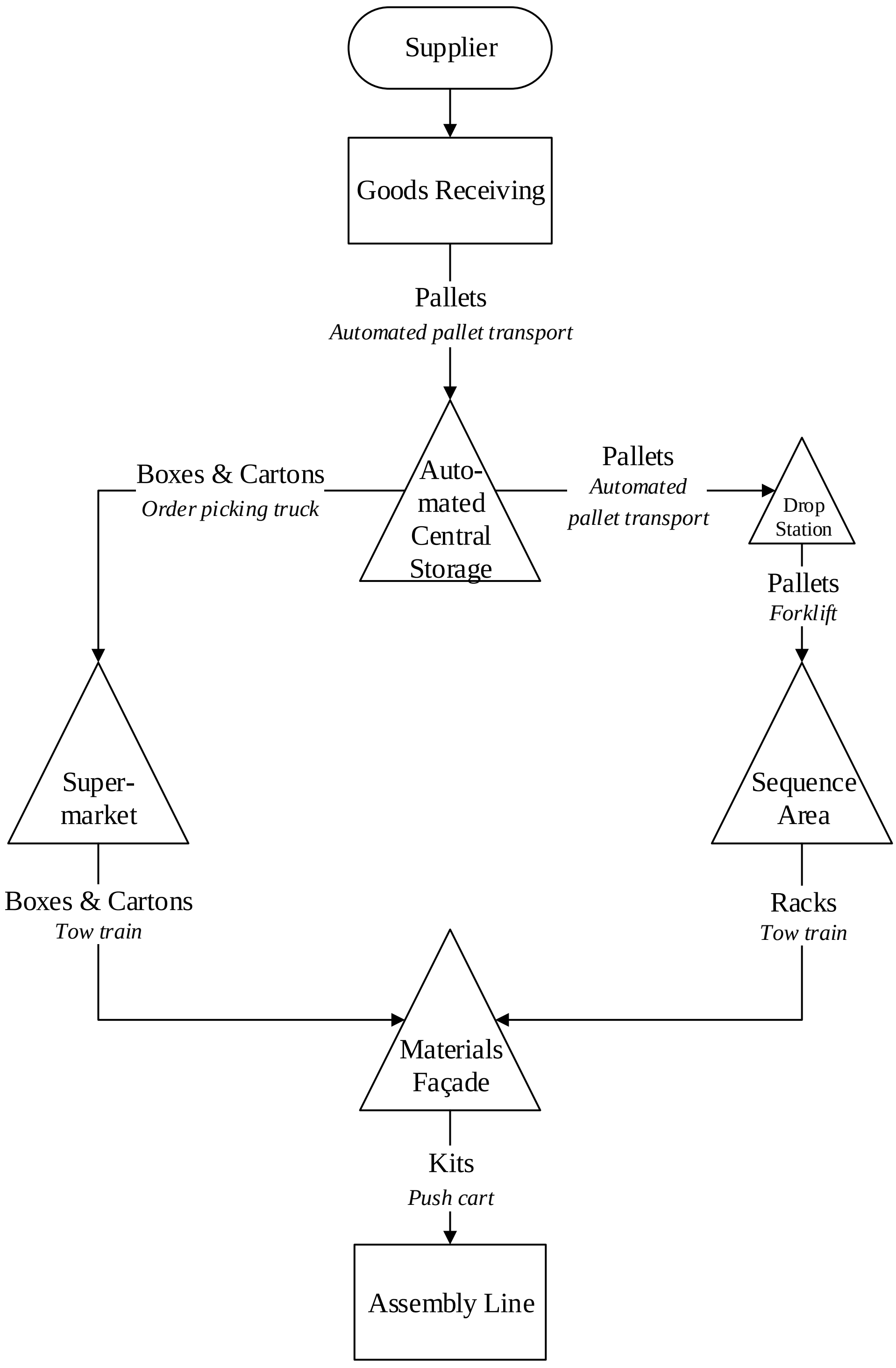

Figure 6. Illustration of the LVP parts feeding system at Company D

APPENDIX II. QUESTIONS FOR SEMI-STRUCTURED INTERVIEWS

General questions

- Can you describe your role in the company?
- Can you describe the Production System in the facility?
  - What products are manufactured? Number of variants?
  - Can you describe the design of the Assembly System?
  - How many parts are used in the facility?
  - How many parts are used for the end-products?
- Which requirements do the customers have on the end-products?
  - Which requirements are perceived as most important for the customer?
- Which KPI’s are used to evaluate the performance of the Assembly System?

General questions about parts feeding

- Can you describe the Parts Feeding System for the Assembly System related to final assembly?
  - If there are multiple flows, can you describe the design for all of them?
- Which department is responsible for the Parts Feeding System?
- How many employees have tasks related to Parts Feeding?
- How do you with improvements related to Parts Feeding?
- What do you perceive your company to be good at related to Parts Feeding?
- What do you perceive your company to be able to improve related to Parts Feeding?
- Which KPI’s are used to evaluate the Parts Feeding System?
- How do you decide which Parts Feeding Policy that should be assigned to a specific part?
  - Which parameters is the decision based on? Part Characteristics?
  - How has this decision support been developed? Is it used?
    - How do you perceive the quality of this decision support?
- In your work related to improvement of Parts Feeding, which aspects are critical to consider?

Storage of parts

- Where are parts stored in the facility?
  - How does the distance to the Lineside Presentation differ between from the different storage locations?
- How are parts stored at the different storage locations?
- How is it decided where a parts should be stored?
  - Which parameters is this decision based on?
  - How has this decision support been developed?
  - Are all parts stored in the facility?
- How large share of the parts have a dedicated storage location at the Lineside Presentation?

Parts feeding of LVPs

- How do you define Low-Volume Parts?
    - Which parameters impact if a part should be classified as a Low-Volume Part?
- How large share of the parts are classified as a Low-Volume Part?
- Is it possible to describe the Low-Volume Parts based on some part characteristics?
- How do you handle Low-Volume Parts in terms of:
    - Storage?
    - Parts Feeding?
    - Can you describe the process from receiving the Low-Volume Parts in the facility to the Point-of-Use at the assembly line?
- How is the handling of Low-Volume Parts perceived?
    - What do you perceive as being good at?
    - Where do you see potential for improvement? How?
- Is it common that Low-Volume Parts are used at multiple workstations in the Assembly System?
- How is it decided which unit load that should be used for Low-Volume Parts?

Miscellaneous

- Which type of Material Handling Equipment is used in the facility?
    - Forklift, Tow Train, Push Cart, Pallet Jack, Other?
- Which type of unit loads are used for parts?
    - Pallets, Boxes, Cartons, Other?
- Can you describe how the Parts Feeding System has been designed historically in your facility?
- Have any other Parts Feeding Policies previously been used?
    - If Yes, why was a change initiated?
    - How did it impact on the performance?
- Do you currently work with improvement activities related to the Parts Feeding in the facility?
    - If Yes, can you describe the changes?
    - Which results do you expect to see with these changes?
- Has it been performed any studies regarding other Parts Feeding Policies than the ones currently used?
    - If Yes, which ones?
    - Which advantages and disadvantages were perceived for these Parts Feeding Policies?