Professional MBA
Automotive Industry

Application of part kitting methodology in high variation automotive assembly processes

Case study at Ford Motor Company Valencia, Spain

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by

Prof. Dr.techn. Dipl.-Ing. Daniel Palm

Dipl. Wirt.-Ing. Benjamin Fastnacht

1525952

Valencia, 29.09.2017

Affidavit

I, **BENJAMIN FASTNACHT**, hereby declare

1. that I am the sole author of the present Master's Thesis, "APPLICATION OF PART KITTING METHODOLOGY IN HIGH VARIATION AUTOMOTIVE ASSEMBLY PROCESSES - CASE STUDY AT FORD MOTOR COMPANY VALENCIA, SPAIN", 83 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 29.09.2017

Signature

Table of content

1 Introduction

The following chapter introduces the background of this master's thesis, which, eventually, leads to the presentation of its purpose and objective as well as the scope of this study.

1.1 Background

"I will build a motor car for the great magnitude", Henry Ford claimed while announcing the Model T in 1908 (Burlingame 1913: 62). It was the time when Henry Ford implemented the first automobile assembly line at Highland Park plant in Michigan and, with it, initiated the era of mass production. Since then, however, the customer demand changed dramatically. Customers put more and more pressure on the market to get quality products timely delivered for low prices and request a wide variety of models and variants. Automotive manufacturers are mass customizing in order to meet their customer's needs, which leads to higher variation and increased amount of parts. These parts are delivered to the assembly line by mainly four different material feeding principles: continuous supply, sequential supply, batch supply and kitting. The difference between these feeding strategies is whether all components are stored at the assembly line at any time and if the end product or part number sort the parts (Gajjar & Thakkar 2014: 891). Delivering the parts in the traditional way with continuous supply and line side stocking results in problems since the increasing number of parts demand an increase in line side storage space (Gajjar & Thakkar 2014: 891).

The Ford Valencia production plant produces six vehicles lines: Mondeo, Kuga, S-MAX, Galaxy, Transit Custom, Transit Connect, all with a growing number of product variations. This results in more and more part numbers which need to be delivered to and stored at the assembly line. Currently, some parts are delivered in sequence to the line to be able to handle variation and takt times. In order to cope with increasing variation, it is important for original equipment manufacturers (OEM) to be in sufficient control of their operations. In the context of in-plant material supply, kitting is often discussed, since it has a number of advantages over more traditional material feeding principles (Hansen & Medbo 2012: 1115). Whereas in line stocking parts are supplied to the line in individual component containers, in kitting parts are grouped together and supplied to the assembly line in kit containers in predetermined quantities (Limère et al. 2012: 4048).

On the one hand, kitting reduces lineside stocking space, operator searching, and walking time; on the other, it requires additional work to prepare the kits. Therefore, the kitting process needs to be designed in an efficient way in order not to move the waste but to eliminate it.

1.2 Purpose and objectives

It is indispensable for OEMs to manage the increased complexity of producing more models and derivatives. Currently, mostly line stocking is used which results in high lineside storage and makes rebalancing of operations hard to accomplish. Companies often spend weeks converting continuous supply to kitting or vice versa in an effort to enhance performance, without being aware which principle better fits their assembly environment (Hua & Johnson 2010: 780). Purpose of this master's thesis is to establish a model to compare different material feeding principles in high variation serial production assembly lines is established. It supports the decision makers in their decision process regarding the appropriate material feeding system for any automotive plant. The target is to minimize lineside storage space, sequencing and logistic cost, operator displacements and to be more flexible in rebalancing work steps from one workstation to another. The thesis focuses on the special requirements of the space restricted Ford Valencia plant but can be adapted to any other automotive assembly plant. Savings and investments are quantified in a business case approach. Furthermore, the design of a kitting process for feeding the material to the trim line is defined.

This model can be used in the beginning of the planning phase in the evaluation process considering the transformation of mixed material feeding principles into a kitted material flow or vice versa. It determines whether kitting is the preferable material feeding principle and whether OEMs can benefit from the kitting introduction.

1.3 Scope and delimitations

Introduction of kitting will be compared with the current situation. The study focuses on the trim line since this part of the assembly line has a lot of part variety and accordingly, huge lineside storage areas. Therefore, it is highly interesting how a kitting process would affect effectivity. Further introduction to other assembly lines nor other possible delivery strategies will not be considered in this masters thesis.

2 Theoretical framework of material feeding principles

The second chapter describes the theoretical framework of this thesis. Firstly, it outlines the material feeding principles with a special focus on part kitting. Secondly, advantages and limitations of kitting as well as the design of a kitting system are discussed. Finally, the state of the art is presented.

2.1 Material feeding principles

Material feeding systems define which principle to use for feeding materials to the shop floor. Four different ways to deliver material to the line can be distinguished: continuous supply, sequential supply, batch supply, and part kitting. These principles can be categorized with regards to the selection of part numbers exposed at the assembly line and the way the parts are sorted at the assembly station (Gajjar & Thakkar 2014: 892). Figure 2.1 shows the material feeding principles by Johansson (1991). However, sequential supply is not mentioned in Johansson's model, it is added to have a full picture.

	Selection of part numbers	All part numbers
Sorted by part number	Batch	Continuous
Sorted by assembly object	Kitting / Sequential	

Figure 2.1: Material feeding principles (adapted from Johannson 1991)

These different material feeding systems can be presented simultaneously and can complement each other (Carlsson & Hensvold2008: 10).

Continuous supply

Continuous supply presents all part numbers at the production line at any time. The material is sorted by part number, is distributed to the assembly line in units suitable for handling and is replaced when empty. Replenishment of components is done either in station fix bins or by a two-bin system where the bins are stored along the assembly line (Gajjar & Thakkar 2014: 892).

Batch supply

Batch supply presents a selection of part numbers of specific assembly objects at the workstation. Similar to the continuous supply, it is sorted by part numbers. In comparison to the continuous supply, fewer part numbers have to be stored at the assembly line since different components are exposed at different points in time. After completion of the batch assembly, the remaining material is returned to the warehouse (Gajjar & Thakkar 2014: 892). Administrative systems are needed for counting the parts.

Sequential supply

The increase of product variants has made continuous supply in some cases impossible due to a lack of space at assembly lines. In order to solve this problem, sequential supply can be used to feed material to the workstation. Hereby, part numbers are not only delivered just-in-time but also in sequence to the production line. Sequencing has thus made it possible to produce customized vehicles while still maintaining the economy of scale (Karlsson & Thoresson 2011: 6). The increased information exchange needed for sequenced deliveries demand a greater coupling between supplier and customer in comparison to continuous supply (Karlsson & Thoresson 2011: 6).

Kitting

Bozer and McGinnis (1992) classify kitting as the process of putting together a kit of components and/or subassemblies before delivering them to the assembly line. Kit assembly refers to the practice of placing the content of a kit in a kit container (Bozer and McGinnis 1992: 1). In similarity to sequential supply, kitting delivers the parts in sequence in which they are assembled to the line. Kitting is particularly advantageous when each work station has many variants of parts to be mounted. Often, kitting is used additional to other material feeding systems. Components like fasteners and plugs are most commonly not included in the kitting process (Bozer and McGinnis 1992: 12). Product complexity and part size are motives for choosing other material feeding systems. Sequenced deliveries – in contrast to kitting, which is less favorable under these circumstances – can be beneficial where few parts are assembled on a serial production line. However, kitting presents several different articles in one kit container while sequenced delivery, mostly displayed in racks, carries only variants of one article sorted by assembly product. The space required for variants of components can be reduced but not the space required for the individual racks. Hence, kitting requires less space at the assembly line.

2.2 Kitting theory

In this chapter, the kitting theory is described.

Benefits of kitting

Compared with other material feeding principles kitting is associated with a number of potential advantages:

- Shorter lead times and increased productivity at each working cell due to reducing of operator’s walking, searching, and fetching (Johansson 1991, Schwind 1992) by presenting material in a suitable picking position relative to the assembly object (Jonsson et al. 2004).
- Space efficient material presentation (Bozer & McGinnis 1992, Medbo 2003, Hua and Johnson 2010) increases flexibility of the assembly line. Product changeover and rebalancing of operations can easily be accomplished (Bozer & McGinnis 1992, Ding 1992, Medbo 2003, Jiao et al 2000).
- Improved assembly quality due to the possibility of having quality checks earlier and error avoidance of wrong or missing parts (Bozer & McGinnis 1992, Johansson 1991, Schwind 1992) and lower learning curves for new employees (Carlsson & Hensvold 2008, Ding & Balakrishnan 1990, Johansson 1991).
- Improved control of the flow of parts on the shop floor. Therefore, better availability of components (Bozer & McGinnis 1992, Ding 1992) and better visibility for work-in-progress, expensive or perishable components and subassemblies (Bozer & McGinnis 1992, Schwind 1992).
- Reduces material delivery to workstations by eliminating the need to supply individual component container (Bozer & McGinnis 1992, Ding & Balakrishnan 1990, Medbo 2003) and diminishing damages in production logistic.

Limitations of kitting

Some of the authors have acknowledged the risk of having a lacking kitting process that turns the above mentioned benefits into limitations:

- Kits need to be prepared with no value add processes (Bozer & McGinnis 1992, Hua & Johnson 2010)
- Increased storage space for kitting area (Carlsson & Hensvold 2008, Bozer & McGinnis 1992)
- Additional transportation when kits are prepared in a different area (Hanson & Medbo 2012)
- Demands additional planning for kit preparation (Bozer & McGinnis 1992)
- Defective parts in kits lead to shortage at working cells (Bozer & McGinnis 1992). When a part breaks during assembly there are no spare parts at the line (Bozer & McGinnis 1992)
- Picking parts is a monotonous working process which can result in injuries and unmotivated personnel (Carlsson & Hensvold 2008, Christmansson et al. 2002)

Before the implementation of a kitting process one should weigh up the benefits of kitting against its limitations. Indeed, one can strongly recommend the introduction of kitting when the advantages exceed the potential limitations.

Design of the kitting system

According to Brynzer and Johansson (1995), decisions need to be made regarding the organization of work and the location of the kitting process. Four main factors play a decisive role in designing a kitting system:

- Where the kitting area is located
- Which parts to be kitted
- Who makes the kit assembly
- How the kit assembly is being progressed

Where to kit?

In the kitting area, the kitting process is performed. Kitting on plant site can either be located at a central kitting area at decentralized areas close to the assembly stations, so-called supermarkets (Carlsson & Hensvold 2008: 14). Furthermore, kitting can also be done off the factory site. Responsible for the process could either be the manufacturer himself, a third party supplier or a supplier who supplies more than one part assembled in the same product (Carlsson & Hensvold 2008: 14). Third party kitting will not be investigated in this master’s thesis.

As shown in figure 2.2, a central picking area provides the possibility of integrating the kitting area with the main material stores to reduce unnecessary material movements (Carlsson & Hensvold 2008: 14). One can also benefit from economies of scale by fabricating different kits in the same area (Gajjar & Thakkar 2014: 894). On the other side, a central picking area lacks communication to assembly line due to its location.

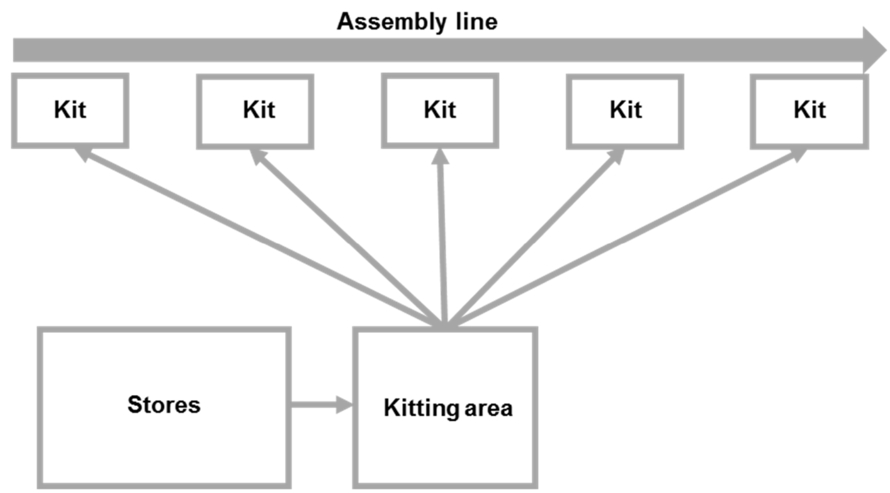

Figure 2.2: Kitting in a centralized picking area (Gajjar & Thakkar 2014: 895)

Decentralized kitting areas, instead, can, as shown in figure 2.3, easily communicate with the assembly line; however, it is difficult to balance the workload of kits production (Gajjar & Thakkar 2014: 894).

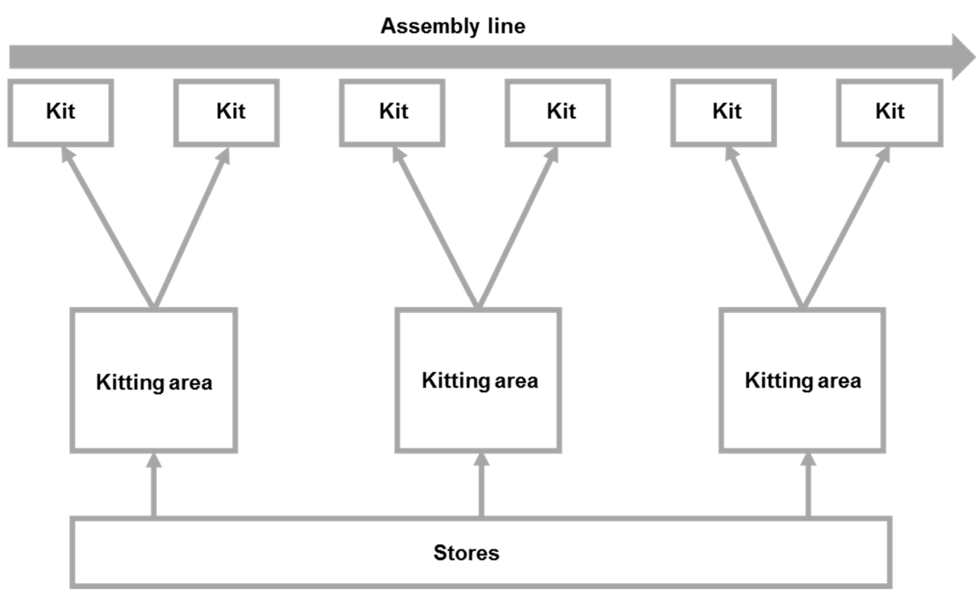

Figure 2.3: Kitting in a decentralized picking area (Gajjar & Thakkar 2014: 895)

What to kit?

Due to product size and complexity, a kit does normally not contain all the parts required to assemble one product (Gajjar & Thakkar 2014: 894). Components such as fasteners or plugs are mostly excluded from the kitting process. These parts are delivered as bulk material directly to the shop floor (Bozer & McGinnis 1992: 6). According to Ding (1992) as a result of size restrictions, there are also kitable and non-kitable parts. Non-kitable parts should be feeded to the assembly line with continuous supply.

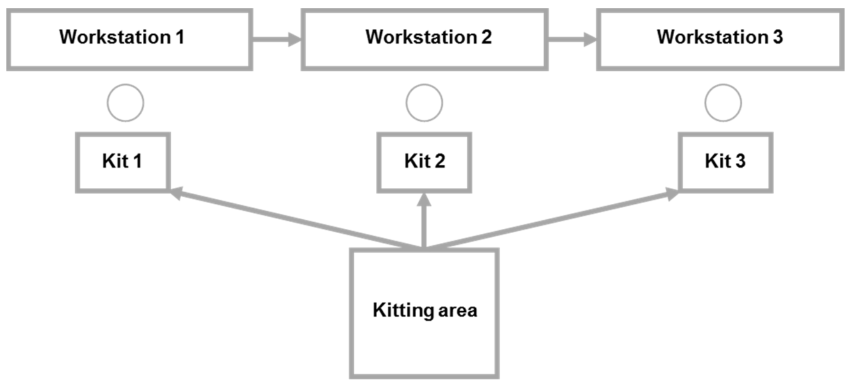

Figure 2.4: Stationary kits (Gajjar & Thakkar 2014: 896)

Bozer and McGinnis (1995) distinguish two types of kits, stationary kits and traveling kits, shown in figure 2.4 and figure 2.5. Stationary kits are delivered to a work cell, where they remain until they are fully depleted (Carlsson & Hensvold 2008: 16). The travelling kit moves alongside the assembly line in simultaneity with the product and can support several assembly stations before it is consumed (Gajjar & Thakkar 2014: 895). Two types of travelling kits exist. The product and the kit are either in the same box or the kit follows the product in parallel in a different container.

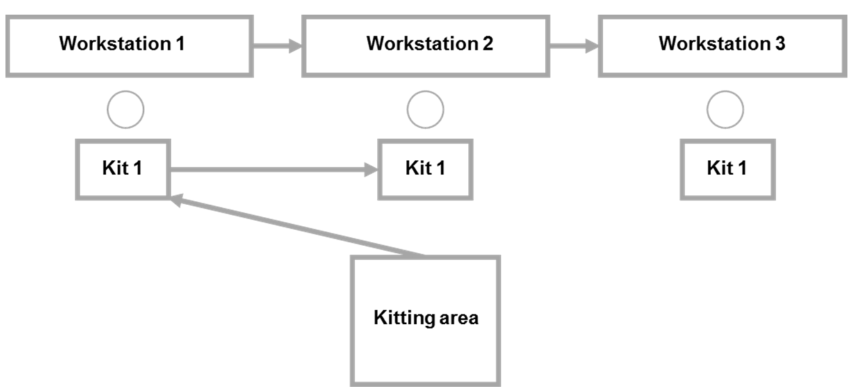

Figure 2.5: Travelling kits (Gajjar & Thakkar 2014: 896)

Who to kit?

There are two ways concerning the question who physically does pick the parts into kits, man or machine (Carlsson & Hensvold 2008: 16). In this research machine kitting will not be considered.

Brynzer and Johansson (1995) discuss different design options of kitting systems. Kits can be made by a special category of operator, the picker, or by the assembly worker himself. Several authors point out the benefits of integrating the kitting process in the assembler's work (Carlsson & Hensvold 2008: 16). Assembly workers obtain higher picking accuracy when they are responsible for the whole job (Gajjar & Thakkar 2014: 896). They have a good understanding of part numbers included in the assembly operation. Furthermore, the integration will enhance the overall productivity by reducing balancing problems (Carlsson & Hensvold 2008: 16).

The advantage of having certain pickers is that assembly operators focus their time on value-added work.

How to kit?

Brynzer and Johansson (1995) define two ways to classify order picking systems, whether the picker moves to the picking area (picker-to-part) or whether the parts are moved to the picker (part-to-picker) (Carlsson & Hensvold 2008: 16). Traditionally, in the automotive industry material picking is done according to the picker-to-part system. Kitting is performed in a kitting area where the picker moves between containers and picks the parts needed for a kit. The kitting process must be designed to ensure that the right part goes into the right kit and the right kit gets delivered to the appropriate workstation. Furthermore, the kit design should allow an easy kitting process and a simple mounting process (Gajjar & Thakkar 2014: 896).

Kitting can be performed in batches. According to Bozer and McGinnis (1992), it is effective to assemble several kits together in order to reduce walking distance and picking time. Kitting in batches only makes sense in case of none or little variation production (Gajjar & Thakkar 2014: 896). It can have a negative impact on the picking accuracy.

The kitting must be in synchronism with the assembly process. Accordingly, the amount of kits prepared per day is equal to the number of vehicles produced every day. There are different ways how to design the picking area to support a synchronous picking process. It can either be one big area or the picking area can be divided into picking zones. In case of one big picking area the picking container gets replenished in one picking tour. Figure 2.6 demonstrates this process.

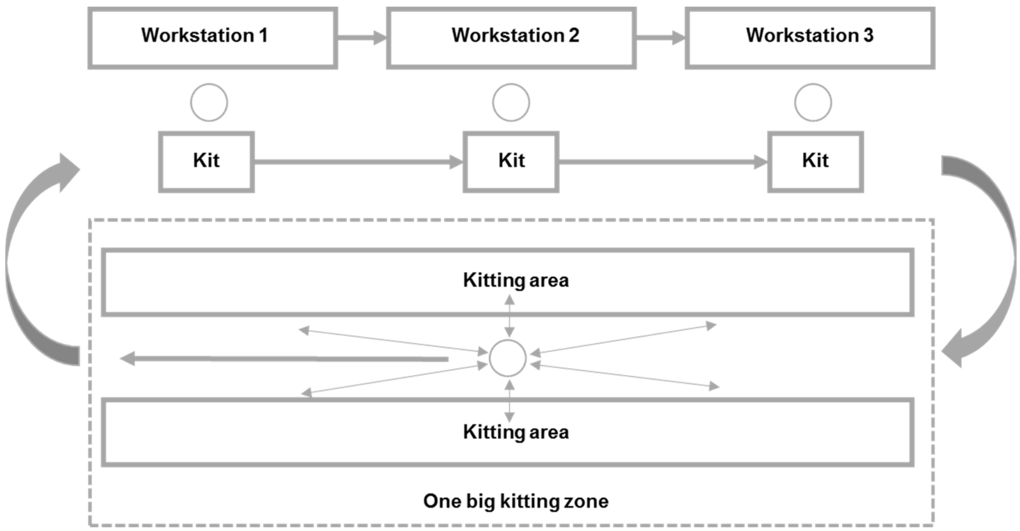

Figure 2.6: Kitting in one big kitting area and travelling kits (Gajjar & Thakkar 2014: 897)

A picking order can be divided and hence can be picked simultaneously in different kitting areas. Brynzer (1995) distinguishes between two types of zone picking, namely progressive zoning and synchronized zoning. Figure 2.7 shows progressive zoning where each kit has to go through all zones until it is ready for delivery (Gajjar & Thakkar 2014: 897)

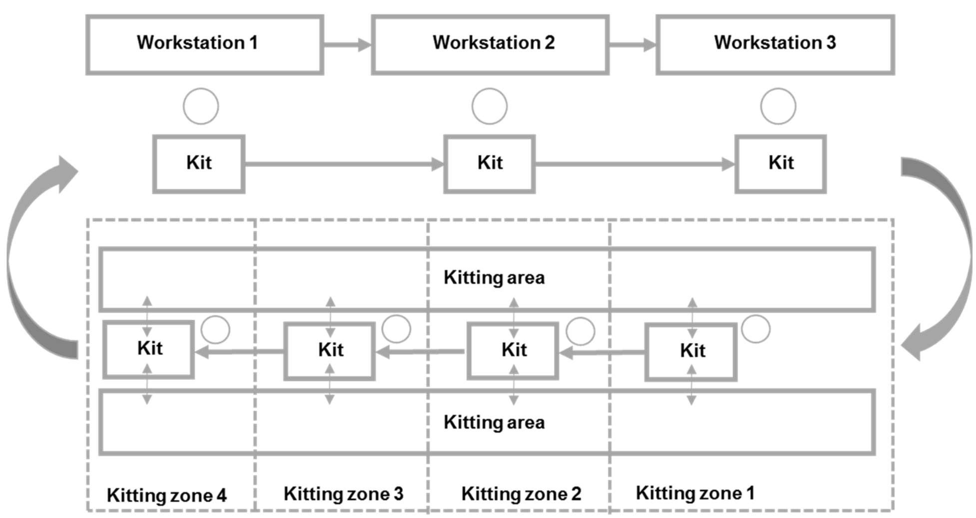

Figure 2.7: Zone picking and travelling kits I (Gajjar & Thakkar 2014: 897)

Synchronized zoning is when different zones are working on the same kit. The parts from different zones are gathered in one kit, as shown in figure 2.8.

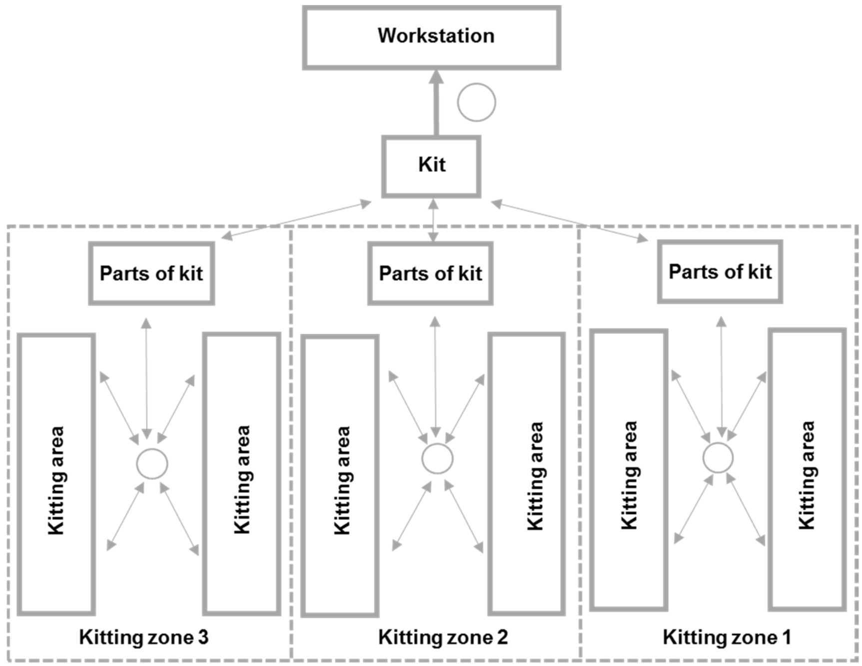

Figure 2.8: Zone picking and travelling kits II (Gajjar & Thakkar 2014: 897)

The picking information design is an important factor concerning picking accuracy and picking productivity (Carlsson & Hensvold 2008: 19). According to Brynzer and Johansson (1995) four different ways of designing the information system can be distinguished:

- A picking list is the most common picking information for the picker. The picker receives a list which specifies the part number regarding location and quantity. One problem that may occur is that experienced pickers may neglect the list and start to pick by experience (Brynzer and Johansson 1995: 119). Additionally, this system has a high risk for inaccuracy through picking the wrong part, especially after design changes with new part numbers. Beneficial is the small investment cost of this traditional picking design (Carlsson & Hensvold 2008: 19).
- Displays and lamps, indicating which and how many parts should be picked at the storage location, reduce the risk of inaccuracies. Pick to light can also be enhanced with buttons installed for the operator to push after picking each picking process (Brynzer and Johansson 1995: 119). On the one hand, this system

requires a relatively huge investment; on the other hand, the picking accuracy is very high due to the use of poka yoke.

- Another alternative of designing the information system is to assign an identifying number, letter or color to each final product and to display this symbol at each storage location. The picker then picks all parts with this sign from the kitting area. This variant requires frequent physical updates when parts are changed (Gajjar & Thakkar 2014: 897).
- For the forth way, the picker needs to be very experienced as he receives the specification of the end product (Carlsson & Hensvold 2008: 20). With this information, the picker gathers all the parts. Beneficial is the simplicity of this design, but product design changes can not be handled (Carlsson & Hensvold 2008: 20).

Beside the kitting information design, the actual design of the kit container is of crucial importance. The kit has to be functional in the picking process as well as in the assembly process (Gajjar & Thakkar 2014: 897). According to Medbo (2003), the assembly worker is supported by the configuration of the kit container. An efficient design leads to a decrease of assembly cycle time (Carlsson & Hensvold 2008: 20). Bryzer (1995) points out that this design should allow the picker to acknowledge where which part needs to be placed and which part is missing.

Parts can be displayed to the assembly worker lying freely in a container or being fixed by dedicated placing for each part. Kit container with determinate places for parts have advantages as well as disadvantages. On the one hand, there is less risk of a part being overlooked in the kit preparation, it assists the operator by reliably ensuring where to find each part and having it presented in a suitable orientation for assembly. Further, many parts have a sensitive surface and the fixed position prevents them from getting scratched (Hanson & Brolin 2012: 984). On the other hand, structured kits can restrict flexibility. When parts are added or deleted from the manufacturing process, the kitting container needs to be redesigned.

2.3 State of the art

An extensive bibliography exists in the area on kitting versus line side stocking.

Womack et al. already stated in 1990 that value-added share of the operator's work should be maximized by efficient assembly operations in manual assembly.

One of the first analysis dealing with the issue of line feeding was from Johansson and Johansson (1991). They state that the kitting process is suitable for assembly systems with parallelized flow, product structures with many part numbers, need for quality assurance and high value components. Ding and Balakrishnan (1990) emphasized that kitting is most suitable for industries which deal with small parts, like the electronic industry. However, they conclude their study with successfully implementing kitting in a tractor assembly plant for front and rear tractor frames (Gajjar & Thakkar 2014: S.893). They stated that the efficiency of the assembly process would be increased by implementing part kitting. It decreased material handling and searching time, improved production control, reduced space and improved productivity. In addition, the implementation leaded to reduced WIP (work-in-progress) inventory. Thus, detailed information of the original line feeding principle is lacking.

Bozer and McGinnis (1992) intended to serve as a framework when studying kitting versus line side storage principles. They invented a descriptive evaluation model, which can evaluate the most effective way to deliver the material to the assembly line. The model can quantify the necessary storage and retrieval of kit containers; the flow of components and component containers as well as the required shop floor space are the performance measures. They show that kitting achieves a better performance in average work-in-progress, reducing space requirements and container flow. Line stocking on the other hand, has advantages regarding retrieval criteria and storage (Sali et al. 2015: 1441). The model is based on several assumptions: single container type, single kit container type, no sharing of components between stations etc. (Hua & Johnson 2010: 782). Although significant differences exist between the in-plant distribution systems, the part picking activity of the assembly worker is not taken into account. Furthermore, the model does not help to design a cost-effective material supply system.

Henderson and Kiran (1993) used simulation to draw a comparison between the performance of a kitting system and line stocking system. With the introduction of line side storage, a pump manufacturer reduced WIP inventory and labor content involved with picking while increasing the number of material deliveries to the line.

Brynzer and Johansson (1995) reviewed multiple case studies and analyzed the design of a kitting system regarding the location of the order picking activity and the work organization as well as in terms of the picking method, the efficiency of kit preparation, the information system and material handling equipment.

Field (1997) studied the use of kitting in a printed circuit board manufacturing of Texas Instruments. After converting the existing kitting system into a line stocking principle, Texas Instruments experienced a drastic change of performance indicators. With the introduction of line storage there was a drop in WIP, average lead time, floor space requirements, material control-related costs, and stock requisition (Hua & Johnson 2010: 782). Field's case study exclusively considers the electronic industry.

Carlsson and Hensvold (2008) examined the feasibility of replacing line side stocking with kitting. They used an Analytic Hierarchy Process to find out the needs of a Caterpillar factory in Leicester. In contrast to the above paper, their study reveals that kitting leads to a decrease in line side stocking, in line side inventory level and line side replenishment as well as in operator walking time while increasing the number of part handling, the space requirement for kitting area, and the time for kit preparation. However, their study is based on machinery industry.

De Souza et al. (2008) developed a model for the assembly line feeding problem which supports to optimize packaging and material exposure. It helps to decide how to pack the necessary parts in containers, to minimize handling costs, holding costs and considers the availability of containers (Limère et al. 2011: 4047). But it does not support the decision which feeding principle to choose.

Battini et al. (2009) studied three different feeding processes: pallet to work station, trolley to work station and kit to assembly line. Their approach supports decisions regarding the centralization or decentralization of storage areas. However, they do not consider different part characteristics.

Hua and Johnson (2010) point out the lack of studies which compare kitting with line side storage. Based on a study in the electronic industry, they identify and analyze factors that may influence the choice between kitting and line stocking. While they assume that kitting should be the best option for an assembly of products with a large variety of components, they consider line stocking preferable for products with similar components (Sali et al. 2015: 1442). However, their study is based on the electronic industry.

Caputo and Pelagagge (2011) invented a quantitative methodology for choosing an assembly system feeding process: line stocking, kitting or continuous supply. For each mode, they offer an analytical expression for work-in-progress, material handling and space utilization (Sali et al. 2015: 1441). The goal was to determine the preliminary size and select a feeding system (Kilic & Durmusoglu 2012: 228). Though, the generated model developed solely considers the case of a single product.

Limère et al. (2012) use a Mixed Integer Programming that manages to reduce labor costs. Their mathematical cost model assigns parts either to kitting or line side storage. The results show that line stocking for all parts is the best solution in terms of costs. Yet, some parts need to be kitted due to space limitations in assembly plants. Altogether, their model is limited inasmuch as they assume constant operator walking distances at the assembly line, notwithstanding that the introduction of kitting in fact reduces these distances.

Hanson and Brolin (2013) showed the effects of kitting and continuous supply on working hour consumption, product quality, flexibility, inventory levels and space requirements. Man hour consumption for kitting exceeds the one of continuous supply as the required time to pick each part in kit preparation exceeds the time saved at the assembly line (Sali et al. 2014: 1441). However, kitting enhances the assembly line flexibility by enabling line rebalancing. There is a neglectable impact on inventory levels.

Most recently, Sali et al. (2015) offered an empirical assessment of the performance of kitting versus line storage versus sequencing. In doing so, they provide evidence that the benefits and limitations of these feeding systems are dependent on the product mix and the part characteristics (Limère 2014: S48).

2.4 Conclusion on theory

The above discussed studies deal with the comparison of kitting versus other material delivery systems. In conclusion, some research recognize kitting to be superior to line stocking while other literature shows exactly the opposite.

Product volume and variety are crucial factors for the choice between line stocking and kitting systems. If product volumes are high while variety is low, a system which stores material at the assembly line would be the most efficient (Hua & Johnson 2010. 785). Hence, a line stocking principle would probably the best option. If individual component volumes, on the contrary, are low while variety is very high, kitting is applicable since the requirements of the component are unknown until the order is received (Hua & Johnson 2010. 785). The grey area in between these extremes is where the real problem of deciding which material feeding principle to choose lies.

Further research is needed to fully explore the trade-off between kitting and line side storage. Accordingly, the purpose of this case study is to extend research insofar as the decision process related to the implementation of kitting itself is the subject of this investigation.

3 Methodology and tools

This chapter outlines the work procedure of this master's thesis. It also presents the different methods and tools used during the course of action. Further, the different approaches and strategies which serve as foundations of this thesis are discussed.

3.1 Research philosophy

The research philosophy is divided into two methods, quantitative and qualitative. The quantitative research uses cold figures measured or evaluated numerically as central unit of analysis (Carlsson & Hensvold 2008: 23). This formulized and structured process of measurement is central as well as the gathering of facts and the study of relations between constellations of these facts through scientific techniques (Karlsson & Thoresson et al. 2011: 10).

The qualitative research is based on soft data such as observations and interviews as the fundamental source of information. These promise according to Holme & Solvang (2001) a deeper understanding of the problem.

In this thesis, a quantitative philosophy is mainly used, but qualitative methods support the decision making process. The problem is qualitatively analyzed in order to get a more comprehensive view of the introduction of kitting.

3.2 Research approach

Generally, there are two different approaches commonly used in academic literature, namely an inductive and a deductive approach (Carlsson & Hensvold 2008: 20). The inductive approach uses facts from the empirical world to construct theories in the theoretical world.

Arbnor et al. (2009) state that deduction is the logical analysis of what the theoretical world says about a specific event tomorrow. This research started with studying theories concerning relevant subjects. Data from the empirical research is then analyzed and correlated with the existing theory. Hence, the research approach of this study is deductive.

3.3 Research strategy

Saunders et al. (2000) point out that a research strategy is a general plan of how to fulfill the objective of the study. Four main strategies exist: experiment, survey, case study and action research (Carlsson & Hensvold 2008: 24). For the topic of this master's thesis case study is the most appropriate scientific research. A beneficial feature of the case study is the researcher's possibility of focusing on a special occasion to find influencing factors for the case. According to Carlsson and Hensvold (2008), the purpose of a case study is to pick a small part of a bigger lapse and to let the case represent a broader picture. The aim of focalizing on a small area in the factory to conduct deeper research, then, is to try to form conclusions that apply to the whole factory or the whole industry (Carlsson & Hensvold 2008: 24).

3.4 Data collection methods

Primary and secondary data are the main two types of data. Primary data has to be collected by the researcher himself via interviews, surveys or observations (Carlsson & Hensvold 2008: 25).

Secondary data refers to information already available and analyzed by other researchers. In this master's thesis both primary and secondary data is used.

3.5 Studies of literature

The theoretical aspects have been gathered through on academic databases. The theory for this thesis dealing with kitting derives from research published in scientific journals.

3.6 Course of action

The thesis begins with an introduction and the formulation of its goals and purpose. After the purpose was defined, the search for a research strategy began. Eventually, the choice was made for a case study. This is followed by an introduction of the company, the factory, and the trim line.

The next important step in this methodology is to decide the scope of this study. The study focuses on the trim line since this part of the assembly line has a lot of part variety and accordingly, huge lineside storage areas. Therefore, it is of high interest how the introduction of kitting would affect effectivity. Different informal interviews with manufacturing engineers were perfomed with the conclusion that the A1-line - which is the beginning line of the trim line - was chosen for a closer examination. This area of study was selected because it represents 1/5 of the whole trim line. A1-line consists of 14 work stations. Further introduction to other assembly lines will not be discussed in this master's thesis. However, getting the full picture once this section is analyzed is a quite easy task.

Before evaluating whether an alternative solution would be of greater contribution, knowledge of the present processes is required stated by Aronsson et al. in 2004. The empirical description aims at achieving an insight of the current material feeding principles; thus, in chapter 4 the current state in Valencia is examined. Parallel to the empirical description a review of literature was initiated.

One of the main steps is the collection of data. The main source of data used was the VPP (Vehicle Parts Progress) software. This software determines part numbers, end product requirements, consumption and material prices of each part. Internal flows within the Valencia plant were studied by direct observations and internal company documentation. Interviews with engineers involved in implementing kitting and with personnel involved in the decision to introduce kitting were conducted. Further, current material flows of all feeding principles were mapped and validated. The interviews were semi-structured and face-to-face. To complement the interviews, some questions were answered by telephone and e-mail.

The case study is supported by a layout plan, from which the walking distance and space data requirements were taken. In the case study, a transition was realized from mixed material supply to kitting.

After collecting and verifying the data, the process of constructing a model followed. Bozer and McGinnis (1992) present a descriptive model concerned with the material trade-off between kitting and lineside storage. Carlsson and Hensvold (2008) adapted this model in order to fit the situation at Caterpillar. The model by Bozer and McGinnis was designed for general purposes; however, some variables and output did not correspond with the conditions at Caterpillar. Carlsson and Hensvold aim was to determine what types of parts could benefit the most from introduction of kitting (Carlsson and Hensvold 2008: 44). The mathematical model of this master's thesis is a revision of the model described by Limère et al. (2015). It is a model to calculate the cost of the line feeding system, line stocking, sequencing and kitting. It is adapted to be more compatible with the special circumstances and constraints at the Ford Valencia plant, since the goal of this research is not to provide an optimal assignment of parts to line feeding principles. The aim is to minimize lineside storage space, to be more flexible in rebalancing worksteps from on workstation to another and to reduce sequencing costs at Ford Valencia by a 100% kitting process for kitable parts.

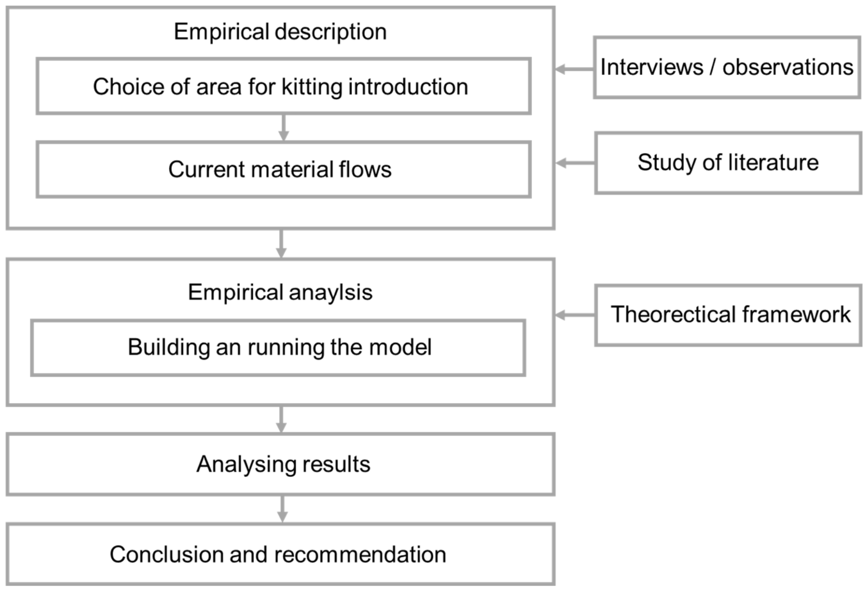

Figure 3.1: Schematic picture of the work procedure

The output of the model is difficult to compare in terms of monetary values. It was necessary to weight the different criteria to receive a clear picture. The weighting was done by a multi criteria decision-making tool. AHP (analytical hierarchy process) produces weights for different criteria through a pairwise comparison (Carlsson and Hensvold 2008: 23). It is a quantitative technique and a suitable tool to facilitate decision making. First, the objective needs to be stated; then, second, problems are decomposed into a hierarchy of criteria. The third step is to pick alternatives. This information is arranged in a hierarchical tree. Decision makers individually point out their statement regarding the importance of the criteria with a 1-9 points systems; 1 equals the two options are equally preferred and 9 means that one option is extremely preferred over the other (Carlsson & Hensvold 2008: 26). Hence, different criterias of the kitting introduction can be weighted by the decision makers.

With the result of the decision-making tool in combination with the mathematical model, the final conclusion can be presented. The analysis is then the foundation for the guiding principles, which intend to make the decision of implementing the kitting process in the whole trim and final line.

3.7 Methodological issues

It is stated that both the external validity and reliability of a case study are limited. However, Yin (2004) emphasizes that case studies rely on analytical generalization as opposed to statistical generalization (Hansen & Medbo 2012: 1118). In this master's thesis, the description of the case study allows to grasp the factors behind the observed effects. This enables to apply the method from this case study to other situations.

The author worked closely with the mentors at Ford Valencia to ensure the usage of accurate data. No assumptions were made without discussion with the project team; this decreases the risk of making assumptions based on misinterpretations. This increases the thesis's validity.

4 Current state at Ford Valencia

In this chapter, the current situation at Ford Valencia plant is described. The outline opens with a description of the Ford Valencia plant's layout and its assembly shop. In the following, the area of investigation is depicted in order to enable the reader to follow the continuation of the report. Here, a general account of the material stores, the part complexity, and the current material feeding principles is offered. Finally, some issues that currently exist at Ford Valencia plant are discussed.

Valencia plant is a major hub of manufacturing for Ford Motor Company in Europe. The plant was opened by King Juan Carlos and Henry Ford II. In 1976, the first Ford Fiesta rolled off the production line. Ford Valencia has produced more than 11 million vehicles and 15 million engines. Nowadays, more than 8.000 people build six Ford nameplates and even more body styles. The plant currently builds the Mondeo wagon, five-door, and four-door, including the Mondeo Hybrid and the Mondeo Vignale, the Kuga SUV and Kuga Vignale; the multi-activity vehicle S-MAX and S-MAX Vignale; the seven-seat people mover Galaxy; the light commercial vehicle Transit and, finally, the people mover Tourneo Connect. 419.000 units were built in 2016 in a three shift operation with 18.077 different parts. These vehicles are delivered to 75 countries. The plant's vehicle production capacity is about 2.000 units per day. New assembly line processes place Valencia among Ford's most efficient facilities. Thus, it is indispensable to manage the increased complexity of producing more models and derivatives in the Valencia plant than in any other Ford facility in Europe.

4.1 Assembly shop

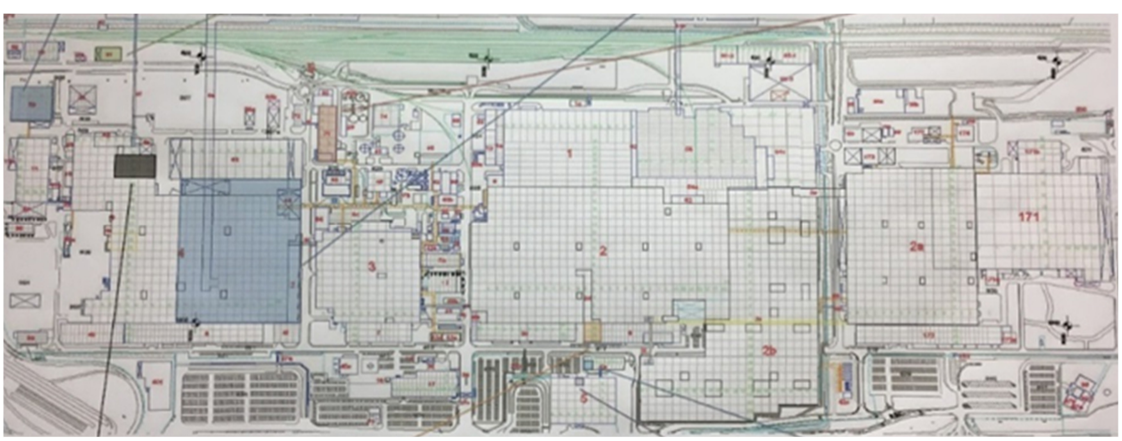

Figure 4.1: Layout of Ford Valencia plant

To get an impression of Ford Valencia plant, the layout of the plant is presented in figure 4.1. The blue marked square is the assembly shop. The assembly performs along two continuously moving assembly lines, in particular along A-line and B-line. Mondeo and S-MAX are built on the A-line whereas Transit and Tourneo run on the B assembly line. For Kuga is a swing model, it can be produced on both lines.

Figure 4.2 shows the trim line as well as storage areas around it:

- Extension 66 (2940 m^2)
- Kitting trim (1800 m^2)
- Call BB trim area (2600 m^2)
- Call CC / V5 chassis storage area (4200 m^2)

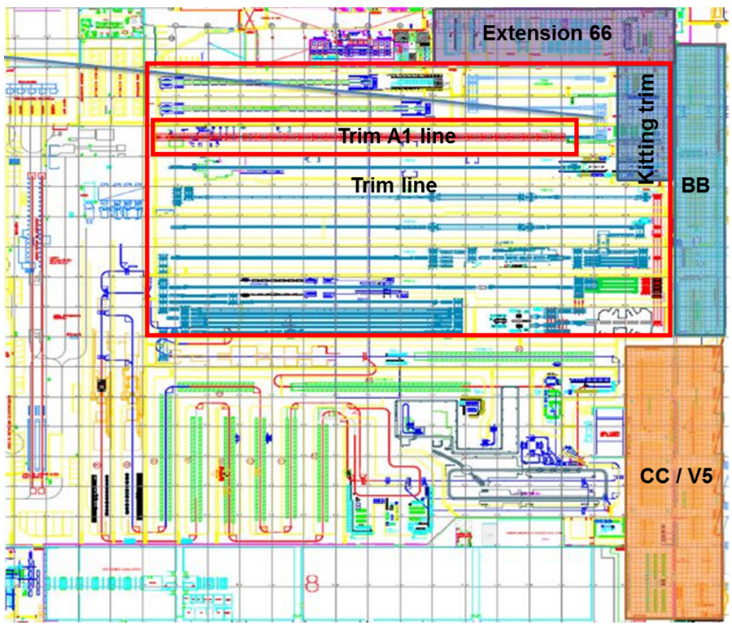

Figure 4.2: Layout of Ford Valencia assembly shop

The case study comprises the assembly line A1, which is the beginning section of the A-line and consists of 14 workstations on each side of the assembly line. The operator picks parts from the point of use stores and mount them to the vehicle. Different workstations have different part numbers and quantities of operators. The assembly work is mainly manually performed. The line is balanced leading to all stations having the same takt time.

4.2 Material stores

All four material stores, shown in figure 4.2, are located inside the assembly shop building. In total, they have approximately 11.540m² storage space. From these stores the material is transported to the trim and chassis line.

The storage area Extension 66 is shown in figure 4.3. It has approximately 2940m², 1235m² of which are used for storage; 1705m² are for aisles or without use. 300m² are occupied by parts that perform the kitting for the A1-line.

Figure 4.3: Extension 66 storage area

Figure 4.4 presents the kitting area in trim. It has approximately 1800m², 845m² of which are used for storage; 955m² are for aisles or without use. 440m² are occupied by parts that accomplish the kitting for A1-line.

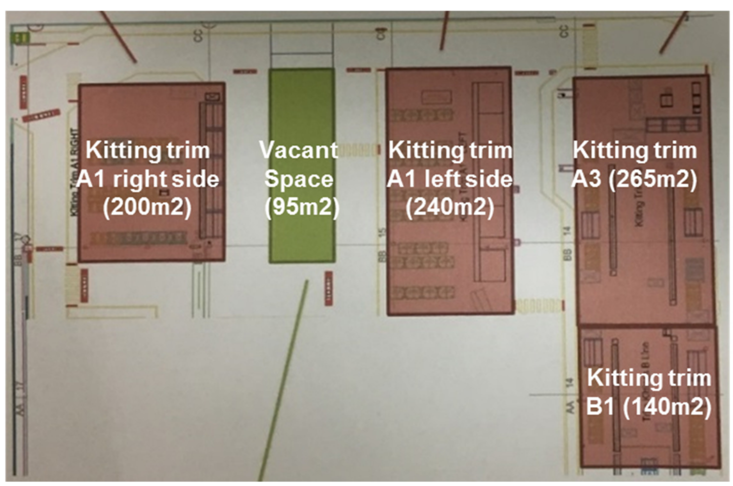

Figure 4.4: Kitting area trim

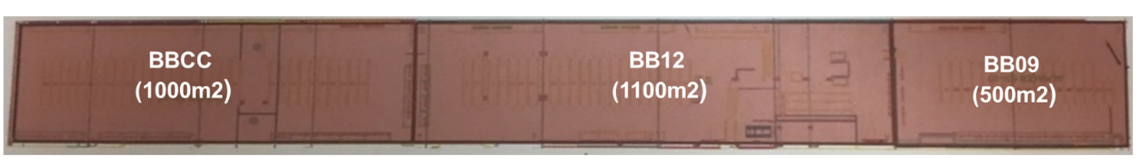

Figure 4.5: Call BB trim storage area

Figure 4.5 presents the Call BB trim storage area with approximately 2600m^2; and figure 4.6 charts the Call CC / V5 chassis storage area with approximately 4200m^2 for storage.

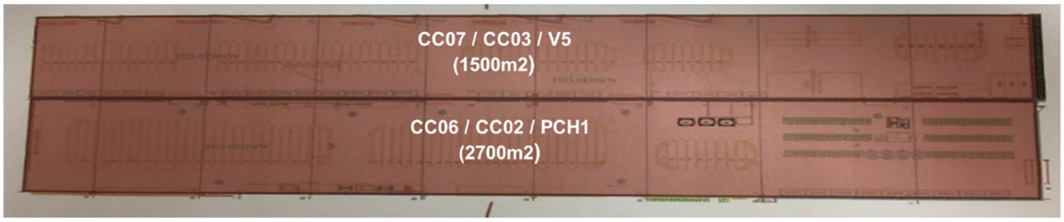

Figure 4.6: Call CC / V5 chassis storage area

4.3 Part complexity

Table 4.1 shows the part complexity for each line ranging from A1 to B3. In line A1, 825 part numbers and 6 sequencing families get assembled to the vehicle. Currently, roof rails, cork parts, fuel housing, curtain airbags, PCM and pedals are being delivered to the A1 assembly line in sequence.

Line	# of references	# sequencing families
A1	**825**	**6**
A2	1285	18
A3	404	4
B1	924	11
B2	735	18
B3	531	4

Table 4.1: Part complexity and number of sequencing families

The parts can be distinguished with regard to the particular delivery processes that moves them to the assembly line. All parts assembled on the A1-line can be found in appendix B.

4.4 Material feeding systems

The different material feeding systems have already been described in the theoretical chapter (chap. 2.1). As elucidated there, different feeding principles can exist simultaneously. This is also the case at Ford Valencia plant. Ford Valencia has three material feeding principles: continuous supply from the internal warehouse Call/BB trim or via Kanban from the logistic supply of Grupo Valautomocion (Valmo), sequential supply, and kitting. Based on site, three logistic suppliers carry out various material handling activities: Walker, Valmo and Ilunion.

Figure 4.7 – figure 4.9 show the different feeding systems used in trim line. Most of the parts are supplied via the material supply system continuous supply to the A1-line. As stated in the theoretical part, the parts are sorted by part numbers and all parts required to fulfill the assembly operation are stored lineside at all the time.

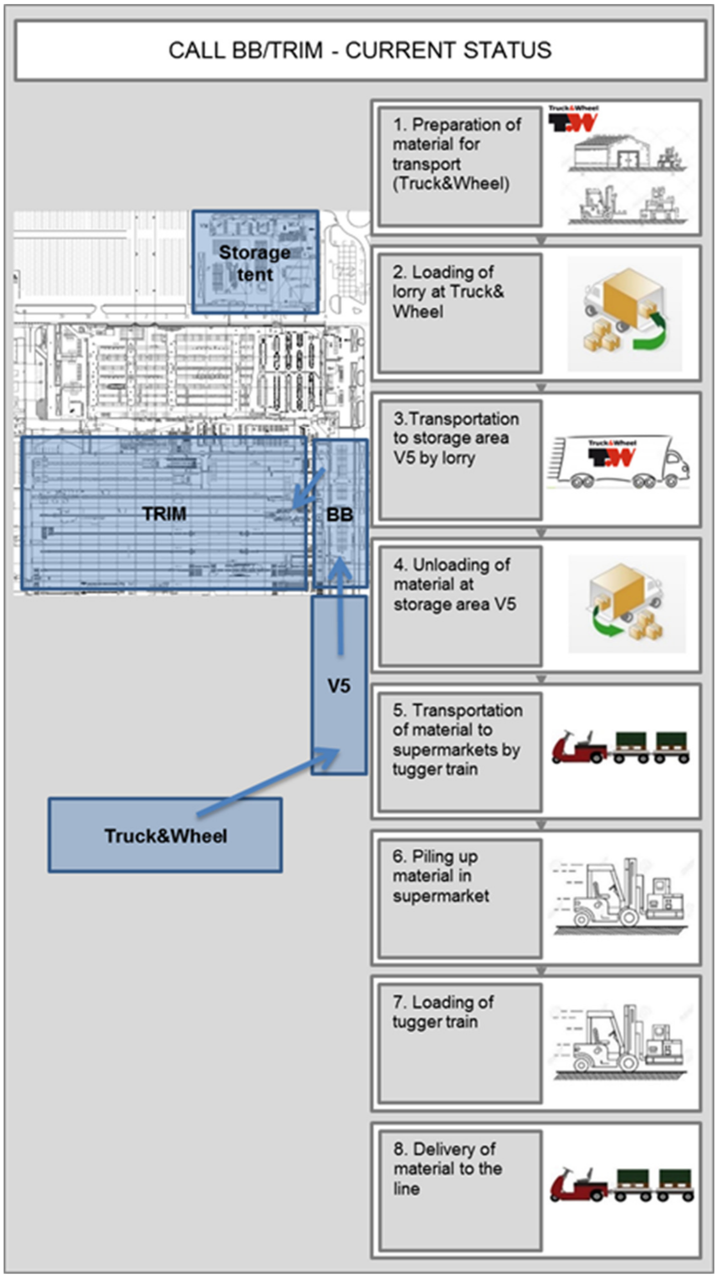

Figure 4.7: Call BB / trim – current status

The studied material flow of the Call BB / trim storage area is highlighted in figure 4.7. When the material is prepared at Truck & Wheel, the truck is loaded and pallets are transported to the storage area V5 by lorry. There the material get unloaded and is transported to the supermarket place via tugger train where it gets piled up. After loading of a tugger train the material is delivered to the assembly stations.

To keep control over the inventory levels and to replenish production material, a two-bin Kanban system is also used in Ford Valencia. The Kanban routes are prepared at the logistic supplier Valmo. When the material is loaded on a lorry, the parts are transported to the storage tent. The logistic personnel is in charge to replenish the material via tugger train.

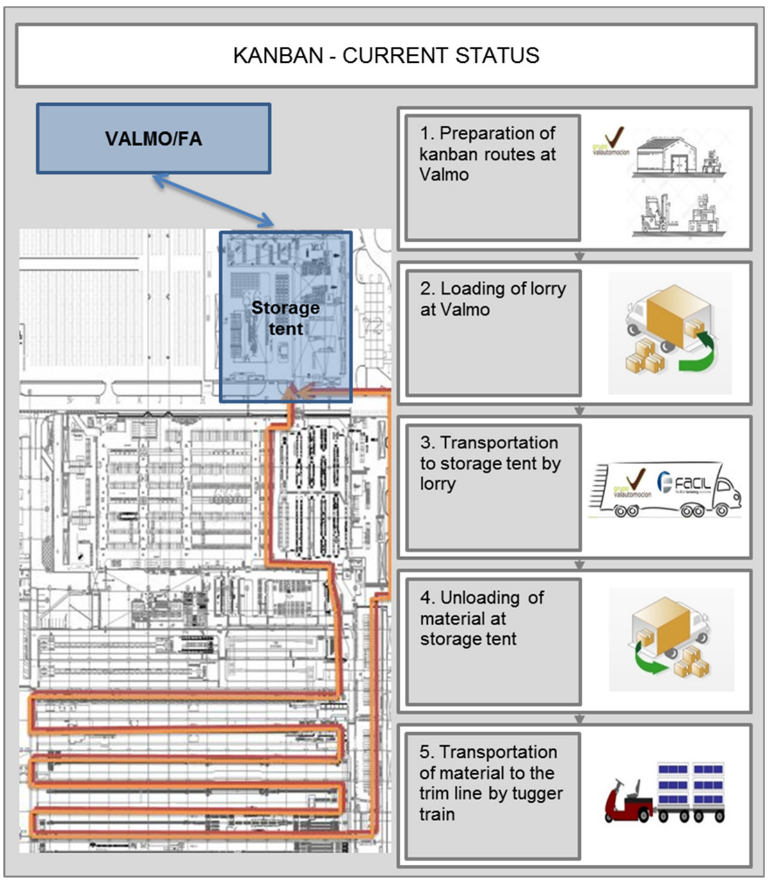

Figure 4.8: Kanban – current status

Some part families are delivered in sequence to the line, as shown in figure 4.9. Sequential supply is effective when part numbers required for a specific number of assembly objects are displayed at the assembly station, sorted by object.

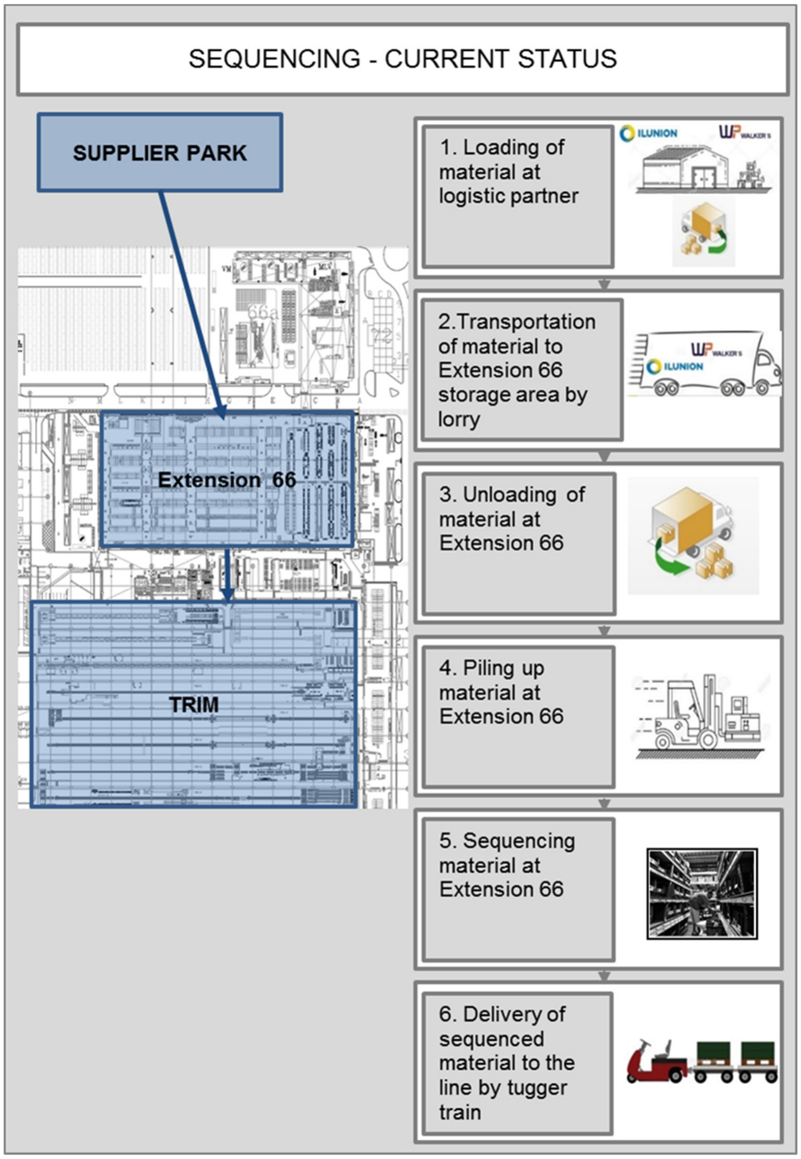

Figure 4.9: Sequencing – current status

When the material is prepared by logistic partner, the truck is loaded and the material is transported to the storage area Extension 66 by lorry. After the material is unloaded, it is transported to the supermarket place via tugger train where it gets piled up. Before the material gets delivered to the assembly stations by tugger train it is sequenced and placed on different types of racks in the storage area Extension 66.

Some of the part numbers are already kitted by Ford employees. These parts come in a multitude of variants that made lineside storage impossible. A kitting area has been set up where kitting operators assemble kits. The kitting area is located close to the A1- line.

4.5 Line side storage

The lineside storage, also called point of use (POU), is the storage along the assembly line. The operator takes the material from the lineside storage and assembles it to the product. POU stores look different depending on the size of the part and the material feeding principle.

Since the assembly object moves continuously during assembly, most of the parts are arranged in containers on racks so that material which is needed early in the assembly cycle is presented at the beginning of each workstation, whereas the parts required later in the cycle are presented further down the assembly line (Hanson & Brolin 2012: 983). Assuming that the operator performs the assembly operation at the planned speed, the distance for picking parts is planned to be relatively short. Table 4.2 presents the different container types and quantities at the A1-line. 35 containers from the Call BB / trim area are stored at the A1-line.

Container	Width [mm]	Length [mm]	Quantity
FLC	1200	1000	17
FSC	1200	1000	10
FE13532	1200	1000	2
FE13256	1800	1200	1
PBX	1200	1400	1
MC490	2260	980	1
MC490	2260	980	1
FE12845	2400	800	1
FE12845	2400	800	1
Total			35

Table 4.2: Size and quantity of call off containers

Table 4.3 and table 4.4 show the containers' width, length, quantity as well as their quantity of shelf places and their particular position in the shelves. The containers are delivered by a Kanban system from Valmo. In total, 146 places in shelves are needed to store the parts at the line.

Container	Width [mm]	Length [mm]	Quantity	Places in shelves	x/position
KLT6429	400	600	46	52	3/position
KLT6418	400	600	6	6	6/position
KLT4329	400	300	12	12	6/position
KLT4315	400	300	27	27	12/position
KLT3215	300	200	9	9	20/position
Specials	400	600	36	40	3/position
			136	146	

Table 4.3: Size, quantity and places in shelves of Kanban containers (Valmo) I

Container	Width [mm]	Length [mm]	Quantity	Places in shelves
KLT6429	400	600	12	12
KLT4329	400	300	1	1
IMC40,80	400	600	3	3
FE13663	400	300	9	3
			24	24

Table 4.4: Size, quantity and places in shelves of Kanban containers (Valmo) II

Part family, sequencer, width, length and quantity of the parts delivered in sequence are shown in table 4.5.

Part family	Sequencer	Width [mm]	Length [mm]	Quantity
Air bag	MLV	1000	1200	2
Roof rail	MLV	1100	2700	4
Fuel housing	WP	1000	1200	1
Pedals	VM	1200	1600	2
PCM	FMV	1200	1600	1
Headliner	WP	1400	2800	1
Cork parts	WP	1200	200	2

Table 4.5: Sequencer, size and quantity of sequencing boxes

The parts which are already present at the line in kits are shown in table 4.6.

Container	Width [mm]	Length [mm]	Quantity
FSC	1200	1000	3
IMC120	1200	1000	5
			8

Table 4.6: Size and quantity of kitting A1 call off containers

Part distribution according to the location in the vehicle

Graphic 4.10 shows in which area of the vehicle most of the trim parts are mounted. Accordingly, the given distribution of parts visualizes and distinguishes the most suitable areas of the vehicle for kitting. The majority of parts are assembled in the rear, followed by the instrument panel area.

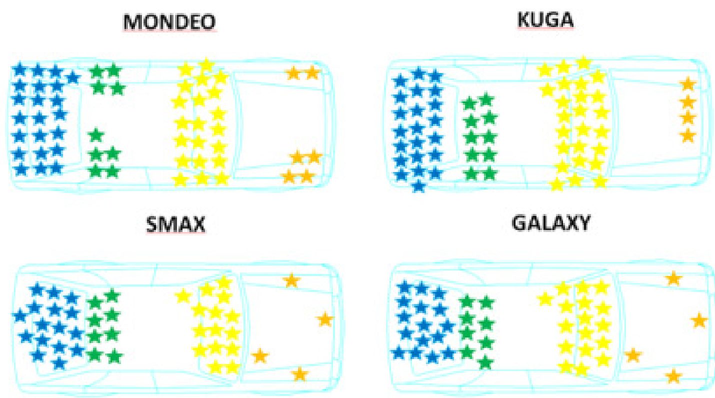

Figure 4.10: Part distribution according to the location in the vehicle

As many operations are performed inside the vehicle, the operator has to step in and out of the vehicle to fetch parts. For these situations, a kit which located inside the vehicle would offer a considerable time saving (Hanson & Brolin 2012: 991).

4.6 Issues at Ford Valencia plant

The collected data in the Ford Valencia plant shows the effect of current material feeding systems:

- Most of the parts are stored at line side which consumes a lot of space.
- Rebalancing of operations from one assembly worker to another and from one workstation to another is difficult as there is hardly no space to move the parts presented at the line.

5 Building a model to compare the impact of different line feeding principles

In the following, a model for the calculation of the business case of a kitting introduction is developed.

5.1 Assumptions of the model

The following assumptions have been taken into account:

- Bulk containers are either transported by forklift trucks or delivered by tugger train milk run processes
- The operator works in the middle of a workstation
- Just in time delivery
- Uniform consumption of material at the assembly line
- Kitting operators in the kitting area pick in batches

5.2 Mathematical model explanation

Since different feeding principles generate different man-hour consumption in handling, picking and transportation activities, it is necessary to apprehend the different causes of costs in order to choose the right feeding principle and, thereby, minimize the total cost for each kind of component (Battini et al. 2008: 235). The objective of this cost analysis model is to calculate total costs of the different feeding principles. Thus, it considers costs for:

- Part preparation / Kit assembly operation
- Internal transportation (component and kit container flow)
- Material handling of the operator
- Shop floor space requirements / Material storage
- Work in progress

The total cost associated with a particular feeding system is gained by summing the relevant cost components for each material feeding principle: line stocking (ls), sequencing (s) and kitting (k). These cost components are discussed in the next section split by the material feeding principle. The presentation of the model is proceeded by an overview that provides the reader with the parameters used.

Data inputs in the model are:

α^{c}	Number of containers staggered at workstations
α^{p}	Number of pallets staggered at workstations
α^{sk}	Number of stationary kits staggered at workstations
α^{tk}	Number of travelling kits staggered at workstations
Δ^{k}	Distance for operator to walk to the kit container
Δ^{ls}	Distance from the assembly line to the container
Δ^{kp}	Distance in the kitting area to walk from one container to the next
Δ^{ww}	Distance from the warehouse to the workstation
Δ^{mr}	Distance of milk run tour
γ_{w}	Equals 0 when no stationary kits are used
Φ_{p}	Effect of picking in batches
Φ_{c}	Average number of containers grasped at once during loading
τ^{pk}	Time to pick a part from a kit
τ^{pc}	Time to pick a part from a from a bulk container
τ^{sc}	Time to search for the required part in the bulk stock
τ^{ak}	Fixed kit assembly time
τ_{1}^{gc}	Time to grasp a container and load on a tugger train
τ_{2}^{gc}	Time to grasp a container and unload from a tugger train
τ_{p}^{k}	Time to pick a certain part in the kitting area
A^{t}	Capacity of a tugger train
b_{c}	Number of facing needed to store containers along a workstation
b_{k}	Number of part numbers selected for kitting
b_{u}	Demand of part containers
b_{w}	Number of containers dispatched to all workstations
B^{k}	Batch size for assembling kits
B^{ls}	Preparation batch size
C^{ls}	Total cost of line stocking
C_{p}^{ls}	Cost for preparation of material for line stocking
C_{p1}^{ls}	Cost for moving in the preparation area
C_{p2}^{ls}	Cost for moving grasping and loading containers

C_{p3}^{ls}	Cost for moving grasping and unloading containers
C_{t}^{ls}	Cost for transportation for line stocking
C_{tm}^{ls}	Cost for transportation of containers with a milk run tour
C_{tf}^{ls}	Cost to transport pallets with a forklift truck
C_{m}^{ls}	Cost for material handling at the line for line stocking
C_{s}^{ls}	Cost for material storage for line stocking
C_{w}^{ls}	Work in progress cost for kitting
C^{s}	Total cost of sequencing
C^{k}	Total cost of kitting
C_{p}^{k}	Cost for preparation of material for kitting
C_{vp}^{k}	Variable cost for preparation of material for kitting
C_{fp}^{k}	Fixed cost for preparation of material for kitting
C_{t}^{k}	Cost for transportation for kitting
C_{m}^{k}	Cost for material handling at the line for kitting
C_{s}^{k}	Cost for material storage for kitting
C_{s1}^{k}	Cost for line side material storage for kitting
C_{s2}^{k}	Cost for buffer material storage for kitting
C_{s3}^{k}	Cost for material storage for kit preparation
C_{w}^{k}	Work in progress cost for kitting
C_{m^2}	Cost for 1m^2 storage area
C_{o}	Operator hour cost
D	Demand of an end product
d_{w}	Demand of part p at workstation w
H^{ls}	WIP for line stocking
h_{w}^{ls}	WIP at workstation w for line stocking
h_{w1}^{k}	Average WIP for kitting with stationary kits
h_{w2}^{k}	Average WIP for kitting with travelling kits
H_{1}^{k}	Total work in progress for kitting with stationary kits
H_{2}^{k}	Total work in progress for kitting with travelling kits
k	Number of kits needed
k_{p}	Number of kits needed to assembly one end product

L^c	Length of a container
L^k	Length of a kit container
L^r	Length of rack with kit container
N_b^k	Number of racks in buffer areas
p	Part number of part p
p^c	Packaging quantity in a container
p^k	Packaging quantity in a kit
p_n	Number of different part numbers
p^p	Packaging quantity on a pallet
p_p	Piece price
r	Number of racks in a buffer area
S	Space requirement of all workstations
S_p	Space requirements for kit preparation
S_w	Space requirement of a workstation
u_p	Number of units of part p assembled per end product
u_w	Maximum number of units in one pick because of weight/volume
U^t	Capacity utilization of a tugger train
V_f	Velocity of a forklift truck
V_o	Velocity of an operator
V_t	Velocity of a tugger train
w_s	Workstation s = 1…14
W^c	Width of a container
W^k	Width of a kit container
W^r	Width of rack with kit container

Line stocking

Under line stocking, all variants of parts are stored in two locations, both lineside and in the storage area. It may be difficult to find space at workstations to present all part numbers in a way that enables the operator to easily access them (Hansen & Brolin 2012: 980). When all part numbers are arranged line side, the walking distance required by the operator to pick each part is increased. The replenishment of the lineside stock is performed by a consumption renewal or Kanban call signal.

Preparation cost – line stocking

The total labor time spent by the logistic operator moving in the preparation area is obtained by multiplying the total number of trips by the time required to realize a single roundtrip. The number of trips is given by $\frac{b_u}{U^t A^t}$, where b_u is the demand of part containers and $U^t A^t$ is the preparation batch size. The time to realize a single trip is given by the velocity of the tugger train, V_t, the width of a container, W^c, and the number of container of components, b_w (Sali et al. 2015: 1446):

$$C_{p1}^{ls} = \frac{b_u}{U^t A^t} \frac{\sum W^c b_w}{V_t} C_o \qquad (1)$$

C_{p1}^{ls}	Cost for moving in a preparation area
b_u	Demand of part containers
U^t	Capacity utilization of a tugger train
A^t	Capacity of a tugger train
W^c	Width of a container
b_w	Number of containers of components
C_o	Operator hour cost
V_t	Velocity of a tugger train

During a trip through the preparation area the logistic operator has to grasp containers and load them on the tugger train. The labor time spent by the logistic operator depends on the number of containers of a component p that is consumed during the considered period and by the time the logistic operator needs to realize a single movement of grasping containers and load them, τ_1^{gc} (Sali et al. 2015: 1446):

$$C_{p2}^{ls} = D \sum \frac{u^p}{p^c \Phi_c} \tau_1^{gc} C_o \qquad (2)$$

C_{p2}^{ls}	Cost for moving grasping and loading containers
D	Demand of an end product
u_p	Number of units of part p assembled per end product
p^c	Packaging quantity in a container
Φ_c	Average number of containers grasped at once during loading
τ_1^{gc}	Time to grasp a container and load on a tugger train

C_o Operator hour cost

Unloading the container from the tugger train by the logistic operator is a symmetrical operation with, τ_2^{gc}, the time needed to realize a single movement of grasping the containers and unloading them (Sali et al. 2015: 1446):

$$C_{p3}^{ls} = D \sum \frac{u^p}{p^c \Phi_c} \tau_2^{gc} C_o \qquad (3)$$

C_{p3}^{ls} Cost for moving grasping and unloading containers

D Demand of an end product

u_p Number of units of part p assembled per end product

p^c Packaging quantity in a container

Φ_c Average number of containers grasped at once during loading

τ_2^{gc} Time to grasp a container and unload from a tugger train

C_o Operator hour cost

Total preparation costs – line stocking

The total preparation costs for line stocking, C_p^{ls}, is the sum of costs for moving in the preparation area, C_{p1}^{ls}, and the costs for uploading, C_{p2}^{ls}, and unloading of the containers, C_{p3}^{ls}.

$$C_p^{ls} = C_{p1}^{ls} + C_{p2}^{ls} + C_{p3}^{ls} \qquad (4)$$

Transportation – line stocking

With line stocking each component container must be retrieved from the storage area and delivered to the appropriate workstation. The total number of component container dispatched to all the workstation is given by b_w (Bozer & McGinnis 1992: 9):

$$b_w = \sum \frac{D\, u_p}{p^c} \qquad (5)$$

b_w Number of component containers dispatched to all the workstation

D Demand of an end product

u_p Number of units of part p assembled per end product

p^c Packaging quantity in a container

The time to carry out a milk run to supply boxes is defined by the distance of the milk run tour, Δ^{mr}, divided by the velocity, V_t (Limère et al. 2015: 51). Furthermore, the number of tours to the line depends on the number of boxes that need to be supplied to the workstation, b_w, on the capacity of the tugger train, A^t, and the expected capacity utilization of the tugger train, U^t (Limère et al. 2015: 51). Accordingly, the cost of the milk run is obtained by:

$$C_{tm}^{ls} = C_o \sum \frac{\frac{\Delta^{mr}}{V_t} b_w}{A^t \, U^t} \qquad (6)$$

C_{tm}^{ls}	Cost for transportation of containers with a milk run tour
C_o	Operator hour cost
Δ^{mr}	Distance of a milk run tour
V_t	Velocity of a tugger train
b_w	Number of component containers dispatched to all the workstation
A^t	Capacity of a tugger train
U^t	Expected capacity utilization of a tugger train

The cost, C_{tf}^{ls}, to transport pallets of part p to the workstation back and forth with a forklift truck is determined by its velocity, V_f, the distance from the pallet warehouse to the workstation, Δ^{ww}, and the pallet demand $\frac{d_w}{n_f^{ls}}$ (Limère et al. 2015: 51):

$$C_{tf}^{ls} = C_o \sum 2 \frac{\Delta^{ww} \, d_w}{V_f \, p^p} \qquad (7)$$

C_{tf}^{ls}	Cost to transport pallets of part p to the workstation with a forklift
C_o	Operator hour cost
d_p	Demand of part p at workstation w
Δ^{ww}	Distance from the pallet warehouse to the workstation
V_f	Velocity of a forklift truck
p^p	Packaging quantity on a pallet of part p

Total internal transportation costs – line stocking

The total transportation costs for line stocking, C_t^{ls}, is the sum of costs for milk run tours, C_{tm}^{ls}, and pallet transportation, C_{tf}^{ls}:

$$C_t^{ls} = C_{tm}^{ls} + C_{tf}^{ls} \quad (8)$$

C_t^{ls}	The total transportation costs for line stocking
C_{tm}^{ls}	Cost for transportation of containers with a milk run tour
C_{tf}^{ls}	Cost to transport pallets of part p to the workstation with a forklift

Picking costs – line stocking

Material handling during the assembly operating with line stocking consists of walking, identifying, and grasping parts from the bulk containers to assemble them on the vehicle. The difference between kitting and continuous supply in regard to activities associated with picking is anticipated to be the greatest. The identification of the variant which has to be mounted to the end product is necessary when the operator has to choose the right variant among several alternatives (Sali et al. 2015: 1446). Equation *(9)* gives the time, τ^{pc}, to pick a unit of part p from a bulk container at workstation w_s. τ^{pc} is determined by the searching time for the required part in the bulk stock, τ^{sc}, and the time the operator needs to go back and forth the distance to the container, Δ^{ls}, at velocity V_o (Limère et al. 2015: 49):

$$\tau^{pc} = 2\frac{\Delta^{ls}}{V_o} + \tau^{sc} \quad (9)$$

τ^{pc}	Time to pick a part from a bulk container
Δ^{ls}	Distance from the assembly line to the container
V_o	Operator velocity
τ^{sc}	Time to pick a part p

The walking distance to a bulk container, Δ^{ls}, depends on the amount of stock at the line. It is assumed that the operator works in the middle of the workstation. The operator has to walk a variable distance along the border of the line. Sometimes, he has to walk half of the workstation length, all the way to the beginning or the end of the last stored box, to pick a part; at other times, indeed, he can pick the part immediately without further movement along the line. On average, the operator walks one fourth of the total stock length of a workstation (Limère et al. 2015: 50). Hence, Δ^{ls}, is given by equation *(10)*:

$$\Delta^{ls} = \frac{b_c W^c}{4} \qquad (10)$$

Δ^{ls}	Distance from the assembly line to the container
b_c	Number of facing needed to store boxes along workstation
W^c	Width of a container

The labor cost for operator picking at the assembly line, C_m^{ls} , is then given by:

$$C_m^{ls} = C_o \sum d_w \tau^{pc} \qquad (11)$$

C_m^{ls}	Cost for material handling at the line for line stocking
C_o	Operator hour cost
d_w	Demand of part p at workstation w
τ^{pc}	Time to pick a part from a from a bulk container

Material storage cost – line stocking

Many companies continuously try to reduce stock inventory levels because the invested capital does not generate any return (Battini et al. 2008: 233). For line stocking, storage costs are related to the storage area required at the line. The number of required square meters at the line is obtained by summing up the ground surface of the boxes (Sali et al. 2015: 6):

$$C_s^{ls} = \sum L^c \; W^c \; C_{m^2} \qquad (12)$$

C_s^{ls}	Cost for material storage for line stocking
L^c	Length of a container
W^c	Width of a container
C_{m^2}	Cost of 1m^2 storage area

Work in progress – line stocking

Under the assumption of just in time delivery of containerd and a uniform consumption the average WIP, h_{w}^{ls}, in the system is given by equation *(13)* (Bozer & McGinnis 1992: 11):

$$h_{w}^{ls} = \frac{1}{2}\left(\alpha^{c}\, p^{c} + \alpha^{p}\, p^{p}\right) \qquad (13)$$

$$H^{ls} = \sum_{w} h_{w}^{ls} \qquad (14)$$

h_{w}^{ls}	WIP at workstation w for line stocking
α^{c}	Number of container staggered at workstation w
p^{c}	Packaging quantity in container of part p
α^{p}	Number of pallets staggered at workstation w
p^{p}	Packaging quantity on pallet of part p
H^{ls}	WIP for line stocking

The costs of work in progress for line stocking are:

$$C_{w}^{ls} = H^{ls}\, p_{p} \qquad (15)$$

C_{w}^{ls}	Work in progress cost for line stocking
H^{ls}	WIP for line stocking
p_{p}	Piece price

Total cost – line stocking

The total cost of line stocking, C^{ls}, is the sum of the preparation costs, C_{p}^{ls}, the transportation costs, C_{t}^{ls}, the material handling costs of the operator, C_{m}^{ls}, and the material storage costs, C_{s}^{ls}, as presented in equation *(16)*:

$$C^{ls} = C_{p}^{ls} + C_{t}^{ls} + C_{m}^{ls} + C_{s}^{ls} \qquad (16)$$

Sequencing

Sequencing at Ford Valencia is performed by the suppliers which charge sequencing costs. The overall sequencing costs are the sum of all the sequencing costs of each supplier.

$$C^s = \sum_{s=1}^{s=x} C^s \qquad (17)$$

Kitting

The effects of kitting compared with continuous supply on man-hour consumption in assembly can be derived from the position where the material is presented in relation to the position of the assembly object (Hanson & Brolin 2013: 980). Kits can be presented closer to the assembly object and thereby reduce time for picking the material.

Kit container flow – kitting

The number of kit container that flow from the kitting area to all the workstations, k, is given by the demand of the end products, D, and the number of kits needed to assemble one end product, k_p:

$$k = D\, k_p \qquad (18)$$

k	Number of kits needed
D	Demand of an end product
k_p	Number of kits needed to assemble one the end product

Kit assembly operation – kitting

The preparation of kits is associated with time and costs. In relation of continuous supply, certain reports show higher man-hour consumption in the material supply operations connected with kitting. Other reports present kitting as a way to reduce material handling (Ding & Puvitharan 1990). Furthermore, continuous supply can possibly require the repacking of parts before delivery to the workstation since - due to space restrictions in packaging – it may be necessary to present parts far smaller than the original packaging size from the supplier (Johansson 1991).

The cost calculation of the kit assembly process is based on the layout of the kitting area. While empty kit containers on racks are provided at one side of the kitting area, replenished kit containers placed on racks are picked up at its other side. During the roundtrip, the operator selects for each component the specific variant required for assembly. A roller shelf is used to ensure an easy moving of the kit containers. The kitting area is designed with the intention that the operator will find all variants of a container of the kitting rack in one and the same isle. Therefore there is a fixed kit assembly time for each kit τ^{ak} (Limère et al. 2015: 50). The fixed costs for all kits, C_{fp}^{k}, is defined as:

$$C_{fp}^{k} = C_o \ \tau^{ak} \ k \tag{19}$$

C_{fp}^{k}	Fixed cost kit assembly
C_o	Operator cost per hour
τ^{ak}	Fixed kit assembly time
k	Number of kits needed

On top of the fixed costs, a variable kitting costs occur for every part that needs to be kitted. In order to pick each part, the operator needs to walk the distance from one container to the next in the kitting area, Δ^{kp}, and the time the operator has to search for the required part in the kitting area stock, τ^{sc} (Limère et al. 2015: 51).

The average time to pick a certain part p in the kitting area, τ_p^k, is calculated as follows:

$$\tau_p^k = \frac{\left(\frac{2\Delta^{kp}}{V_o}\right) + \tau^{pc}}{\Phi_p} \tag{20}$$

τ_p^k	Time to pick a part p in the kitting area
Δ^{kp}	Distance in the kitting area to walk from one container to the next
V_o	Operator velocity
τ^{pc}	Time to pick a part from a bulk container
Φ_p	Probability to pick in batches

Hence, the variable costs for all kits, C_{vp}^{k}, is:

$$C_{vp}^{k} = C_o \ d_w \, \tau_p^k \tag{21}$$

C_{vp}^{k}	Variable kitting cost
C_o	Operator cost per hour
$\mathrm{d_w}$	Demand of part p at workstation w_s
τ_p^k	Time to pick a part from a bulk container

The complete labor costs for kit assembly, C_p^k, is presented in equation *(22):*

$$C_p^k = C_{fp}^k + C_{vp}^k \tag{22}$$

Material handling of the operator – kitting

Kitting enables shorter distances between the parts' presentation and the assembly object and, hence, facilitates potential reductions in the time spent for picking parts (Hanson & Medbo 2012: 1115). The costs for the picking during the assembly consist of the costs for the parts that need to be picked out of a kit to assembly them on the end product. The time to pick a unit from a kit, τ^{pk}, is determined by the time to walk the distance to the kit container, Δ^k, back and forth (Limère et al. 2015: 49). In contrast to line stocking, only the needed variants are presented within a kit container. Thus, the operator does not need to spend time for searching and identifying parts.

τ^{pk} is defined as:

$$\tau^{\mathrm{pk}} = \frac{2\Delta^k}{V_o} \tag{23}$$

τ^{pk}	Time to pick a part from a kit
Δ^k	Distance for operator to walk to the kit container
V_o	Operator velocity

The walking distance towards a kit, Δ^k, is assumed to be constant, as a kit is positioned in the best location, close to the point of use at the line (Limère et al. 2015: 49). The labor cost for operator picking at the assembly line, C_m^k, is then calculated as follows:

$$C_m^k = C_o \; \mathrm{d_w} \tau^{\mathrm{pk}} \tag{24}$$

C_m^k	Cost for operator to pick from a kit
C_o	Operator hour cost
d_w	Demand of part p at workstation w_s
τ^{pk}	Time to pick a part from a kit

Material storage cost – kitting

With the introduction of kitting the inventory level moves away from the assembly line to the kitting area.

Lineside storage space – kitting

A workstation needs enough space to accommodate stationary kits. In case no stationary kit container is used γ_w is set to 0.

$$S_w = \gamma_w L^k W^k \alpha^{sk} \tag{25}$$

$$S = \sum S_w \tag{26}$$

S_w	Space requirement of a workstation
γ_w	Equals 0 when no stationary kit is used
L^k	Length of a kit container
W^k	Width of a kit container
α^{sk}	Number of stationary kits staggered at each workstation
S	Space requirement of all workstations

The costs for line side storage space are shown in equation *(28):*

$$C_{s1}^k = S \; C_{m^2} \tag{27}$$

C_{s1}^k	Cost for line side material storage for kitting
S	Space requirement of all workstations
C_{m^2}	Cost for 1m^2 storage area

The already kitted parts at the line, in the buffer area and on the way to the line contribute to a net addition in comparison to the previous inventory level (Hanson & Brolin 2012: 985). This effect is relatively small. Racks with kit container of length L^k and W^k has associated storage costs of:

$$C_{s2}^{k} = N_{b}^{k}\, L^{r}\, W^{r}\, C_{m^2} \qquad (28)$$

C_{s2}^{k}	Cost for buffer material storage for kitting
N_{b}^{k}	Number of racks in buffer areas
L^{r}	Length rack with kit container
W^{r}	Width rack with kit container
C_{m^2}	Cost of $1m^2$ storage area

Material storage cost for kit preparation – kitting

The costs for material storage for kit preparation are shown in equation *(29):*

$$C_{s3}^{k} = \quad S_{p}\, C_{m^2} \qquad (29)$$

C_{s3}^{k}	Cost for material storage for kit preparation
S_{p}	Space requirements for kit preparation
C_{m^2}	Cost of $1m^2$ storage area

The total material storage costs for kitting are:

$$C_{s}^{k} \;=\; C_{s1}^{k} + C_{s2}^{k} \qquad (30)$$

Work in progress – kitting

The average WIP in the system with stationary kits, h_{w1}^{k}, is given by the number of stationary kit containers staggered at each work station, α^{sk}, and the number of pieces used in a kit, p_{sk} (Bozer & McGinnis 1992: 11):

$$h_{w1}^{k} = ½\, \alpha^{sk}\, p^{k} \qquad (31)$$

$$H_1^k = \sum_w h_{w1}^k \quad (32)$$

h_{w1}^k	Average WIP for kitting with stationary kits
α^{sk}	Number of stationary kits container staggered at each workstation
p^k	Number of pieces used in a kit
H_1^k	Total work in progress for kitting with stationary kits

The number of travelling kits in the system is a function of the partially assembled products in the system. As the end product moves through the assembly operation, more and more components out of the travelling kit become part of the product. The average WIP, h_{w2}^k, depends on the delay in travelling from on workstation to another, D_t, the number of travelling kits that travel along with the product, β_{tkw}, and the total number of pieces in a kit container p_{sk}. (Bozer & McGinnis 1992: 11):

$$h_{w2}^k = \frac{1}{2} D_t \sum \alpha^{tk} \ p^k \quad (33)$$

$$H_2^k = \sum_w h_{w2}^k \quad (34)$$

h_{w2}^k	Average WIP for kitting with travelling kits
D_t	Delay in travelling from on workstation to another
α^{tk}	Number of travelling kits container staggered at each workstation
p^k	Number of pieces used in a kit
H_2^k	Total work in progress for kitting with travelling kits

The cost of work in progress for kitting is defined in equation *(35):*

$$C_w^k = H_2^k \, p_p \quad (35)$$

C_w^k	Work in progress cost for kitting
H_2^k	Total work in progress for kitting with travelling kits
p_p	Piece price

Total cost – kitting

The total cost of kitting, C^k, is the sum of the kit assembly operation cost, C_p^k, the kit transportation cost, C_t^k, the material handling cost of the operator, C_m^k, and the material storage cost, C_s^k, as presented in equation *(36)*:

$$C^k = C_p^k + C_t^k + C_m^k + C_s^k \tag{36}$$

5.3 Intangible effects of kitting

The mathematical model only captures quantifiable values. Yet, in the theoretical framework, benefits and limitations of intangible nature have been presented as well. These factors will be discussed in this section.

As mentioned in the theoretical framework, kitting can improve the build quality, since the operator does not need to concern with parts to assemble. A correctly structured kit can guide the operator as it functions as a work instruction. That is why the assembler can focus on how to assemble the parts (Hanson & Brolin 2012: 980) and the possibility of making mistakes is reduced. However, a high production quality requires kits of high quality, without missing, incorrect or defective parts. Mistakes in the kit preparation result in incorrect or missing parts in the kits. Quality deficiencies may lead to misbuilds or to replacements of faulty or missing parts by parts from other kits (Hanson & Brolin 2012: 980). This may cause time consuming rework of the end product or shortages and requires additional resources to discover and correct such mistakes in the kit preparation. Accordingly, a high accuracy of the prepared kits is of major importance (Carlsson & Hensvold 2008: 62).

Kitting is seen as a more flexible material feeding principle than continuous supply. In contrast, with continuous supply the available space at the workstation constrains the amount of part numbers which can be assembled at one station (Hanson & Brolin 2012: 981). Kitting, however, offers greater flexibility at each assembly station. With it, a larger number of part variants can be handled with kitting. There is also a greater flexibility in rebalancing the assembly line, as it is possible to move assembly work tasks between workstations without rearranging the component racks and in-plant logistic. Furthermore, product changeovers can be facilitated easily, for material is not staggered at the workstations. Kitting also support the operator by presenting parts in a way that reflects the assembly operation (Hanson & Brolin 2012: 981). This aspect further increases flexibility by facilitating changes in assembly operation like the introduction of new products (Hanson & Brolin 2012: 981).

On the other hand, kitting requires more planning. The sequence of production at the assembly line as well as the parts required in total for the vehicle have to be known before starting the kit assembly process. The material planning is integrated in the production system. In addition, the material planning for kitting should also be captured in this system (Carlsson & Hensvold 2008: 62). It necessarily has to equip the picking operator with knowledge about the specific distribution of parts to the different kits. This might lead to a restructuring of the production system (Carlsson & Hensvold 2008: 62).

5.4 Analytical hierarchy process

It is necessary to weight the different criteria to receive a clearer picture. The weighting is done by an analytical hierarchy process (AHP). Through pairwise comparison, it determines the relative importance of criterion one others (Carlsson & Hensvold 2008: 26).

First, the objective needs to be stated; then, problems are segmented into a hierarchy of criteria and sub criteria. Finally, an alternative solution is compared with the objective. This information is arranged in a hierarchical tree, as shown in figure 5.1:

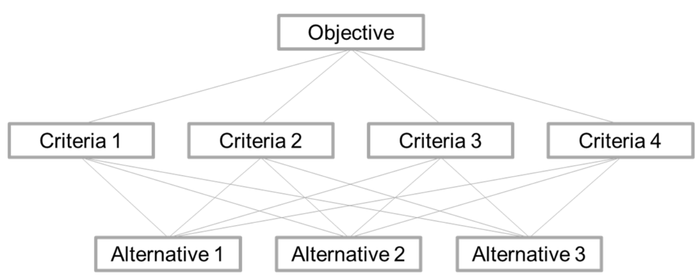

Figure 5.1: Hierarchical tree

Decision makers individually point out their statement regarding the relative importance of the criteria with a 1-9 points systems; 1 equals the two choice option – both, then, are equally preferred – while 9 marks an extreme preference of one choice over the (Carlsson & Hensvold 2008: 26), as shown in table 5.1.

	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value
Operator picking time	1					
Lineside storage space		1				
Required kitting space			1			
Lineside replenishment				1		
Kitting preparation time					1	
Lineside inventory value						1

Table 5.1: Criteria in matrix form – 1: equal, 3: moderate, 5: strong, 7: very strong, 9: extreme

To be able to rank priorities, the matrix needs to be transformed into an eigenvector by matrix multiplication.

Criteria	Eigenvector / Normalised weight
Criteria 1	
Criteria 2	
Criteria 3	

Table 5.2: Computed eigenvector

To make criteria with different units comparable, they are normalized, as shown in table 5.3.

	Alternative 1	Alternative 2		Alternative 1	Alternative 2
Criteria 1					
Criteria 2					
Criteria 3					

Table 5.3: Normalization of criteria

To obtain the final weighted result, the criteria are multiplied with the eigenvector after the normalization, as shown in table 5.4 and 5.5.

	Criteria 1	Criteria 2	Criteria 3
Alternative 1			
Alternative 2			

Table 5.4: Normalized criteria

Criteria	Eigenvector / Normalised weight
Criteria 1	
Criteria 2	
Criteria 3	

Table 5.5: Computed eigenvector

The output of the AHP is a score for each of the alternatives, which gives a relatively objective overview, table 5.6.

	Result
Alternative 1	
Alternative 2	

Table 5.6: Final result

Before the conclusion will be presented, the following chapter discusses the results of the decision-making tool in combination with the mathematical model. The analysis is then the foundation for the guiding principles, which intent to decide upon the implementation of the kitting process in the trim line.

6 Results and analysis

Table 6.1 presents the general problem parameter.

Parameter	Description	Value
α^c	Number of container staggered at workstations	326
α^p	Number of pallets staggered at workstations	139
α^{sk}	Number of stationary kits staggered at workstation w	0
α^{tk}	Number of travelling kits staggered at workstation w	1
Δ^k	Distance for operator to walk to the kit container	1m
Δ^{kp}	Distance in the kitting area to walk from one container to the next	5m
Δ^{ww}	Distance from the warehouse to the workstation	100m
Δ^{mr}	Distance of milk run tour	250m
γ_w	Equals 0 when no stationary kits are used	0
Φ_c	Average number of container grasped at once during loading	1.2
Φ_p	Effect of picking in batches	1.2
τ^{sc}	Time to search for the required part in the bulk stock	1s
τ^{ak}	Fixed kit assembly time	9.6s/part
τ_1^{gc}	Time to grasp a container and load on tugger train	5s
τ^{ak}	Fixed kit assembly time	20s
A^t	Capacity of the tugger train	20
b_c	Number of facing needed to store container along workstation	8
b_k	Number of part numbers selected for kitting	167
b_w	Number of containers of components	465
B^k	Batch size for assembling kits	40
C_{m^2}	Cost for 1m² storage area	10€/m²
C_o	Operator hour cost	30€/h
D	Demand of the end product	1940/day
D_t	Delay in travelling from on workstation to another	58sec
d_w	Demand of part p at workstation w	Appendix B
k_p	Number of kits needed to assembly one end product	1
L^c	Length of a container	800mm
L^k	Length of a kit container	800mm
L^r	Length of rack with kit container	800mm
N_b^k	Number of racks in buffer areas	10
p^c	Packaging quantity in container	Appendix B
p^k	Packaging quantity in kit	40
p_n	Number of different part number	465
p^p	Packaging quantity on pallet	Appendix B
p_p	Average piece price	2,92€
r	Number of racks in buffer area	10
S_p	Space requirements for kit preparation	1723m²
u_p	Number of units of part p assembled per end product	Appendix B
u_w	Maximum number of units in one pick because of weight/volume	3
U^t	Capacity utilization of the tugger train	0.8

V_f	Velocity of a forklift truck	10km/h
V_o	Velocity of an operator	3km/h
V_t	Velocity of a tugger train	10km/h
W^c	Width of a container	800mm
W^k	Width of a kit container	400mm
W^r	Width of rack with kit container	800mm

Table 6.1: General problem parameters

6.1 Results of the mathematical model

Hanson and Medbo (2012) focus on the impact that kitting has on the work of an operator in a manual assembly system. They analyzed four different case studies and video recorded the work of the operators. With this approach, they categorized the recorded work into predefined activities and registered the time consumption of each activity. The time spent for turning, walking, reaching out, grasping, and walking back to the assembly objects was measured for kitting as well as for continuous supply. The average time spent by the operator picking each part is 63% lower for parts presented in kits than for component container (Hanson & Medbo 2012: 1122).

Christmansson et al. (2002) also used video recording to classify the work of a material picker to the types of work activities they carry out. The different work activities are necessary work, handling and transportation, handling packaging, administration, as well as miscellaneous work and disturbance (Christmansson et al. 2002: 53). The necessary work of a material picker is to grasp parts from storage package and to place it in the material package. For each of the work activities they measured the time needed. On average a picker needs 9.6 seconds per part.

Formula	Parameter	Description	Value
(1)	C_{p1}^{ls}	Cost for moving in preparation area	40.87€/d
(2)	C_{p2}^{ls}	Cost for moving grasping and loading container	20.34€/d
(3)	C_{p3}^{ls}	Cost for moving grasping and unloading container	20.34€/d
(4)	C_{p}^{ls}	Cost for preparation for line stocking	81.55€/d
(5)	b_w	Number of comp. container dispatched to all	586/d
(6)	C_{tm}^{ls}	Cost of the milk run	3,295.56€/d
(7)	C_{tf}^{ls}	Cost to transport pallets to the workstation	
(8)	C_{t}^{ls}	Transportation cost for line stocking	3,295.56€/d
(9)	τ^{pc}	Time to pick a part from a from a bulk container	4.84s
(10)	Δ^{ls}	Distance from the assembly line to the container	1.6m
(11)	C_{m}^{ls}	Cost for material handling at the line for line stocking	2,771.7€/d
(12)	C_{s}^{ls}	Cost for material storage for line stocking	0

(13)	h_w	WIP at workstation w	1,294.84
(14)	H^{ls}	WIP for line stocking	18,127.85
(15)	C_w^{ls}	Work in progress cost for line stocking	52,922.32€/d
(16)	C^{ls}	Total cost of line stocking	6,148.87€/d
(17)	C^s	Total cost of sequencing	661,883€/5
(18)	k	Number of kits needed	1940
(19)	C_{fp}^k	Fixed cost kit assembly	323€/day
(20)	τ_p^k	Time to pick a part p in the kitting area	14.03s
(21)	C_{vp}^k	Variable kitting cost	8,033.86€/d
(22)	C_p^k	Cost for kit assembly	8,356.86€/d
(23)	τ^{pk}	Time to pick a part from a kit	2.4s
(24)	C_m^k	Cost for operator to pick from a kit	1,374.4€/d
(25)	S_w	Space requirement of a workstation	0
(26)	S	Space requirement of all workstations	0
(27)	C_{s1}^k	Cost for line side material storage for kitting	0
(28)	C_{s2}^k	Cost for buffer material storage for kitting	2.13€/d
(29)	C_{s3}^k	Cost for material storage for kitting preparation	574.34€/d
(30)	C_s^k	Cost for material storage for kitting	576.47€/d
(31)	h_w	Average WIP for kitting with stationary kits	0
(32)	H	Total work in progress for kitting with stationary kits	0
(33)	h_2^k	Average WIP for kitting with travelling kits	80
(34)	H_2^k	Total work in progress for kitting with travelling kits	1120
(35)	C_w^k	Work in progress cost for kitting	3,270.4€/d
(36)	C^k	Total cost for kitting	10,307.73€/d

Table 6.2: Calculations

Table 6.3 summarizes the results with 465 different parts to be supplied to 14 workstations.

Cost line stocking/year		1,414,226€
(230 working days)	Preparation cost	18,756€
	Transportation cost	757,978€
	Picking cost	637,491€
Cost sequencing/year		132,376.6€
	Sequencing cost MLK/Walkers	132,376.6€
Cost kitting/year		2,561,777€
	Preparation cost	1,922,077€
	Transportation cost	Investment/10year: 191,000€
	Picking cost	316,112€
	Storage	132,588€
Investment cost kitting		1,910,000€
	AGV	1,320,000€
	OHC	590,000€

Table 6.3: Results of the mathematical model

Line stocking and sequencing add up to 1,546,602€ per year compared 2,561,777€ per year for kitting. In view of the given results of the mathematical model, one has to note that the the costs for kitting exceed the cost for line stocking.

6.2 Results of the analytical hierarchy process

The outcome of the mathematical model shows that kitting has positive as well as negative effects. In order to summarize and to support a reasonable conclusion concerning the question whether kitting is beneficial for Ford Valencia, the criteria are weighted in regards to their importance. This weighting is done with the help of an analytical hierarchy process.

The project completed a pairwise comparisons of six criterias: operator picking time, lineside storage space, required kitting space, lineside replenishment, kitting preparation time, lineside inventory value. The group was introduced to the analytical hierarchy process and come to a final conclusion the results were discussed within the group.

	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value
Operator picking time	1	0,14	0,33	3	3	3
Lineside storage space	7	1	5	7	5	9
Required kitting space	3	0,20	1	3	5	5
Lineside replenishment	0,33	0,14	0,33	1	3	3
Kitting preparation time	0,33	0,20	0,20	0,33	1	3
Lineside inventory value	0,33	0,11	0,20	0,33	0,33	1

Table 6.4: Criteria in matrix form – 1: equal, 3: moderate, 5: strong, 7: very strong, 9: extreme

To be able to rank priorities, the matrix needs to be transformed into an eigenvector by matrix multiplication, as shown in appendix A.

Table 6.5 presents the computed eigenvector.

Criteria	Eigenvector / Normalised weight
Lineside storage space	0,520761551
Required kitting space	0,199736034
Operator picking time	0,114039235
Lineside replenishment	0,078632852
Kitting preparation time	0,054583276
Lineside inventory value	0,032247053

Table 6.5: Computed eigenvector

The output of the AHP is to be interpreted as follows: lineside storage space is the most important criterion followed by required kitting space and operator picking time. Hence, these three are the most important for Ford Valencia. Lineside inventory value is considered to be least important. The model can be apprehended as a supportive tool in the context of the decision making on kitting introduction.

To be able to compare criteria with different units they are normalized as shown in table 6.6.

	No kitting	100% kitting		No kitting	100% kitting
Lineside storage space	1723m²	0		1	0
Required kitting space	0	1723m²		0	1
Operator picking time	4.82s	2.4s		0.67	0.33
Lineside replenishment	757,978€	191,000€		0.79	0.21
Kitting preparation time	0	14.03s		0	1
Lineside inventory value	52,933€	3270€		0.94	0.06

Table 6.6: Normalization of criteria

To obtain the final weighted result, the criteria are multiplied with the eigenvector after the normalization.

	Lineside storage space	Required kitting space	Operator picking time	Lineside replenishment	Kitting preparation time	Lineside inventory value
No kitting	1	0	0.67	0.79	0	0.94
100 % kitting	0	1	0.33	0.21	1	0.06

Table 6.7: Normalized criteria

Criteria	Eigenvector / Normalised weight
Lineside storage space	0,520761551
Required kitting space	0,199736034
Operator picking time	0,114039235
Lineside replenishment	0,078632852
Kitting preparation time	0,054583276
Lineside inventory value	0,032247053

Table 6.8: Computed eigenvector

The score for each of the alternatives gives a relatively objective overview.

	Result
No kitting	0.52
100 % kitting	0.32

Table 6.9: Final results

In contrast to the result of the mathematical model kitting the analytical hierarchy process show that kitting can be superior.

6.3 Design of the kitting system

According to the theoretical framework, decisions regarding the implementation of a kitting process involve the organization of the kitting system as well as location of the kitting area (Carlsson & Hensvold 2008: 65). The paragraphs below discuss the final decisions in terms of the locus and the subject of kitting, of who is in charge of kitting as well as the defined kitting procedure.

Where to kit?

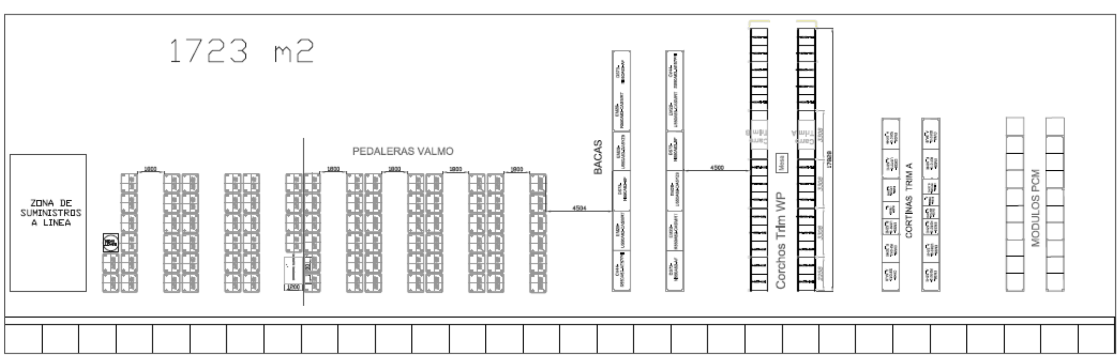

Figure 6.1: Layout of A1 kitting area

Theory describes two potential geographical locations of the picking store, central or decentralized (Carlsson & Hensvold 2008: 65). The project team decided that a central picking close to the beginning of the trim line would be most suitable. Chapter 4.2 presented potential areas where kitting could be located: Extension 66, with an already existing kitting area for trim, trim warehouse BB and chassis warehouse CC and VS.

The project team decided upon a kitting area for A1-line. The first step is to define the required square meters for the kitting area. Figure 6.1 shows the layout of the kitting area, for all parts for the A1-line with 1723m^2.

What to kit?

The question what parts to put in a kit has already been answered satisfactorily above. As previously stated, small components such as fasteners and plugs are not included in the kits. Operators often pick the fasteners together with the power tools that are used to tighten them (Hanson & Brolin 2012: 984). These parts are delivered as bulk material with continuous supply directly to the shop floor and are presented in component racks next to the power tools. Some parts were found too large to fit in the kitting shelve and, thus, are not included in the kitting process.

As explained in the theoretical chapter, there are two types of kits: travelling and stationary kits. Travelling kits have the advantage that they reduce the number of lineside replenishments (Carlsson & Hensvold 2008: 65). Yet, the multitude of parts contained in travelling kits represent a possible limitation since they make an assembly in takt time difficult. Ford Valencia values the number of lineside replenishments higher than the kitting time. Hence, travelling kits are more suitable.

In total, 465 different parts are delivered to the assembly line in traveling kits, which move alongside in a different container in parallel with the product and support all 14 assembly stations before they are consumed.

Who to kit?

Kits are assembled by assembly worker which rotate their jobs as the picking accuracy is likely to be higher when operator, who are familiar with the assembling process, are responsible for the kit preparation (Hanson & Brolin 2012: 991).

How to kit?

The kitting process begins with an operator pulling an order card which lists all the components, their quantities, and their shelf locations. The orders are sorted according to the production schedule. The project team decided to have a picker-to-part system which is common in the automotive industry. The picking area is divided into picking zones. A picking order is divided and hence can be picked simultaneously in different kitting zones, called synchronized zoning. The parts from different zones are gathered in one kit before they are delivered to the assembly line.

The picking information design

It is necessary that kits are prepared without any mistakes. Displays and lamps indicating which and how many parts should be picked at the storage location reduce the risk of inaccuracies.

Design of kitting container

It is of interest to investigate if the material for the trim line actually fits on a kit of a relatively decent size. This is done by gathering all parts that are fitted on one vehicle on the trim line, as shown in figure 6.2.

Figure 6.2: Overview of parts to kit

After collecting all parts, the analysis of the kitting container requirements commenced. Foremost, the kit has to be functional in the picking as well as in the assembly process as the assembly worker is to be supported by the configuration of the kit container. An efficient design leads to a decrease of assembly cycle time.

Box	Trolley
(+) no interferences with vehicle/station layouts	(+) possibility of solution for big / special parts
(-) Limited to small / medium sized parts	(-) Interferences with actual station layouts

Table 6.10: Kitting container design box vs. trolley

Table 6.10 demonstrates the advantages and disadvantages of a kitting container design box in comparison to a trolley.

Boxes have no interferences with the vehicle and work station layout as they are smaller than trolleys. However, a box is limited to small or medium sized parts. Trolleys, on the contrary, have the advantage to be a solution for big or special parts; yet, due to their size, they can interfere with the station layout. In order to assess whether all parts fit on a kit, a rack prototype was built, as shown in figure 6.3. As a result, all parts mounted on the trim line for one vehicle fit on this rack. Each trolley has multiple shelves and compartments and contains parts for the trim line. The parts are presented in boxes or hang on the side of the trolley. Parts are displayed to the assembly worker with dedicated placing for each part.

Figure 6.3: Rack prototype

To sum up, it is possible to kit all parts on one travelling kit container shelf.

Material feeding systems

The proposal of the material flow from storage area Call BB / trim is highlighted in Figure 6.4. When the material is prepared at Truck & Wheel, the truck is loaded and the material is transported to the storage tent by lorry. After the material is unloaded, it is transported to the kitting area via tugger train. After the kitting assembly, the kits are delivered to the assembly line.

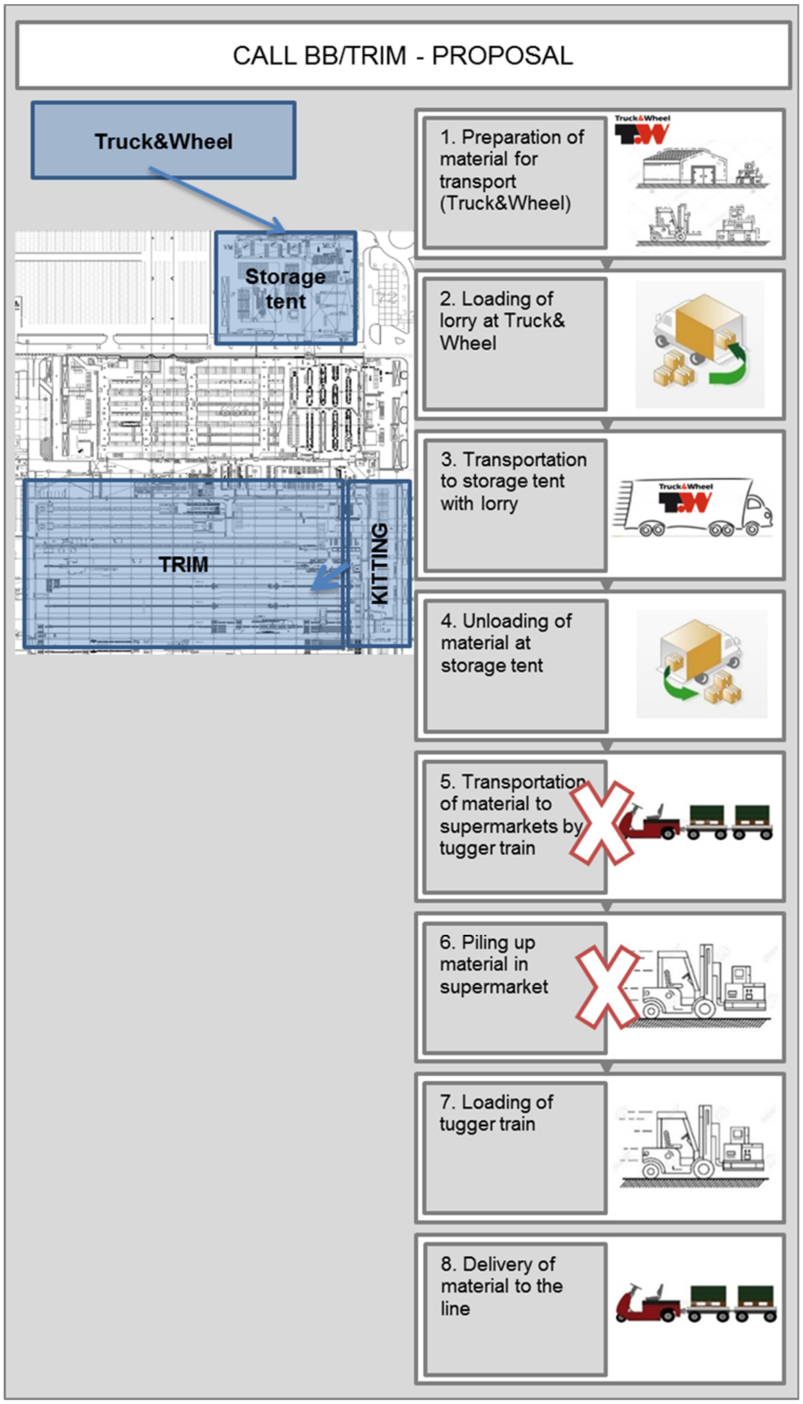

Figure 6.4: Call CC / trim - proposal

Figure 6.5 shows the recommendation for the Kanban process. When the material is loaded on a lorry, the parts are transported to the storage tent. From there, the parts get delivered to the kitting area for the assembly of the kits.

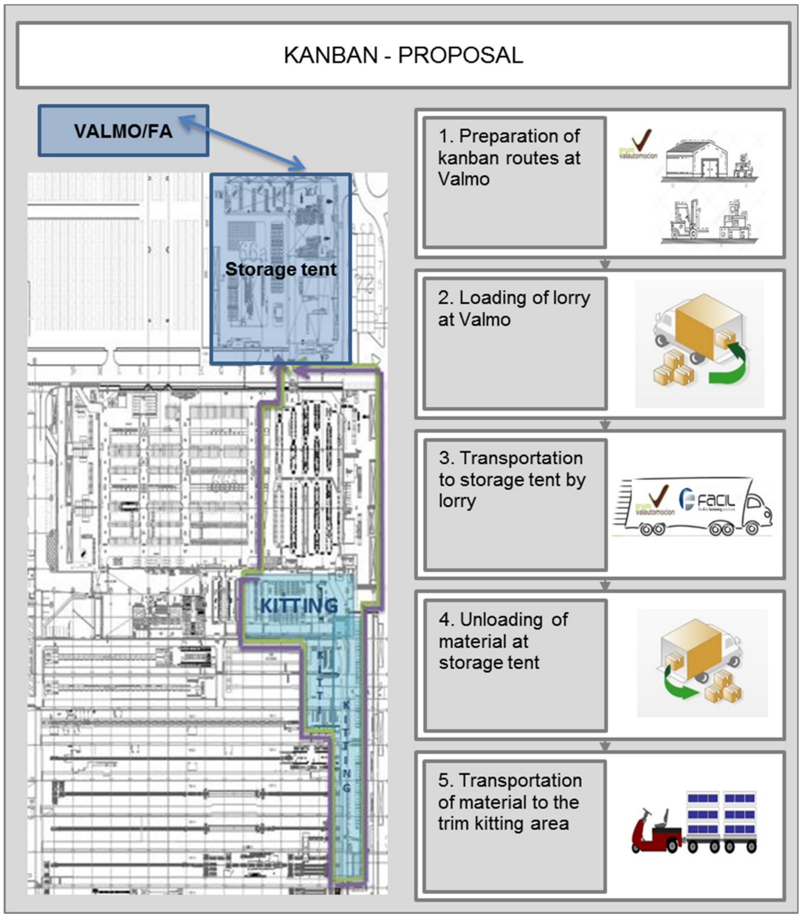

Figure 6.5: Kanban - proposal

With the introduction of kitting, the sequencing costs can be saved. When the material is prepared by the logistic partner, the truck is loaded and the material is transported to the storage area Extension 66 by lorry. After the material is unloaded, it is piled up. Before the material gets delivered to the assembly stations, it is transported to the kiting are where it is placed in kits, as shown in figure 6.6.

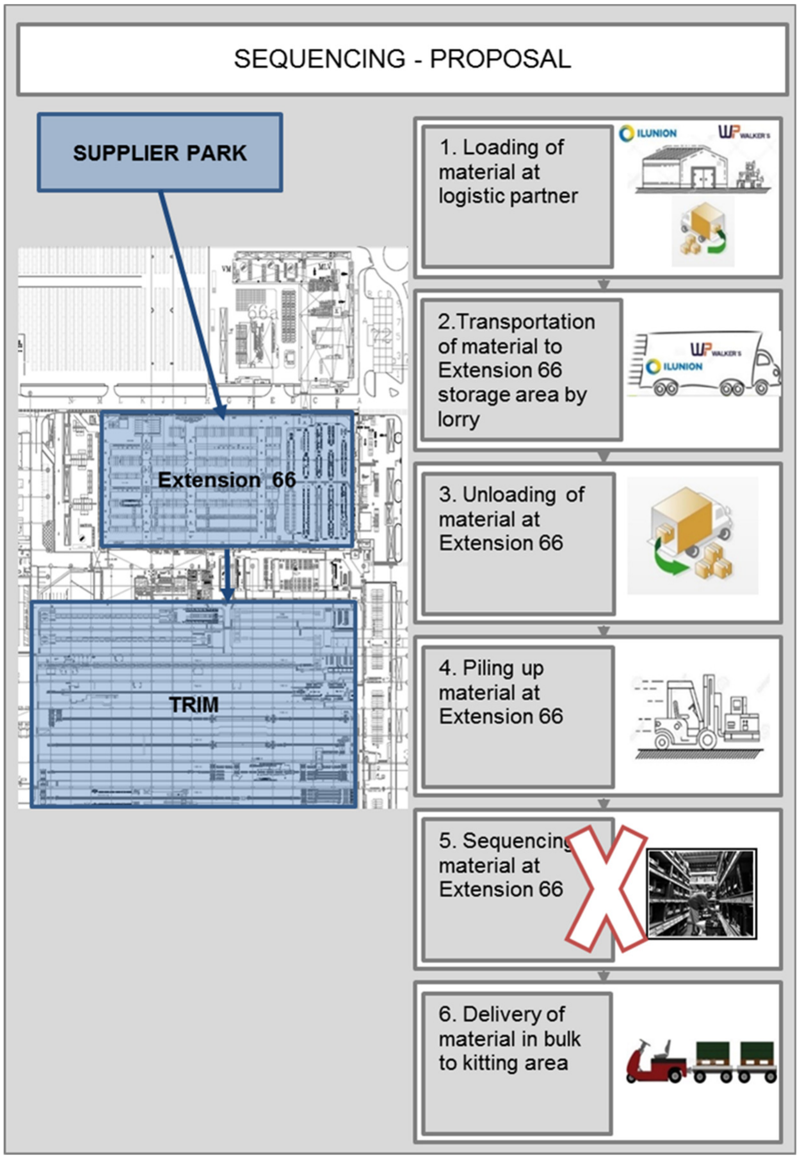

Figure 6.6: Sequencing - proposal

Kitting transport method to and along the line

There are different possibilities how transportation of the kit to the line and back is organized. Graphic 6.7 shows the necessary investment of each kitting transport method over its flexibility. The transportation methods are:

- Full AGV (from kitting area to the line and following the line)
- Floor Belt conveyor
- Overhead conveyor plus AGV
- Skillet

Skillet has less investment costs as well as low flexibility whereas AGV have high investment costs and high flexibility.

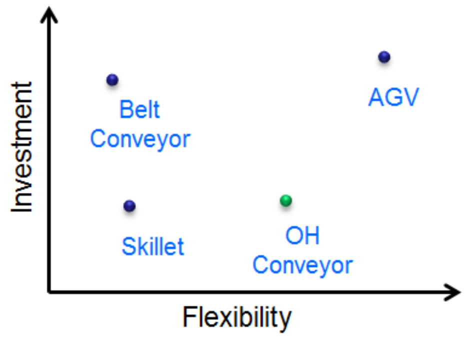

Figure 6.7: Investment over flexibility of kitting transport method

Figures 6.8-6.11 present the four different transport methods, automated guided vehicle, skillet, overhead conveyor and belt conveyor

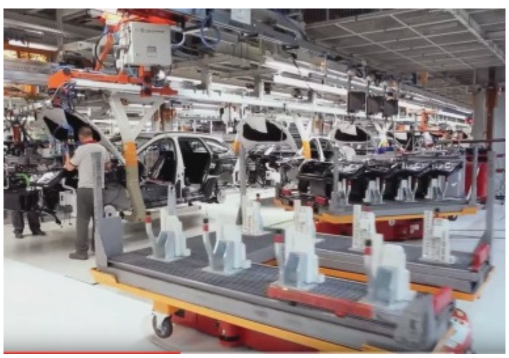

Figure 6.8: Automated guided vehicle

Figure 6.9: Skillet

Figure 6.10: Overhead conveyor

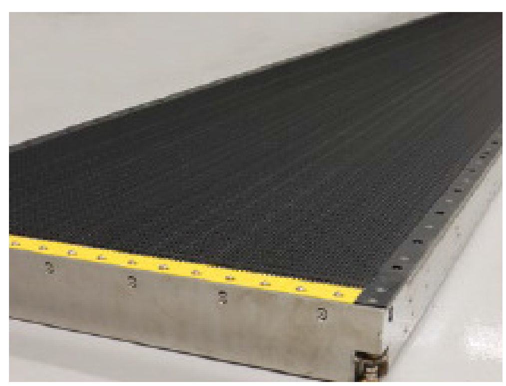

Figure 6.11: Belt conveyor

Here, it was decided upon a combination of overhead conveyor on each side of the eight assembly lines. To move the racks from the end of each assembly line to the beginning of the next assembly line, automated vehicles should be operating. Figure 6.12 shows the layout of the trim line with the material flow from the kitting area to A1.1, A1.2, A1 and A2 as well as to B1 and B2 line.

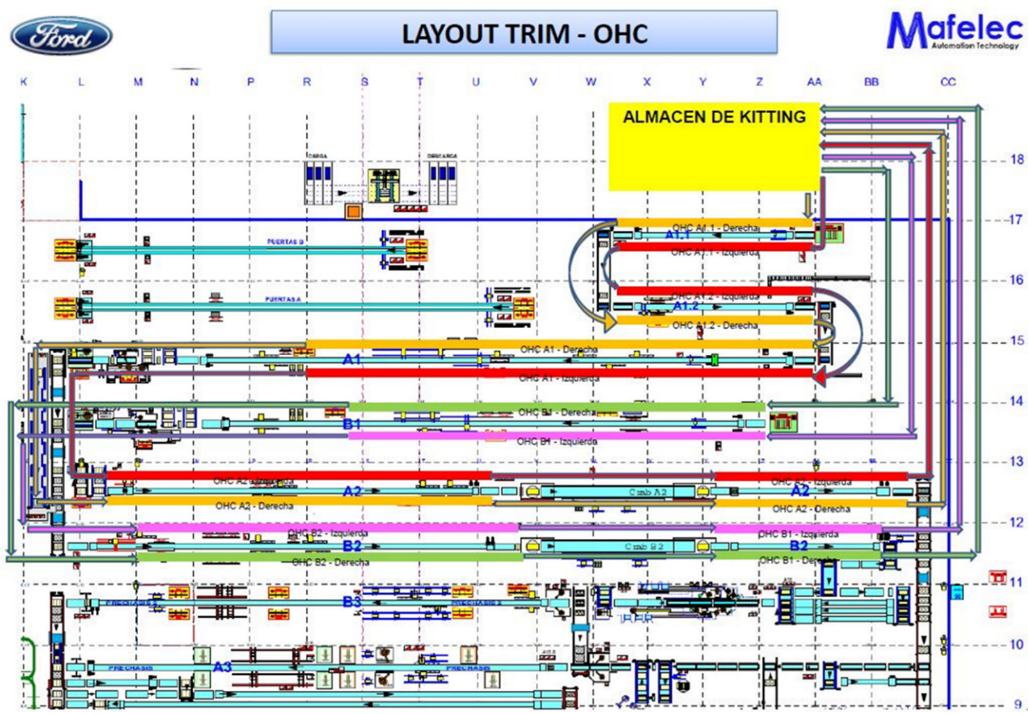

Figure 6.12: Kitted material flow

Figures 6.13 and 6.14 show the design of the overhead conveyor. Parts are presented within arm’s reach of the operator (1m).

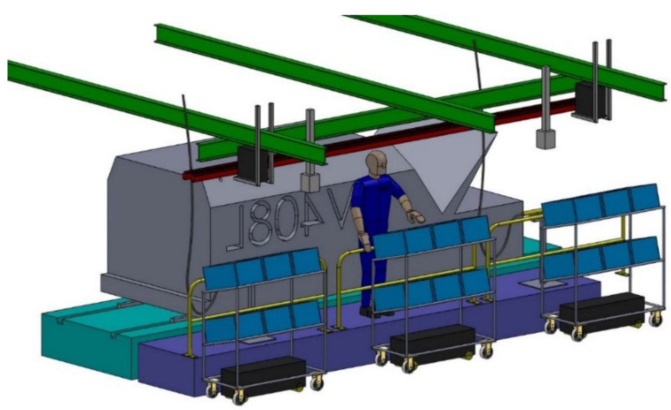

Figure 6.13: Design of overhead conveyor I

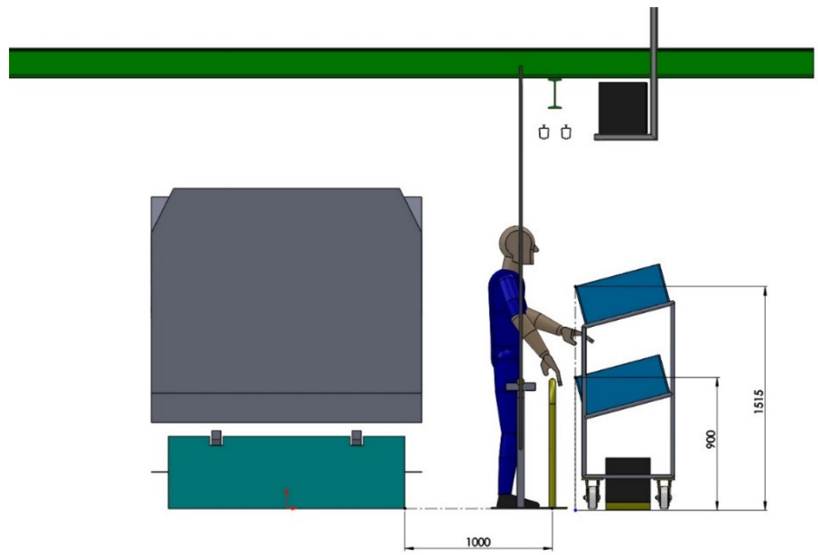

Figure 6.14: Design of overhead conveyor II

Below, table 6.11 demonstrates the cost for overhead conveyor belts for the trim line. Each line varies in its distance and, consequently in its investment costs. For A1, two overhead conveyor belts – one on each side – are necessary. With the distance of 135 meter, the investment costs are 590.000 Euro.

OHC belts	# of OHC belts	Distance	Costs
OHC A1.1	2	60 m	300.000 €
OHC A1.2	2	60 m	300.000 €
OHC A1	**2**	**135 m**	**590.000 €**
OHC A2	2	105 m	470.000 €
OHC A2.1	2	45 m	210.000 €
OHC B1	2	105 m	470.000 €
OHC B2	2	90 m	410.000 €
OHC B2.1	2	45 m	210.000 €
Total cost	16	645	2.960.000 €

Table 6.11: Investments for overhead conveyor belts

Table 6.12 shows how many automated guided vehicles are needed in Valencia plant. The layout of the trim area (6.15) points out where AGVs are required. They are supposed to deliver the racks from the kitting area to the first line (A1.1), from the end of line A1.1 to the beginning of A1.2, and further on. At the end of line A2 and B2, the AGVs deliver the empty racks to the kitting area. We assume that 25% of the AGVs constantly charge and that 10% of the total volume need maintenance. In total 284 AGVs are needed to support rack delivery from kitting area to the line, from the end of a line to the beginning of the next line as well as the delivery from the end of the line to kitting area. For A1-line, 44 AGVs are needed.

Routes of AGV	# AGV in use	# AGV charging	# Back up AGV
Kitting – OHC A1.1	16	4	2
OHC A1.1 – OHC A1.2	8	2	1
OHC A1.2 – OHC A1	**8**	**2**	**1**
OHC A1 – OHC A2	**24**	**6**	**3**
OHC A2 – OHC A2.1	12	3	2
OHC A2.1 – Kitting	32	8	4
Kitting – OHC B1	32	8	4
OHC B1 – OHC B2	28	7	3
OHC B2 – OHC B2.1	12	3	2
OHC B2.1 – Kitting	34	9	4
Total	**206**	**52**	**26**

Table 6.12: Investments for AGV

A first supplier quote of an AGV suitable for the Valencia plant's requirements is 30.000 Euro. This would sum up to an investment for A1-line of 1.32 million Euros for A1-line. The next step demands the search for a supplier which has the capacity to deliver 44 AGVs for a drastically reduced price. Currently, negotiations with different suppliers are on process.

Material belts

Figure 6.15: Material belts I

A belt can be useful for further reduction of picking time as parts can be picked and stored in the part belt. Currently, the majority of assembly line workers refuse to use belts for short term part storage. The refusal partly emanates from the belts' material; as it covers the complete loin, it gets hot underneath. Additionally, one belt is supposed to be shared by a number of workers; this can be regarded as unhygienic for a belt is covered with sweat after a shift. Furthermore, a loincloth is not compatible with any body shape. Pictures 6.15 show the belt currently used in production. Main usage is for fixtures and plugs.

Pictures 6.16 show little bags, which – according to the preferences of the operator – can be attached to one's own belt or can be placed independently around the waist. The material is more robust, sweat resistant and very convenient in use. As all reasons for not using a belt do not apply for these attachable bags, the project team assumes that workers will recognize the advantage of being able to store parts in constant and immediate proximity of their body. Various workers already use their pockets to have all parts in reach for a couple of operations. This saves a lot of walking and reaching time.

Figure 6.16: Material belts II

7 Conclusion

This chapter offers a conclusive discussion of the results of the analysis.

In this master's thesis, a model to compare different material feeding principles in high variation serial production assembly lines is established. It supports the decision makers in their decision process regarding the appropriate material feeding system for any automotive plant. The model consists out of a mathematical model and an analytical hierarchy process which weights selected criteria. It includes preparation, transportation, picking, storage and work-in-progress costs and compares lineside storage space, operator picking time, required picking space, lineside replenishment, kitting preparation time and lineside inventory value with each other.

The results presented in chapter 6 show that kitting has a higher cost impact as line side stocking. However, the case study demonstrates that kitting can be an alternative to lineside storage due to limited space. Whether kitting is preferable depends of the special requirements of a company. In the case of Ford Valencia, the analytical hierarchy process demonstrates the necessity to reduce lineside storage. Therefore, kitting can be seen as a very suitable material feeding system. However, other companies might value other criteria higher which leads to the choice of a different material feeding system. Using an analytical hierarchy process beside a business case calculation is therefore indispensable for OEMs thinking about the introduction of kitting.

The design of a kitting system shows that Ford Valencia should use a central kitting area close to the beginning of the trim line. Small components such as fasteners and plugs should not be included in the kits. They are delivered as bulk material with continuous supply to the line. The kitting process itself is handled by the assembly workers who rotate their position to ensure higher picking accuracy. The kitting preparation is done by a picker-to-part system with order cards, which list the components, their quantities and shelf locations. Displays and lamps support the picker to reduce the risk of inaccuracies. Parts are displayed on trolleys with multiple shelves to the assembly line. The parts either are presented in boxes or hang on the side of the trolley with dedicated places. The trolleys move alongside the line with overhead conveyors on each side of the assembly line. To move the racks from the end of each assembly line, automated guided vehicles are operating.

With the introduction of kitting, the increased complexity of producing more models and derivatives can be managed. Evidently, kitting reduces man-hour consumption of operators at the assembly line by presenting parts closer to the assembly object. The main reason for the improved material presentation is constituted by the fact that – in contrast to continuous supply – not all part numbers need to be presented at once and the operator can focus on the value added assembly work. Moreover, kitting can facilitate balancing work tasks of the assembly line.

Rebalancing work task from one workstation to another results in potential savings that are difficult to quantify. The biggest interest for further investigations is to be able to quantify these qualitative effects. Beside these effects third party kitting and the combination of kitting and continuous supply are areas for further research. Such an interacting and reciprocal approach can combine the benefits of both kitting and continuous supply.

References

Arbnor, I., Bjerke, B. (2009). Methodology for creating business knowledge 3rd edition, Sage Inc., Thounsand Oaks.

Aronsson, H., Ekdahl, B.,Oskarsson, B. (2004). Modern Logistic 2nd edition, Liber AB, Lund.

Battini, D., Faccio, M., Persona, A. and Sgarbossa, F. (2009). Design of the optimal feeding policy in an assembly system, International Journal of Production Economics, Vol. 121, No. 1, pp. 233-254.

Baudin, M. (2004). Lean logistics: the nuts and bolts of delivering materials and goods, New York: Productivity Press.

Bozer Y.A., McGinnis, L.F. (1992). Kitting versus line stocking: a conceptual framework and a descriptive model. International Journal of Production Economics, Vol 28, No. 1, pp. 1-19.

Brynzér H., Johansson M.I. (1995). Design and performance of kitting and order picking systems. International Journal of Production Economics, Vol. 41, No. 1, pp. 115-125.

Brynzér, H. (1995). Evaluation of kitting systems: implications for kitting systems design, Licentiate thesis, Department of Transportation and Logistics, Chalmers University of Technology, Gothenburg.

Burlingame (1913), Henry Ford, The precise year in which Ford issued the "multitude" statement is not known. Earliest source 6/6/13 Ford Times. Probably said 1903-1906, when expressed same views to associates.

Carlsson, O., Hensvold, B. (2008). Kitting in a high variation assembly line: a case study at Caterpillar BCP-E. Master's thesis, Lulea University of Technology.

Caputo, A.C., Pelagagge, P.M. (2011). A methodology for selecting assembly systems feeding policy, Industrial Management and Data Systems, Vol. 111, No. 1, pp. 84-112

Chen and Wilhem (1993, 1994 and 1997)

Choobineh F., Mohebbi E. (2004). Material planning for production kits under uncertainty. Production Planning & Control, Vol. 15, No. 1, 63-70

Christmansson, M., et al. (2002). A case study of a principally new way of materials kitting – an evaluation of time consumption and physical workload. International Journal of Industrial Ergonomics, 30 (1), pp. 49-65.

De Souza M.C., de Carvalho C.R.V., Brizon W.B. (2008). Packing items to feed assembly lines. European Journal of Operational Research, 184, pp. 480-489.

Ding, F.Y. (1992). Kitting in JIT production: a kitting project at a tractor plant. Industrial Engineering, 24 (9), pp. 42–43.

Ding F.-Y., Balakrishnan P. (1990). Kitting in Just-In-Time production. Production and Inventory Management Journal 31(4), pp. 25-28.

Finnsgård, C., Wänström, C. (2009). Factors impaction manual work using video recording and personal computer techniques, International Journal of Industrial Ergonomics, 19 (4), pp. 291-298.

Finnsgård, C., Medbo, L., Johansson M. I. (2011). Describing and assessing performance in material flows in supply chains: a case study in the Swedish automotive industry, Unpublished paper, Chalmers University of Technology, Department of Technology management and economics, Division of Logistics and transportation, Gothenburg

Gajjar, J. M., Thakkar, H. R. (2014). Improvement in material feeding system through introducing kitting concept in lean environment of MSME: A review study.

Gu, J., M. Goetschalckx, McGinnis, L.F. (2010). Research on Warehouse Design and Performance Evaluation: A Comprehensive Review. European Journal of Operational Research 203, pp. 539–549.

Gunther, H.O., Gronalt, M., Piller, F. (1996). Component kitting in semi-automated printed circuit board assembly. International Journal of Production Economics, 43 (2–3), pp. 213–226.

Hansen, R., Medbo, L. (2012). Kitting and time efficiency in manual assembly, International Journal of Production Research, 50:4, pp. 1115-1125.

Hua, S.Y., Johnson, D.J. (2010). Research issues on factors influencing the choice of kitting versus line stocking. International Journal of Production Research, Vol. 48, No. 3, pp. 779–800.

Hua, W., Zhou, C. (2008). Clusters and filling-curve based storage assignment in a circuit board assembly kitting area", IIE Transactions, Vol. 40 No. 6, pp. 569-85.

Johansson, M.I. (1991). Kitting systems for small size parts in manual assembly systems. In: M. Pridham and C. O'Brien, eds. Production research: approaching the 21st century. London: Taylor & Francis, pp. 225-230.

Karlsson, E., Thoresson, T. (2011). A comparative study of the material feeding principles kitting and sequencing at Saab Automobile, Chalmers University of Technology, Gothenburg.

Kilic, H. S., Durmusoglu, M. B. (2012). Design of Kitting System in Lean-based Assembly Lines. Assembly Automation, Vol. 32, No. 3, pp. 226–234.

Kilic, H.S., Durmusoglu, M.B., Baskak, M. (2012). Classification and modeling for in-plant milk-run distribution systems", International Journal of Advanced Manufacturing Technology, 10 January.

Jonsson, D., Medbo, L., and Engström, T. (2004). Some considerations relating to the reintroduction of assembly lines in the Swedish automotive industry. International Journal of Operations & Production Management, 24 (8), 754–772.

Joshi, A., Phadnis, S.S., Srihari, K., Seeniraj, R. (2002). Use of simulation to improve the kitting process at an EMS provider's facility, Electronics Packaging Technology Conference, pp. 440-5.

Leshno, M., Ronen, B. (2001). The complete kit concept-implementation in the health care system, Human Systems Management, Vol. 20 No. 4, pp. 313-8

Limère, V. (2012). To Kit or Not to Kit: Optimizing Part Feeding in the Automotive Assembly Industry.PhD diss., University of Gent.

Limère, V., van Landeghem, H., Goetschalckx, M., Aghezzaf E.-H., McGinnis L. F. (2012). Optimising Part Feeding in the Automotive Assembly Industry: Deciding between Kitting and Line Stocking. International Journal of Production Research, Vol. 50, No. 15, pp. 4046–4060.

Limère, V., v Landeghem, H., Goetschalckx, M. (2015). A decision model for kitting and line stocking with variable operator walking distances, Assembly Automation, Vol. 35, Iss. 1, pp. 47-56.

Limère, V., van Landeghem, H., Goetschalckx, M., Aghezzaf E.-H., McGinnis L. F. (2012). Optimising Part Feeding in the Automotive Assembly Industry: Deciding between Kitting and Line Stocking. International Journal of Production Research, Vol. 50, No. 15, pp. 4046–4060.

Limère, V., v Landeghem, H., Goetschalckx, M. (2015). A decision model for kitting and line stocking with variable operator walking distances, Assembly Automation, Vol. 35, Iss. 1, pp. 47-56.

Medbo, L. (2003). Assembly work execution and materials kit functionality in parallel flow assembly systems. International Journal of Industrial Ergonomics, Vol. 31, No. 4, pp. 263–281.

Neumann, W. P., L. Medbo (2010). Ergonomic and Technical Aspects in the Redesign of Material Supply Systems: Big Boxes vs. Narrow Bins. International Journal of Industrial Ergonomics 40: pp. 541–548.

Ramachandran S., Delen D. (2005). Performance analysis of a kitting process in stochastic assembly systems. Computers & Operations Research, 32, pp. 449-463.

Ronen, B. (1992). The complete kit concept, International Journal of Production Research, Vol. 30 No. 10, pp. 2457-66.

Sali, M., Sahin, E., Patchong, A. (2015). An empirical assessment of the performances of three line feeding modes used in the automotive sector: line stocking vs. kitting vs. sequencing, International Journal of Production Research, Vol. 53, No. 5, pp. 1439-1459.

Schwind G.F. (1992). How storage systems keep kits moving, Material Handling Engineering, Vol. 47, Issue 12, pp. 43-45.

Som P., Wilhelm W.E., Disney R.L. (1994). Kitting process in a stochastic assembly system. Queueing Systems, 17, pp. 471-490.

Saunders M., Lewis P., Thornhill A. (2000). Research methods for business students. Harlow: Financial times Prentice-Hall Inc.

Svensson, G. (2006). Sequential service quality in service encounter chains: case studies. Journal of Services Marketing, vol. 20, Iss: 1 pp. 51-58.

Wänström, C., Medbo, L. (2008). The impact of materials feeding design on assembly process performance. Journal of Manufacturing Technology Management, Vol. 20, No. 1, pp. 30–51.

Womack, J.P., Jones, D.T., Roos, D. (1990). The machine that changed the word. New York: Rawson Associates.

Yin, R. (2014). Case Study Research: Design and Methods. 5th ed. London: SAGE.

https://www.at.ford.com/en/homepage/news-and-clipsheet/plants/eu/valencia-engine-plant.html - accessed on June 8, 2017.

List of abbreviations

AGV	Automated guided vehicles
d	day
h	Hours
m	Meter
OHC	Overhead conveyor
OEM	Original Equipment Manufacturer
POU	Point of use
s	Seconds
WIP	Work in progress
WP	Walkerpack
VM	Grupo Valautomocion

List of figures

List of tables

List of appendixes

Appendix A: Calculation AHP

Original matrix	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value
Operator picking time	1	0,14	0,33	3,00	3,00	3,00
Lineside storage space	7,00	1	5,00	7,00	5,00	9,00
Required kitting space	3,00	0,20	1	3,00	5,00	5,00
Lineside replenishment	0,33	0,14	0,33	1	3,00	3,00
kitting preparation time	0,33	0,20	0,20	0,33	1	3,00
lineside inventory value	0,33	0,11	0,20	0,33	0,33	1

Matrix square 1	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	kitting preparation time	lineside inventory value	Sum	Eigenvector
Operator picking time	6,00	1,71	3,58	10,00	18,38	26,95	66,63	0,1177
Lineside storage space	36,00	6,00	17,47	54,67	80,00	100,00	294,13	0,5195
Required kitting space	11,73	2,81	6,00	19,73	30,67	44,80	115,75	0,2044
Lineside replenishment	4,67	1,33	2,69	6,00	10,38	18,95	44,03	0,0778
kitting preparation time	3,78	0,87	2,22	4,67	6,00	10,80	28,34	0,0500
lineside inventory value	2,27	0,42	1,24	3,16	4,22	6,00	17,31	0,0306
						Total	566,18	1,00

Matrix square 2	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value	Sum	Eigenvector
Operator picking time	316,93	71,37	174,22	455,21	685,14	1043,32	2746,19	0,1137
Lineside storage space	1420,94	331,63	787,90	2049,56	3147,07	4852,86	12590	0,5210
Required kitting space	551,54	125,81	304,17	792,37	1202,69	1840,30	4816,90	0,1993
Lineside replenishment	217,76	48,63	118,96	316,93	479,59	719,26	1901,13	0,0787
kitting preparation time	148,93	33,95	81,37	219,19	337,12	506,28	1326,84	0,0549
lineside inventory value	87,75	20,35	48,34	127,98	197,18	300,66	782,25	0,0324
						Total	24163	1,00

Matrix square 3	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value	Sum	Eigenvector
Operator picking time	590667	134839	324773	856570	1306302	1985612	5198763	0,1140
Lineside storage space	2696973	615796	1482960	3911277	5965593	9068357	23740957	0,5208
Required kitting space	1034489	236174	568813	1500214	2287992	3477887	9105569	0,1997
Lineside replenishment	407277	92967	223927	590667	900801	1369110	3584749	0,0786
kitting preparation time	282688	64534	155425	410012	625351	950443	2488454	0,0546
lineside inventory value	167003	38129	91825	242211	369431	561533	1470134	0,0322
						Total	45588625	1

Matrix square 4	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value	Sum	Eigenvector
Operator picking time	2,1E+12	4,8E+11	1,2E+12	3E+12	4,6E+12	7,1E+12	1,8E+13	0,1140
Lineside storage space	9,6E+12	2,2E+12	5,3E+12	1,4E+13	2,1E+13	3,2E+13	8,4E+13	0,5208
Required kitting space	3,7E+12	8,4E+11	2E+12	5,3E+12	8,1E+12	1,2E+13	3,2E+13	0,1997
Lineside replenishment	1,4E+12	3,3E+11	8E+11	2,1E+12	3,2E+12	4,9E+12	1,3E+13	0,0786
kitting preparation time	1E+12	2,3E+11	5,5E+11	1,5E+12	2,2E+12	3,4E+12	8,8E+12	0,0546
lineside inventory value	5,9E+11	1,4E+11	3,3E+11	8,6E+11	1,3E+12	2E+12	5,2E+12	0,0322
						Total	1,6E+14	1,00

Matrix square 5	Operator picking time	Lineside storage space	Required kitting space	Lineside replenishment	Kitting preparation time	Lineside inventory value	Sum	Eigenvector
Operator picking time	2,6E+25	6E+24	1,5E+25	3,8E+25	5,9E+25	8,9E+25	2,3E+26	0,1140
Lineside storage space	1,2E+26	2,8E+25	6,6E+25	1,8E+26	2,7E+26	4,1E+26	1,1E+27	0,5208
Required kitting space	4,6E+25	1,1E+25	2,6E+25	6,7E+25	1E+26	1,6E+26	4,1E+26	0,1997
Lineside replenishment	1,8E+25	4,2E+24	1E+25	2,6E+25	4E+25	6,1E+25	1,6E+26	0,0786
kitting preparation time	1,3E+25	2,9E+24	7E+24	1,8E+25	2,8E+25	4,3E+25	1,1E+26	0,0546
lineside inventory value	7,5E+24	1,7E+24	4,1E+24	1,1E+25	1,7E+25	2,5E+25	6,6E+25	0,0322
						Total	2E+27	1

Criteria	Normalised weight
Lineside storage space	0,5208
Required kitting space	0,1997
Operator picking time	0,1140
Lineside replenishment	0,0786
Kitting preparation time	0,0546
Lineside inventory value	0,0322

Appendix B: Parts used on A1-line

Station	Part number	Container No: (daia)	Proposed material feeding	Req. per unit	Req. per day	Pcs/Cont: (daia)	containers used per day
1	DV44-S46016-AB	KLT3215	Kitting	0,01	10,20	50	0,20
1	DV44-S46016-BA	KLT3215	Kitting	0,01	13,38	50	0,27
1	DS73-16C618-AE	KLT6429	Kitting	0,14	277,75	250	1,11
1	EM2B-R444A22-AE	KLT4315	Kitting	0,14	270,04	96	2,81
1	EM2B-U444A22-BF	KLT4315	Kitting	0,05	91,43	34	2,69
1	SECU-AIRBAG-	FE13531	Kitting			34	
1	8A61-A020C02-AA	CTN (carton)	Line stocking	5,50	10672,66	25000	0,43
1	-W715197-S439	KLT4329	Line stocking	11,42	22157,06	4300	5,15
1	-W703283-S450B	KLT3215	Line stocking	5,14	9976,44	1000	9,98
1	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51
1	-W705436-S300	KLT4329	Line stocking	5,40	10479,22	4500	2,33
1	-W706131-S437	KLT3215	Line stocking			3000	
1	-W706681-S439	KLT3215	Line stocking	0,05	94,31	1200	0,08
1	-W708568-S424	KLT3215	Line stocking	1,72	3338,46	600	5,56
1	-W708617-S439	KLT3215	Line stocking	0,29	555,49	2000	0,28
1	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
1	-W715197-S439	KLT4329	Line stocking	11,42	22157,06	4300	5,15
1	-W716424-S437	KLT3215	Line stocking	0,01	26,76	300	0,09
2	CJ54-S02684-AD	KLT4315	Kitting	1,12	2167,83	75	28,90
2	DS73-17A423-CB	KLT4329	Kitting	0,05	102,17	400	0,26
2	DS7T-18C847-AA	KLT6415	Kitting	0,14	272,91	110	2,48
2	7CP1-18K891-AA	KLT4315	Kitting	0,09	170,75	150	1,14
2	DS73-F026A52-EA	KLT6429	Kitting	0,14	278,21	30	9,27
2	EM2B-R513C54-AD	KLT3215	Kitting	1,04	2017,40	220	9,17
2	EM2B-R026A52-AD	KLT6429	Kitting	0,02	30,82	120	0,26
2	EM2B-U026A52-AD	KLT6429	Kitting	0,01	25,88	120	0,22
2	SECU-BACAS-	FE13543	Kitting			120	
2	GV44-S550A62-AA5YZ	FE12845	Line stocking			72	
2	CJ54-S50462-AG5YZ9	IMC490	Line stocking	0,05	92,28	132	0,70
2	7S71-412A36-AA	COP	Line stocking	0,48	934,33	0	
2	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
2	-W505423-S450B	KLT3215	Line stocking	0,23	452,90	1200	0,38
2	-W703715-S437	KLT3215	Line stocking	0,80	1550,70	1800	0,86
2	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51
2	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
2	-W716025-S439	KLT3215	Line stocking	3,33	6456,72	750	8,61
2	-W716284-S300	IMC060	Line stocking	0,65	1258,23	2400	0,52
2	-W717140-S439	KLT3215	Line stocking	1,12	2167,83	1000	2,17
2	-W717376-S439	KLT3215	Line stocking	0,29	556,41	250	2,23
3	CJ54-S444A18-AB	KLT4315	kitting	0,46	899,37	150	6,00
3	CJ54-S444A28-AC	IMC100	kitting	0,93	1798,73	15000	0,12
3	CJ54-78501A94-CF	IMC060	kitting	0,09	170,56	100	1,71
3	9V41-13K732-AA	KLT3215	Kitting	0,04	71,46	6000	0,01
3	DS73-17A423-BE	KLT6429	Kitting	0,07	140,31	40	3,51
3	BE53-5402688-CA	IMC090	Kitting	0,04	71,46	720	0,10
3	DS73-A444A18-AB	KLT3215	Kitting	0,02	37,95	60	0,63
3	DS73-A444A18-BA	KLT4315	Kitting	0,03	64,21	60	1,07
3	DS73-N444A18-AC	KLT4315	Kitting	0,11	221,70	63	3,52
3	DS7T-18C847-CB	KLT6415	Kitting	0,09	173,93	110	1,58

3	DS7T-18C847-HA	KLT6415	Kitting	0,05	98,72	110	0,90
3	EM2B-R020A26-AC	FLC1210	Kitting	0,12	226,45	70	3,24
3	EM2B-R444A18-AF	KLT4315	Kitting	0,06	114,40	80	1,43
3	EM2B-R444A18-BG	KLT4315	Kitting	0,04	77,82	80	0,97
3	EM2B-U444A18-AF	KLT4315	Kitting			50	
3	EM2B-U444A18-BE	KLT4315	Kitting	0,02	37,49	56	0,67
3	3M51-R23726-AA	CTN (carton)	Line stocking	0,04	71,46	0	
3	EM2B-412A36-AA	COP	Line stocking	0,14	270,04	0	
3	-W520100-S437	KLT3215	Line stocking	0,66	1282,69	5000	0,26
3	-W520822-S439	KLT3215	Line stocking	1,35	2616,63	1000	2,62
3	-W700407-S300	KLT3215	Line stocking	2,92	5667,15	500	11,33
3	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
3	-W703283-S450B	KLT3215	Line stocking	5,14	9976,44	1000	9,98
3	-W710613-S300	IMC050	Line stocking	5,80	11260,01	5300	2,12
3	-W714115-S437	KLT3215	Line stocking	0,21	408,66	1500	0,27
3	-W714117-S300	COP	Line stocking	0,11	204,33	0	
3	-W714793-S300	KLT3215	Line stocking	0,79	1524,86	1000	1,52
3	-W716236-S300	IMC050	Line stocking	3,71	7194,93	5500	1,31
3	-W711412-S300	KLT3215	Line stocking	0,07	129,46	1000	0,13
3	-W713579-S300	KLT3215	Line stocking	0,93	1798,73	1000	1,80
3	-W717723-S439	FKLT3215	Line stocking	0,25	484,95	200	2,42
4	AV6N-14A206-AB	FLC1210	kitting	0,62	1194,48	240	4,98
4	F1GC-18B066-AB	COP	kitting	0,01	13,38	0	
4	DS7A-9660872-BC	FLC1210	kitting	0,14	278,21	54	5,15
4	DS7A-9661320-BE	FLC1210	kitting	0,14	278,21	90	3,09
4	EM2B-R310A26-BF	FSC1206	kitting	0,12	226,45	45	5,03
4	-W504775-S303XD	KLT3215	Line stocking	2,38	4615,44	350	13,19
4	-W520102-S437	KLT3215	Line stocking	1,39	2698,10	2000	1,35
4	-W520822-S439	KLT3215	Line stocking	1,35	2616,63	1000	2,62
4	-W528044-S300	IMC060	Line stocking	0,47	905,81	3000	0,30
4	-W700407-S300	KLT3215	Line stocking	2,92	5667,15	500	11,33
4	-W700505-S300	KLT3215	Line stocking	0,85	1658,31	750	2,21
4	-W702751-S442	KLT3215	Line stocking	3,28	6368,32	2000	3,18
4	-W705904-S300	IMC060	Line stocking	0,47	905,81	500	1,81
4	-W706019-S300	KLT4314	Line stocking	2,40	4662,02	2500	1,86
4	-W707293-S439	KLT3215	Line stocking	0,30	588,15	1000	0,59
4	-W708761-SS3JA6	FKLT3215	Line stocking	1,85	3597,46	625	5,76
4	-W711215-S300	KLT4315	Line stocking	1,94	3759,05	1600	2,35
4	-W714171-S439	KLT4315	Line stocking	1,88	3637,60	5000	0,73
4	-W717345-S300	IMC040	Line stocking	0,70	1358,71	125	10,87
5	CV44-S27936-AC	IMC190	Kitting			72	
5	4N5H-19A699-AD	KLT6429	Kitting	0,74	1435,34	400	3,59
5	BM51-A16C266-BA	FLC1210	Kitting	1,48	2870,69	360	7,97
5	DS73-17A422-AD	KLT6429	Kitting	0,12	242,48	40	6,06
5	EM2B-17A422-AB	KLT6429	Kitting	0,07	135,02	30	4,50
5	EM2B-R24344-BD	KLT6429	Kitting	0,02	38,83	40	0,97
5	EM2B-17A422-BA	KLT6429	Kitting	0,05	91,43	30	3,05
5	7S71-412A36-AA	COP	Line stocking	0,48	934,33	0	
5	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
5	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
5	-W702686-S300	KLT3215	Line stocking	4,64	8993,66	500	17,99
5	-W707238-S300	KLT4315	Line stocking			130	
5	-W702751-S442	KLT3215	Line stocking	3,28	6368,32	2000	3,18
5	-W709066-S437M	KLT3215	Line stocking	0,93	1798,73	300	6,00

6	CJ54-16A570-AA	IMC090	Kitting			500	
6	CJ54-17408-AC	KLT6429	Kitting			100	
6	BM51-A02292-BB	CTN (carton)	Kitting	0,14	280,62	0	
6	DS7T-18C847-CB	KLT6415	Kitting	0,09	173,93	110	1,58
6	DS7T-18C847-HA	KLT6415	Kitting	0,05	98,72	110	0,90
6	7CP1-18K891-CA	KLT4315	Kitting	0,09	170,75	150	1,14
6	DG9T-54234B76-BA	COP	Kitting	0,29	556,41	0	
6	DS73-A02078-AD	FSC1206	Kitting	0,14	278,21	96	2,90
6	EM2B-R46016-BD	KLT4329	Kitting	0,07	126,16	80	1,58
6	DS73-U313A68-AF3JA6	KLT4315	Kitting	0,25	478,74	80	5,98
6	EM2B-U46016-BD	KLT4329	Kitting	0,04	82,31	80	1,03
6	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
6	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
6	-W707119-S300	KLT3215	Line stocking	2,41	4671,53	800	5,84
6	-W712231-S303	KLT3215	Line stocking	3,45	6688,05	1500	4,46
6	-W712518-S303	KLT3215	Line stocking	1,12	2168,83	300	7,23
6	-W713158-S442	KLT3215	Line stocking	0,47	905,81	1400	0,65
6	-W716076-S300	FKLT3215	Line stocking	0,29	556,41	1000	0,56
6	-W717450-S442	KLT3215	Line stocking	1,04	2017,40	500	4,03
7	FG1A-7H417-MA	IMC040	Kitting	0,15	297,45	36	8,26
7	F1FA-9D370-GA	KLT6415	Kitting	0,74	1435,80	45	31,91
7	GG93-F602B82-AA3AM	KLT6429	Kitting	0,49	954,42	21	45,45
7	6M5Y-412A36-AA	CTN (carton)	Line stocking	0,95	1847,69	33000	0,06
7	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
7	-Pedalera-	KLT3215	Kitting			4000	
7	-Embrague-	KLT3215	Kitting			4000	
7	G1BB-16B114-AA	KLT3215	Line stocking	0,04	69,08	340	0,20
7	FS73-16702-NASMAS	KLT3215	Line stocking	0,03	64,17	160	0,40
7	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
7	-W705963-S300	IMC060	Line stocking	0,12	226,45	2800	0,08
7	-W716131-S300	KLT3215	Line stocking	1,47	2859,19	45	63,54
8	7CP1-18C847-CA	KLT6429	Kitting	0,46	899,37	275	3,27
8	CV4T-18K891-AA	KLT4315	Kitting	0,46	899,37	150	6,00
8	GV61-19812-AB	POP	Kitting	0,03	61,72	1	61,72
8	AM51-R10968-AC	KLT3215	Kitting	0,46	899,37	100	8,99
8	DS73-16K808-AA	IMC040	Kitting	0,29	556,41	450	1,24
8	7S71-A40452-AB	KLT4329	Kitting			250	
8	DS73-A40452-AC	IMC060	Kitting	0,04	71,46	500	0,14
8	-Modulo-	KLT3215	Kitting			500	
8	EM2B-R40174-AD	IMC050	Kitting	0,23	452,90	500	0,91
8	6M21-R29760-AA	KLT3215	Line stocking	3,70	7168,93	1500	4,78
8	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
8	-W504775-S303XD	KLT3215	Line stocking	2,38	4615,44	350	13,19
8	-W520822-S439	KLT3215	Line stocking	1,35	2616,63	1000	2,62
8	-W702751-S437	KLT3215	Line stocking	2,44	4736,39	2000	2,37
8	-W709764-S440	KLT3215	Line stocking	0,06	123,44	200	0,62
8	-W710330-S439	KLT3215	Line stocking	1,21	2345,94	1300	1,80
8	-W712518-S303	KLT3215	Line stocking	1,12	2168,83	300	7,23
8	-W715197-S439	KLT4329	Line stocking	11,42	22157,06	4300	5,15
8	-W716195-S450B	KLT3215	Line stocking	0,02	40,14	1600	0,03
8	-W716470-S303	KLT3215	Line stocking	0,21	408,66	2000	0,20
8	-W717982-S417	KLT3215	Line stocking	0,47	905,81	1000	0,91
8	-W718550-S439	KLT3215	Line stocking	0,50	961,09	1500	0,64
9	-W520212-S440	KLT3215	Line stocking	1,04	2018,63	1000	2,02

9	-W520412-S437	KLT3215	Line stocking	2,52	4897,29	4000	1,22
9	-W520413-S437	KLT3215	Line stocking	5,22	10123,12	1750	5,78
9	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51
9	-W708568-S424	KLT3215	Line stocking	1,72	3338,46	600	5,56
9	-W709601-S442	FKLT3215	Line stocking	0,63	1216,06	380	3,20
9	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
9	-W716596-S437	KLT3215	Line stocking	0,46	896,38	500	1,79
10	6G9T-11A152-AA	COP	Kitting	0,49	958,33	0	
10	3M5T-14197-GA	KLT3215	Kitting	1,52	2945,29	1800	1,64
10	DS73-F20708-AJ	FLC1210	Kitting	0,14	278,21	90	3,09
10	DG98-10C736-AB	IMC200DW	Kitting	0,01	18,21	32	0,57
10	F65A-7B591-AA	IMC040	Kitting	0,57	1115,24	200	5,58
10	EM2B-R20708-AF	FLC1210	Kitting			90	
10	EM2B-U20708-AF	FLC1210	Kitting	0,09	182,86	90	2,03
10	6M21-R29760-AA	KLT3215	Line stocking	3,70	7168,93	1500	4,78
10	6M21-412A36-BA	CTN (carton)	Line stocking	2,70	5233,80	16000	0,33
10	8A61-A020C02-AA	CTN (carton)	Line stocking	5,50	10672,66	25000	0,43
10	6L34-1523726-AB	CTN (carton)	Line stocking	1,88	3644,31	6000	0,61
10	6L34-1523726-BB	CTN (carton)	Line stocking	10,73	20825,80	24500	0,85
10	6M21-R026A76-AA	CTN (carton)	Line stocking	3,19	6180,51	6000	1,03
10	-W520212-S440	KLT3215	Line stocking	1,04	2018,63	1000	2,02
10	-W520414-S437	KLT3215	Line stocking	0,12	240,87	600	0,40
10	-W707144-S437	KLT3215	Line stocking	0,76	1480,43	1250	1,18
10	-W709601-S442	FKLT3215	Line stocking	0,63	1216,06	380	3,20
10	-W716596-S437	KLT3215	Line stocking	0,46	896,38	500	1,79
10	-W500854-S437	KLT3215	Line stocking	0,06	107,34	3000	0,04
10	-W507043-S437	KLT3215	Line stocking	0,40	766,76	3000	0,26
10	-W520413-S437	KLT3215	Line stocking	5,22	10123,12	1750	5,78
10	-W651013-S	IMC060	Line stocking	0,04	80,51	3200	0,03
10	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
10	-W707144-S437	KLT3215	Line stocking	0,76	1480,43	1250	1,18
10	-W709643-S300	KLT3215	Line stocking	1,84	3576,80	150	23,85
10	-W709764-S440	KLT3215	Line stocking	0,06	123,44	200	0,62
10	-W717080-S300	IMC050	Line stocking	2,08	4037,25	3000	1,35
11	GV41-110867-AA	FSC1206	Kitting	0,46	899,37	500	1,80
11	BB53-78407A82-AA	COP	Kitting	0,58	1126,55	0	
11	GJ54-S406A76-AC	IMC130	Kitting	0,17	336,09	40	8,40
11	DS73-110867-AA	KLT4315	Kitting	0,02	30,67	9	3,41
11	DS73-A279A66-AC	FSC1206	Kitting	0,04	71,50	200	0,36
11	DS73-A406A76-AC	FSC1206	Kitting	0,02	30,67	80	0,38
11	DS73-N279A66-AD	KLT6429	Kitting	0,04	81,39	40	2,03
11	DS73-N406A76-AD	KLT6429	Kitting	0,03	58,92	20	2,95
11	DS73-R16C266-BA	FLC1210	Kitting	0,04	71,46	195	0,37
11	DG9H-18D649-AA	KLT3215	Line stocking	0,02	47,96	1500	0,03
11	DG9H-18D649-BA	KLT4315	Line stocking	0,00	3,91	2500	0,00
11	-W520111-S437	KLT3215	Line stocking	1,02	1974,46	3300	0,60
11	-W705436-S300	KLT4329	Line stocking	5,40	10479,22	4500	2,33
11	-W706010-S300	IMC060	Line stocking	1,53	2961,16	2500	1,18
11	-W706350-S300	KLT4329	Line stocking	5,84	11337,22	4500	2,52
11	-W707930-S300	KLT4329	Line stocking	5,07	9842,50	2200	4,47
11	-W709723-S303	KLT3215	Line stocking	3,55	6880,34	1000	6,88
11	-W716904-S439	KLT3215	Line stocking	0,15	299,29	700	0,43
11	-W717400-S450L	KLT3215	Line stocking	1,12	2174,62	950	2,29
11	-W717917-S300	COP	Line stocking	0,57	1111,36	0	

11	-W712231-S303	KLT3215	Line stocking	3,45	6688,05	1500	4,46
12	-TECHO-	KLT3215	Kitting			1500	
12	8V41-16C618-BE	KLT4329	Kitting	0,23	452,90	350	1,29
12	AM51-54424-AD	KLT6429	Kitting	0,93	1798,73	300	6,00
12	FG1A-7H417-MA	IMC040	Kitting	0,15	297,45	36	8,26
12	AM51-16828-AB	KLT3215	Kitting	0,46	899,37	22	40,88
12	AS43-7824694-AA	IMC100	Line stocking	3,87	7510,32	8991	0,84
12	-W505253-S450L	KLT3215	Line stocking	19,78	38368,95	2500	15,35
12	-W707119-S300	KLT3215	Line stocking	2,41	4671,53	800	5,84
12	-W707293-S439	KLT3215	Line stocking	0,30	588,15	1000	0,59
13	DS7T-15K603-AA	KLT4329	Kitting	1,51	2920,71	128	22,82
13	DS7T-15603-CA	IMC060	Kitting	0,17	327,89	130	2,52
13	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
13	8A61-A020C02-AA	CTN (carton)	Line stocking	5,50	10672,66	25000	0,43
13	-W714949-SS3JA6	KLT3215	Line stocking	0,11	210,01	1700	0,12
14	AM51-R01906-AA	FLC1210	Kitting	0,74	1435,34	176	8,16
14	6G9T-11A152-AA	COP	Kitting	0,49	958,33	0	
14	CM5T-14B006-AA	KLT4329	Kitting	2,17	4212,07	234	18,00
14	8T4T-9G854-AA	COP	Kitting	1,00	1940,00	0	
14	8T4T-9G854-AA	COP	Kitting	1,00	1940,00	0	
14	DS7T-19H320-AB	IMC030	Kitting	0,02	44,47	20	2,22
14	DS73-F01692-BC	FSC1206	Kitting	0,00	2,07	760	0,00
14	DS73-F01692-CD	FSC1206	Kitting	0,03	52,94	760	0,07
14	EM2B-R025C16-AA	KLT6429	Kitting	0,07	129,27	900	0,14
14	-W505253-S450L	KLT3215	Line stocking	19,78	38368,95	2500	15,35
14	-W505256-S439	KLT3215	Line stocking	2,11	4084,14	1500	2,72
14	-W709920-S437M	KLT3215	Line stocking	0,06	118,96	500	0,24
14	-W711215-S300	KLT4315	Line stocking	1,94	3759,05	1600	2,35
14	-W715926-S300	KLT3215	Line stocking	2,30	4469,07	1250	3,58
14	-W717345-S300	IMC040	Line stocking	0,70	1358,71	125	10,87
1	DV44-S46017-AB	KLT4315	Line stocking	0,01	10,20	80	0,13
1	DV44-S46017-BA	KLT3215	Line stocking	0,01	13,38	50	0,27
1	DS73-A02079-AC	FSC1206	Kitting	0,14	278,21	96	2,90
1	EM2B-R020A27-AC	FLC1210	Kitting	0,12	226,45	70	3,24
1	-AIRBAG-	IMC040	Kitting			70	
1	6M21-R026A76-AA	CTN (carton)	Line stocking	3,19	6180,51	6000	1,03
1	-W520822-S439	KLT3215	Line stocking	1,35	2616,63	1000	2,62
1	-W706131-S437	KLT3215	Line stocking			3000	
1	-W711215-S300	KLT4315	Line stocking	1,94	3759,05	1600	2,35
1	-W714793-S300	KLT3215	Line stocking	0,79	1524,86	1000	1,52
1	-W716076-S300	FKLT3215	Line stocking	0,29	556,41	1000	0,56
1	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51
1	-W705436-S300	KLT4329	Line stocking	5,40	10479,22	4500	2,33
1	-W706681-S439	KLT3215	Line stocking	0,05	94,31	1200	0,08
1	-W708568-S424	KLT3215	Line stocking	1,72	3338,46	600	5,56
1	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
2	CJ54-S02684-AD	KLT4315	Line stocking	1,12	2167,83	75	28,90
2	CJ54-S026A53-AA	KLT6429	Line stocking	0,46	899,37	64	14,05
2	DS73-13A601-BH	KLT6429	Kitting	0,05	102,17	25	4,09
2	DS7T-18C847-CB	KLT6415	Kitting	0,09	173,93	110	1,58
2	7CP1-18K891-CA	KLT4315	Kitting	0,09	170,75	150	1,14
2	DS73-F026A53-EA	KLT6429	Kitting	0,14	278,21	30	9,27
2	EM2B-R513C54-AD	KLT3215	Kitting	1,04	2017,40	220	9,17
2	EM2B-R026A53-AD	KLT6429	Kitting	0,02	30,82	120	0,26

2	EM2B-U026A53-AD	KLT6429	Kitting	0,01	25,88	120	0,22
2	-BACAS-	KLT3215	Kitting			120	
2	CV44-274A82-AA	COP	Line stocking	0,01	19,05	30	0,64
2	7S71-412A36-AA	COP	Line stocking	0,48	934,33	0	
2	CJ54-S50463-AG5YZ9	IMC490	Line stocking	0,05	92,28	132	0,70
2	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
2	-W703715-S437	KLT3215	Line stocking	0,80	1550,70	1800	0,86
2	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51
2	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
2	-W716025-S439	KLT3215	Line stocking	3,33	6456,72	750	8,61
2	-W716284-S300	IMC060	Line stocking	0,65	1258,23	2400	0,52
2	-W717140-S439	KLT3215	Line stocking	1,12	2167,83	1000	2,17
2	-W717376-S439	KLT3215	Line stocking	0,29	556,41	250	2,23
3	389114-S	KLT3215	Line stocking			250	
3	CJ54-S444A18-BB	KLT3215	Line stocking	0,17	336,09	80	4,20
3	CJ54-S444A19-AB	KLT4329	Line stocking	0,29	563,27	115	4,90
3	CJ54-S444A28-AC	IMC100	Line stocking	0,93	1798,73	15000	0,12
3	BE53-5402688-CA	IMC090	Kitting	0,04	71,46	720	0,10
3	DS73-A444A19-BA	KLT4315	Kitting	0,03	64,21	69	0,93
3	DS73-A444A19-AB	KLT4315	Kitting	0,02	37,95	69	0,55
3	DS73-N444A18-AC	KLT4315	Kitting	0,11	221,70	63	3,52
3	DS73-N444A19-AB	KLT4315	Kitting	0,03	58,92	81	0,73
3	EM2B-R444A18-AF	KLT4315	Kitting	0,06	114,40	80	1,43
3	EM2B-R444A19-BE	KLT4315	Kitting	0,04	77,82	120	0,65
3	EM2B-U444A18-AF	KLT4315	Kitting			50	
3	EM2B-U444A19-BD	KLT4315	Kitting	0,02	37,49	64	0,59
3	EM2B-412A36-AA	COP	Line stocking	0,14	270,04	0	
3	CV61-19E523-AA	CTN (carton)	Line stocking	0,17	336,09	5000	0,07
3	3M51-R23726-AA	CTN (carton)	Line stocking	0,04	71,46	0	
3	9V41-13K732-AA	KLT3215	Line stocking	0,04	71,46	6000	0,01
3	-W520100-S437	KLT3215	Line stocking	0,66	1282,69	5000	0,26
3	-W520111-S437	KLT3215	Line stocking	1,02	1974,46	3300	0,60
3	-W702219-S300	FKLT3215	Line stocking	0,07	128,69	200	0,64
3	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
3	-W703638-S300	KLT4329	Line stocking	0,95	1852,67	1300	1,43
3	-W711412-S300	KLT3215	Line stocking	0,07	129,46	1000	0,13
3	-W712150-S300	KLT3215	Line stocking	0,04	81,39	200	0,41
3	-W716470-S303	KLT3215	Line stocking	0,21	408,66	2000	0,20
3	-W717723-S439	FKLT3215	Line stocking	0,25	484,95	200	2,42
3	-W703283-S450B	KLT3215	Line stocking	5,14	9976,44	1000	9,98
3	-W707238-S300	KLT4315	Line stocking			130	
3	-W714115-S437	KLT3215	Line stocking	0,21	408,66	1500	0,27
3	-W714117-S300	COP	Line stocking	0,11	204,33	0	
3	-W716236-S300	IMC050	Line stocking	3,71	7194,93	5500	1,31
4	BM51-A16C266-BA	FLC1210	Line stocking	1,48	2870,69	360	7,97
4	AV6N-14A206-BB	FLC1210	Line stocking	0,12	240,87	320	0,75
4	AV6T-14A301-CB	KLT4329	Line stocking	0,12	240,87	50	4,82
4	AV6T-14A301-EC	KLT4329	Line stocking	0,12	240,87	100	2,41
4	DG9T-14A254-AC	KLT6429	Kitting	0,06	112,94	14	8,07
4	DG9T-14A254-CB	KLT6429	Kitting			22	
4	DS7T-18C847-AA	KLT6415	Kitting	0,14	272,91	110	2,48
4	7CP1-18K891-AA	KLT4315	Kitting	0,09	170,75	150	1,14
4	DS73-U313A68-AF3JA6	KLT4315	Kitting	0,25	478,74	80	5,98
4	EM2B-R46017-BD	KLT4329	Kitting	0,07	126,16	80	1,58

4	EM2B-U46017-BD	KLT4329	Kitting	0,04	82,31	80	1,03
4	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
4	6L34-1523726-BB	CTN (carton)	Line stocking	10,73	20825,80	24500	0,85
4	-W505253-S450L	KLT3215	Line stocking	19,78	38368,95	2500	15,35
4	-W708761-SS3JA6	FKLT3215	Line stocking	1,85	3597,46	625	5,76
4	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
4	-W520102-S437	KLT3215	Line stocking	1,39	2698,10	2000	1,35
4	-W702751-S437	KLT3215	Line stocking	2,44	4736,39	2000	2,37
4	-W707144-S437	KLT3215	Line stocking	0,76	1480,43	1250	1,18
4	-W710330-S439	KLT3215	Line stocking	1,21	2345,94	1300	1,80
4	-W712518-S303	KLT3215	Line stocking	1,12	2168,83	300	7,23
4	-W713158-S442	KLT3215	Line stocking	0,47	905,81	1400	0,65
4	-W717311-S437	KLT3215	Line stocking	0,08	164,16	1000	0,16
4	-W717450-S442	KLT3215	Line stocking	1,04	2017,40	500	4,03
5	DS7T-18C847-YB	KLT6415	Kitting	0,07	140,31	220	0,64
5	DS73-F025B33-EA	KLT6429	Kitting	0,14	278,21	60	4,64
5	GG93-F602B82-AA3AM	KLT6429	Kitting	0,49	954,42	21	45,45
5	EM2B-78114B44-AB	KLT6429	Kitting	0,23	452,90	500	0,91
5	EM2B-R100C05-AD	KLT6429	Kitting	0,12	226,45	11	20,59
5	EM2B-R24345-BD	KLT6429	Kitting	0,02	38,83	40	0,97
5	EM2B-R24345-CE	KLT6429	Kitting	0,12	226,45	52	4,35
5	8A61-A020C02-AA	CTN (carton)	Line stocking	5,50	10672,66	25000	0,43
5	-W520822-S439	KLT3215	Line stocking	1,35	2616,63	1000	2,62
5	-W707491-S439	KLT3215	Line stocking	0,02	36,42	1600	0,02
5	-W708761-SS3JA6	FKLT3215	Line stocking	1,85	3597,46	625	5,76
5	-W709066-S437M	KLT3215	Line stocking	0,93	1798,73	300	6,00
5	-W717345-S300	IMC040	Line stocking	0,70	1358,71	125	10,87
6	DS7T-18812-GG	KLT6429	Kitting	0,05	102,17	0	
6	BG1T-18971-CA	COP	Kitting	0,01	23,54	0	
6	DS73-A404A06-AB	KLT6429	Kitting	0,05	102,17	64	1,60
6	HG98-10B759-CA	PBX (Pallet Box)	Line stocking	0,01	18,21	1	18,21
6	7S71-412A36-AA	COP	Line stocking	0,48	934,33	0	
6	-W707491-S439	KLT3215	Line stocking	0,02	36,42	1600	0,02
6	-W505253-S450L	KLT3215	Line stocking	19,78	38368,95	2500	15,35
6	-W716298-S450	KLT3215	Line stocking	1,55	3001,07	300	10,00
6	-W716528-S300	KLT4329	Line stocking	2,22	4306,03	1750	2,46
6	-W706766-S424	KLT3215	Line stocking	0,07	129,46	5000	0,03
6	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
7	FV4T-18D273-AAC	KLT4315	Line stocking			75	
7	FV4T-18D273-ABC	KLT4315	Line stocking			150	
7	GV4T-18D273-ABB	KLT4315	Line stocking			150	
7	DS7T-18C847-AA	KLT6415	Kitting	0,14	272,91	110	2,48
7	-W500223-S450	KLT3215	Line stocking	0,01	18,21	900	0,02
7	-W504774-S303XD	KLT3215	Line stocking	1,00	1940,15	500	3,88
7	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
7	-W702751-S442	KLT3215	Line stocking	3,28	6368,32	2000	3,18
7	-W713903-S300	KLT4315	Line stocking	0,12	226,45	1500	0,15
7	-W714115-S437	KLT3215	Line stocking	0,21	408,66	1500	0,27
7	-W717491-S442	KLT3215	Line stocking	0,01	18,40	1000	0,02
8	6G9T-11A152-AA	COP	Kitting	0,49	958,33	0	
8	9L34-2L523-AA	KLT4315	Kitting	0,99	1921,79	600	3,20
8	-W520212-S440	KLT3215	Line stocking	1,04	2018,63	1000	2,02
8	-W520413-S437	KLT3215	Line stocking	5,22	10123,12	1750	5,78
8	-W705132-S439	KLT3215	Line stocking	13,66	26505,37	1000	26,51

8	-W707144-S437	KLT3215	Line stocking	0,76	1480,43	1250	1,18
8	-W708568-S424	KLT3215	Line stocking	1,72	3338,46	600	5,56
8	-W709513-S450	KLT3215	Line stocking	0,54	1045,73	750	1,39
8	-W713437-S303	KLT3215	Line stocking	5,49	10657,94	2700	3,95
9	GJ54-S404B12-AB	KLT4315	Line stocking	0,46	899,37	42	21,41
9	DG93-10723-CD	IMC197	Kitting	0,01	18,21	119	0,15
9	DS7T-10A818-AB	IMC060	Kitting	0,01	18,21	190	0,10
9	DS73-A310A27-AC	CTN (carton)	Kitting	0,07	140,31	3920	0,04
9	7S71-A40452-AB	KLT4329	Kitting			250	
9	EM2B-7827786-BA	FSC1206	Kitting	0,05	91,43	252	0,36
9	6M21-R026A76-AA	CTN (carton)	Line stocking	3,19	6180,51	6000	1,03
9	6L34-1523726-BB	CTN (carton)	Line stocking	10,73	20825,80	24500	0,85
9	-W500215-S442	FKLT3215	Line stocking	0,74	1435,34	1300	1,10
9	-W504775-S303XD	KLT3215	Line stocking	2,38	4615,44	350	13,19
9	-W700407-S300	KLT3215	Line stocking	2,92	5667,15	500	11,33
9	-W710611-S439	KLT3215	Line stocking	0,54	1050,30	1000	1,05
9	-W711712-S300	KLT4315	Line stocking	5,23	10146,19	1600	6,34
9	-W716470-S303	KLT3215	Line stocking	0,21	408,66	2000	0,20
10	GV44-13K140-AB	KLT6429	Line stocking	0,23	441,33	20	22,07
10	DV4B-17A423-AB	KLT6429	Line stocking			100	
10	7CP1-18C847-EA	KLT6429	Line stocking	0,33	644,62	275	2,34
10	7CP1-18C847-HA	KLT6429	Line stocking	0,13	254,74	275	0,93
10	FG1A-7H417-MA	IMC040	Kitting	0,15	297,45	36	8,26
10	DS7T-18C847-BB	KLT6415	Kitting	0,03	56,97	220	0,26
10	DS7T-18C847-XB	KLT6429	Kitting	0,04	83,30	275	0,30
10	6M21-R026A76-AA	CTN (carton)	Line stocking	3,19	6180,51	6000	1,03
10	6L34-1523726-BB	CTN (carton)	Line stocking	10,73	20825,80	24500	0,85
10	7S71-19E523-EA	CTN (carton)	Line stocking	4,38	8497,28	4000	2,12
10	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
10	-W505583-S442	KLT3215	Line stocking	0,06	115,24	2000	0,06
10	-W528044-S300	IMC060	Line stocking	0,47	905,81	3000	0,30
10	-W707108-S439	KLT3215	Line stocking	0,03	54,63	500	0,11
10	-W714115-S437	KLT3215	Line stocking	0,21	408,66	1500	0,27
10	-W717400-S450L	KLT3215	Line stocking	1,12	2174,62	950	2,29
11	BB53-78407A82-AA	COP	Line stocking	0,58	1126,55	0	
11	AM51-R10968-AC	KLT3215	Line stocking	0,46	899,37	100	8,99
11	GJ54-S406A77-AC	COP	Line stocking	0,17	336,09	20	16,80
11	DS73-F404B12-BC	KLT4315	Kitting	0,24	468,93	42	11,16
11	EM2B-R24345-DA	KLT6429	Kitting	0,09	168,37	400	0,42
11	EM2B-R16B990-AD	FLC1210	Kitting	0,12	226,45	144	1,57
11	-W520513-S437	KLT3215	Line stocking	0,01	18,21	1800	0,01
11	-W702807-S300	KLT4329	Line stocking	0,70	1352,58	2100	0,64
11	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
11	-W703283-S437M	KLT3215	Line stocking	5,18	10048,44	1200	8,37
11	-W706350-S300	KLT4329	Line stocking	5,84	11337,22	4500	2,52
11	-W709723-S303	KLT3215	Line stocking	3,55	6880,34	1000	6,88
11	-W716284-S300	IMC060	Line stocking	0,65	1258,23	2400	0,52
12	AM51-R10968-AC	KLT3215	Line stocking	0,46	899,37	100	8,99
12	CM5T-14B006-AA	KLT4329	Kitting	2,17	4212,07	234	18,00
12	DS73-F20709-AJ	FLC1210	Kitting	0,14	278,21	90	3,09
12	DG9T-54234B76-BA	COP	Kitting	0,29	556,41	0	
12	DS73-F404B12-BC	KLT4315	Kitting	0,24	468,93	42	11,16
12	EM2B-R20708-AF	FLC1210	Kitting			90	
12	EM2B-U20708-AF	FLC1210	Kitting	0,09	182,86	90	2,03

12	6M21-R026A76-AA	CTN (carton)	Line stocking	3,19	6180,51	6000	1,03
12	-W502674-S303	KLT3215	Line stocking	1,48	2870,69	2500	1,15
12	-W507043-S437	KLT3215	Line stocking	0,40	766,76	3000	0,26
12	-W651013-S	IMC060	Line stocking	0,04	80,51	3200	0,03
12	-W703063-S300	KLT4329	Line stocking	0,64	1235,77	500	2,47
12	-W706281-S901	KLT3215	Line stocking	0,28	541,08	1500	0,36
12	-W707491-S439	KLT3215	Line stocking	0,02	36,42	1600	0,02
12	-W712231-S303	KLT3215	Line stocking	3,45	6688,05	1500	4,46
12	-W713579-S300	KLT3215	Line stocking	0,93	1798,73	1000	1,80
12	-W714777-S300	KLT3215	Line stocking	2,03	3942,64	2000	1,97
12	-W715197-S439	KLT4329	Line stocking	11,42	22157,06	4300	5,15
13	DS73-A279A67-AC	FSC1206	Kitting	0,04	71,50	200	0,36
13	DS73-A406A77-AC	FSC1206	Kitting	0,02	30,67	80	0,38
13	DS7T-19B135-AA	COP	Kitting			0	
13	DG9T-54234B76-BA	COP	Kitting	0,29	556,41	0	
13	DS73-N279A67-AD	KLT6429	Kitting	0,04	81,39	40	2,03
13	DS73-N406A77-AD	KLT6429	Kitting	0,03	58,92	20	2,95
13	-W505253-S439	KLT3215	Line stocking	1,53	2968,67	500	5,94
13	-W714115-S437	KLT3215	Line stocking	0,21	408,66	1500	0,27
13	-W505253-S902	KLT3215	Line stocking	0,04	78,67	2500	0,03
14	AM51-R01907-AA	FLC1210	Line stocking	0,74	1435,34	176	8,16
14	8T4T-9G854-AA	COP	Kitting	1,00	1940,00	0	
14	GU5T-15604-BFD	IMC100	Kitting			18	
14	GU5T-15604-CFC	IMC100	Kitting			18	
14	GU5T-15604-DFC	IMC100	Kitting			18	
14	3M5T-14197-GA	KLT3215	Line stocking	1,52	2945,29	1800	1,64
14	-W505256-S439	KLT3215	Line stocking	2,11	4084,14	1500	2,72
14	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
14	-W703063-S300	KLT4329	Line stocking	0,64	1235,77	500	2,47
14	-W706281-S901	KLT3215	Line stocking	0,28	541,08	1500	0,36
14	-W707119-S300	KLT3215	Line stocking	2,41	4671,53	800	5,84
14	-W707491-S439	KLT3215	Line stocking	0,02	36,42	1600	0,02
14	-W709920-S437M	KLT3215	Line stocking	0,06	118,96	500	0,24
14	-W701014-S442	KLT3215	Line stocking	0,26	504,66	2000	0,25
14	-W702357-S300	KLT4315	Line stocking	2,47	4797,19	3000	1,60
14	-W702751-S442	KLT3215	Line stocking	3,28	6368,32	2000	3,18
14	-W707119-S300	KLT3215	Line stocking	2,41	4671,53	800	5,84
14	-W715926-S300	KLT3215	Line stocking	2,30	4469,07	1250	3,58