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UDK: 658.562.5 **Research paper**

Location of kit preparation – Impact on in - plant materials supply performance

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Abstract

The current paper aims to determine how the location of kit preparation affects in-plant materials supply performance. To achieve this, three different cases were identified, where principally different locations for kit preparation could be studied and compared: (1) at the assembly line, (2) in the main storage of the assembly plant, and (3) in a separate kit preparation area in-between storage and assembly line. By use of a theoretical framework, developed in the paper, an analysis is made of how the materials supply performance in the cases is linked to the location of the kit preparation.

Key words: *Kitting, location of kit preparation, in-plant materials supply*

1. INTRODUCTION

Kitting is a materials feeding principle that can be used to supply an assembly process with parts. According to Bozer and McGinnis [1], a kit is "a specific collection of components and/or subassemblies that together (i.e., in the same container) support one or more assembly operations for a given product or shop order." The operations of grouping parts together into kits can be referred to as kit preparation.

As elaborated on in section 2, it is clear that the location of the kit preparation can affect several performance areas of the in-plant materials supply, but based on existing literature, it is not clear how. Accordingly, the aim of this paper is to determine how the location of kit preparation affects in-plant materials supply performance. The paper is based on three case studies from the automotive assembly industry, in each of which kitting is used. The cases differ from each other by having three fundamentally different locations for kit preparation: (1) at the assembly line, (2) in the main storage of the assembly plant, and (3) in a separate kit preparation area in-between storage and assembly line. By use of a theoretical framework, developed in the paper, an analysis is made of how the materials supply performance in the respective cases is linked to the location of the kit preparation.

2. THEORETICAL FRAMEWORK

The current section seeks both to identify the performance areas that can be affected by which location is used for the kit preparation, and to provide a basic understanding of how these performance areas can be affected by which location is used.

As there is little existing literature available addressing how the location of kit preparation can affect in-plant materials supply performance, the section combines literature addressing the related areas of kit preparation, order picking, and location of parts storage.

As pointed out by de Koster et al. [2], the location of picking operations has a strong impact on travel distances within a facility. In the context of storage location within a warehouse, Tompkins et al. [3] state that items that have a higher frequency of deliveries from the storage than to it (because of differences in unit load size), should be positioned by the departure point of the storage, rather than by the entrance point, and vice versa.

Hales and Andersen [4] acknowledge that if storage is located close to the consuming operations, visual control over the inventory levels is facilitated, which can then eliminate the need for costly information systems. On the other hand, Battini et al. [5] state that a centralised storage can reduce storage quantities, inventory costs and space requirements by the assembly line.

Another aspect that is related to the distance between the assembly and the kit preparation area is the possibility to let the assemblers perform the kit preparation. Picking accuracy is likely to be higher when the picker is familiar with the assembly operations [6,7,8]. In the context of lean production, the importance of continuous improvement is often emphasized (e.g. [9]; [10]).It seems that continuous improvement of both assembly and materials supply operations could be facilitated by letting assemblers perform the kit preparation, as the assemblers then have an

understanding of both the kit preparation and the receiving assembly operations.
Depending on where picking operations are performed, there may be different conditions for arranging a picking area, e.g. in terms of available space [3]. If the kit preparation is performed in a location that serves other purposes too, such as in a main storage facility or at an assembly line, the freedom for arranging kit preparation may be restricted.
Another aspect of the efficiency of the kit preparation is the ability to achieve a high level of utilisation of the pickers and to maintain it when there are variations in production volumes. As described by Jane [11] and Jane and Laih [12] in the context of order picking, flexibility to handle changes in order volumes can be achieved by moving tasks between pickers working in adjacent picking zones.
With decentralised kit preparation areas, the distance between different kit preparation areas may be long and, hence, it may be difficult to achieve a high level of utilisation of the pickers without long travel distances.
In the context of parts presentation in component racks at assembly stations, Wänström and Medbo [13] find that increased space available for presenting parts increases flexibility for handling changes in production volumes, new product introductions, product modifications, and changes in product mix. In manual kit preparation, parts are often picked from component racks similar to those used to present parts at assembly stations. Hence, it is likely that the flexibility of a kit preparation area too is related to the amount of free space available.
Based on the literature described above, the current paper studies how the location of the kit preparation affects performance in the following seven performance areas: 1) the amount of transportation required, 2) the inventory levels and space requirements, 3) the potential for visual control of the kit preparation and of the delivery of kits 4) the flexibility in relation to the demands of the assembly, 5) the efficiency of the kit preparation, 6) the quality of the kits and the responsiveness to quality deficiencies, 7) and the ability of continuous improvement.

3. METHOD

Three different cases were identified, where principally different locations for kit preparation could be studied and compared. The three cases were from three different assembly plants, each from a different OEM within automotive industry. Each of the case studies focuses on the in-plant materials supply supporting the assembly operations within a limited section of the respective assembly plant. In all of the assembly plants, production was performed according to build-to-order principles. The products were relatively standardised in terms of their basic architecture, but there was a large amount of different part numbers that could be assembled into different product variants.
The three cases differed from each other by having three fundamentally different locations for kit preparation: (1) at the assembly line, (2) in the main storage of the assembly plant, and (3) in a separate kit preparation area in-between storage and assembly line.

4. CASE DESCRIPTIONS

The current section presents the empirical data from the three cases that were studied. For each case, a general description is provided, followed by a description of the performance in each of the seven performance areas identified in section 2.

4.1 **Case 1**

Case 1 comprises the materials supply supporting the assembly of instrument panels within an automotive assembly plant.
The kits were prepared in a kit preparation area located close to the assembly line, but not in direct association with it. Hence, transportation was needed between the kit preparation area and the assembly line.
Assembly and in-plant materials supply were divided into two different organisational units within the case company. In the current case, the materials supply unit was responsible for all in-plant storage and transportation, including the transportation of kits and empty kit containers between the kit preparation area and the assembly line. The assembly unit, instead, was responsible for performing the assembly at the assembly line, as well as for preparing the kits.
The vast majority (approximately 90%) of the part numbers included in the kits were delivered to the kit preparation area from a large central storage within the plant. A few other part numbers were delivered from small, decentralised storage areas located relatively close to the kit preparation area. Yet another few part numbers, for which the consumption rate was very low, were instead delivered to the kit preparation area directly from goods reception, without passing through any storage.

4.1.1 *Amount of transportation in case 1*

Space utilisation within the kit containers was much lower than in the part number specific containers delivered to the kit preparation area. Therefore, the transport frequency was much higher from the kit preparation area than to it.

4.1.2 *Inventory levels and space requirements in case 1*

Within the company, inventory levels were decided based on a number of aspects, such as frequency of use and distance to suppliers, but were not affected by the storage or materials handling principles within the plant. Accordingly, the inventory levels were not related to the location of the kit preparation.

4.1.3 *Potential for visual control in case 1*

The kit preparation area and the assembly line were located close enough to enable visual contact. Yet, visual control was not used for initiating delivery of kitsfrom the kit preparation area, but these deliveries were instead initiated in regular intervals, linked to the cycle time at the assembly line. However, visual control helped ensuring that the kit preparation followed the

same pace as the assembly and that the kit preparation stopped if the assembly line did, so that no unnecessary buffers were built up.

4.1.4 *Flexibility in case 1*

At the kit preparation area, there was relatively much space available, which meant that there was a relatively large freedom to design the kit preparation area in terms of size and dimensions. It was possible to vary the size of the kit preparation area depending on the number of part numbers that needed to be displayed. This enabled a flexibility to accommodate changes in product mix and production volume.

4.1.5 *Efficiency of the kit preparation in case 1*

A large area was available for the kit preparation, which meant that there was a freedom to design the kit preparation area according to the wishes of the case company. In order to achieve time efficient kit preparation, the company tried to place the different part numbers in the kit preparation area so that the walking distances associated with preparing each kit could be minimised. The kit preparation area was, however, located in relative isolation compared with the other kit preparation and picking areas within the plant. The company experienced difficulties achieving a high level of utilisation of the two operators in the kit preparation area and to maintain this level of utilisation when production volumes changed.

4.1.6 *Quality in the kit preparation in case 1*

The kit preparation was associated with some quality deficiencies, where the wrong parts were picked into the kits and delivered to the assembly line. When faulty parts were discovered at the assembly line, it was possible to replace them quickly, because of the short distance between the assembly line and the kit preparation area. The replacing of a part normally took between 1 and 2 minutes.

4.1.7 *Ability of continuous improvement in case 1*

The case company worked systematically with continuous improvements within the assembly plant. Accordingly, based on comments and suggestions from the operators, the company was continuously trying to improve the materials supply by kitting, for example by making adjustments to the kit contents, to the kit preparation and to the presentation of the kits at the assembly line. In this improvement work, company representatives reported that there were obvious benefits associated with having the kit preparation and the assembly being performed within the same organisational unit of the company. Originally, when the assemblers from the assembly line were themselves responsible for preparing the kits, the improvement work was stated to have run even better, as the assemblers then possessed profound knowledge both of the kit preparation and of the assembly, thus making it easier to foresee and evaluate the full consequences of changes made either at the kit preparation area or at the assembly line.

4.2 **Case 2**

Case 2 is from a truck cab assembly plant and focuses on the materials supply supporting two assembly stations at an assembly line

The preparation of the kits was performed by assemblers from the assembly line. With regular intervals of 30 minutes, the assemblers rotated between different work stations and in this rotation, the kit preparation area was included as one work station. (However, in order to distinguish between the assembly work and the kit preparation work in the current text, the term “assembler” is used only to denote those workers occupied at the actual assembly stations.)

The kits were prepared in direct association with the assembly line, meaning that no transportation was necessary to relay the kits between the kit preparation area and the receiving assembly stations. When a kit had been prepared, the operator in the kit preparation area placed it in a small buffer, from which the assembler at the assembly line could easily fetch it when it was needed. As there was normally a buffer of finished kits, the kit preparation was to some extent decoupled from the assembly. Hence, unlike at the assembly stations, the cycle time in the kit preparation could vary to some extent.

Within the assembly plant, there were three principally different materials flows supplying the kit preparation area. From the goods reception at the assembly plant to the kit preparation area, parts were supplied either via an AS/RS, via a decentralised storage, or via both the AS/RS and a decentralised storage.

4.2.1 *Amount of transportation in case study 2*

To the kit preparation area, parts were transported either from the AS/RS or from decentralised storage areas within the assembly plant, as described before. However, from the kit preparation area, no actual transportation was required. As described before, each kit that had been prepared was placed in a small buffer situated right between the kit preparation area and the receiving assembly station, where the kit was within reach of the assembler at that station.

4.2.2 *Inventory levels and space requirements in case 2*

According to the company, the overall inventory levels within the plant were not significantly affected by the location of the kit preparation. Had the kit preparation been performed in a location further away from the assembly line, the company would have increased the number of finished kits slightly, but the inventory levels within other parts of the materials flows would not have been affected. Accordingly, since the inventory kept in kits constituted a very small part of the overall inventory levels, the overall effects on inventory levels would have been negligible.

4.2.3 *Potential for visual control in case 2*

As the kit preparation area was located in direct association with the assembly line, there was a clear visual contact between the two. This visual contact was

utilised for controlling the pace of the kit preparation. Between the kit preparation area and each of the two assembly stations, there was only limited space for the operator in the kit preparation area to place finished kits in and for the assembler to place empty kit containers in.

4.2.4 *Flexibility in case 2*

The kit preparation area had limitations in terms of flexibility for handling changes in production volumes and flexibility for handling a large number of part variants. It was not possible to expand the kit preparation area, as it was limited by the length of the two assembly stations it served. Accordingly, if a need were to arise for presenting a larger amount of part numbers at the kit preparation area, this could be difficult to achieve.

4.2.5 *Efficiency of the kit preparation in case 2*

The possibilities for arranging component racks for parts presentation in the kit preparation area were somewhat restricted. As the kit preparation area was located along the assembly line, it was only possible to supply one side of the kit preparation area with parts and, accordingly, parts were mainly presented on one side of the kit preparation area. This to some extent reduced the density of the parts presentation and, hence, increased the average distance for fetching each part during the kit preparation.
At the two assembly stations, a number of sub-assembly tasks were possible to perform off-line. Accordingly, as production volumes changed, sub-assembly tasks could be transferred between the assembly line and the kit preparation area to achieve a balance of the workload between these two areas. This way, it was possible to achieve a relatively high and even utilisation of both the assemblers at the assembly line and the operator in the kit preparation area.

4.2.6 *Quality in the kit preparation in case 2*

Quality problems, in terms of the wrong parts being picked, sometimes occurred. When these quality problems occurred, they were generally discovered at the assembly line, before the parts in question were assembled, and could accordingly be rectified immediately. As the kit preparation area was located right by the assembly, the time required for replacing a part that was faulty was very short.

4.2.7 *Ability of continuous improvement in case 2*

Working with continuous improvements was an established practice within the company and the operators were themselves to a large extent responsible for arranging their work stations and their work processes. In relation to the kit preparation and assembly in focus in the current case study, both operators and other company representatives reported that the work with achieving continuous improvements was running very smoothly. Since the same operators were responsible for both assembly and kit preparation, it was found to be relatively easy to find solutions that were satisfactory in both places.

4.3 **Case study 3**

Case 3 is from an automobile assembly plant and describes the materials supply supporting a number of successive assembly stations in the general assembly plant.
The kits were prepared in a large storage, consisting of two sections, located in the same facility as the assembly line, but at a distance of approximately 400 metres from the assembly station where the kits were delivered.
One of the two storage sections was for parts stored on large pallets, whereas the other section was for parts stored in smaller plastic containers. The pallet section of the storage was replenished by forklifts, fetching parts from the goods reception of the plant. The storage section for plastic containers was instead served by an AS/RS, automatically supplying containers to the kit preparation area. Operators from the materials handling division of the company were responsible for preparing and delivering the kits to the assembly line. The kits were prepared and transported to the assembly line in batches of 12. After having prepared and delivered a batch of 12 kits, the operators would rotate to another type of kit.

4.3.1 *Amount of transportation in case 3*

Each kit contained much fewer parts than an average part number specific container (both compared to pallets and plastic containers) held in the storage. As described before, the kits were transported from the storage, where they were prepared, to the assembly line in batches of 12. Within the case company, the long distance between storage and the assembly line was perceived as a problem, as it made the transportation of kits very time consuming.

4.3.2 *Inventory levels in case 3*

According to the company, the inventory levels would not have been significantly affected if the location of the kit preparation had changed. If a kit preparation area had been set up close to the assembly line, this would most likely have added a process step and also the increased the inventory levels, but only marginally. The overall inventory levels were based mainly on aspects related to the inbound deliveries to the plant, rather than on storage cost or in-plant materials handling.

4.3.3 *Potential for visual control in case 3*

Because of the large distance between the assembly line and the storage area, no direct visual contact was possible. Only upon delivery could the operator performing the kit preparation get a view of the situation at the assembly line. As a result, it frequently occurred that delivery to the assembly line was made too soon, which then resulted in the buffers at the assembly line being overfull and kits being placed on the floor instead of in the component racks where they were meant to be. This, in turn, resulted in risks both of the parts on the floor being damaged and of the sequence of kits being broken.

4.3.4 *Flexibility in case 3*

In the storage area, there was enough space available to allow for a considerable flexibility to handle changes in production volumes and product mix. The capacity of the AS/RS constituted a certain restriction to the amount of different part numbers that could be handled, but compared to the existing amount of part numbers, the AS/RS had a considerable over-capacity.

4.3.5 *Efficiency of the kit preparation in case 3*

In the kit preparation, the average distance between the different part numbers to be included in each kit was relatively long. This was partly due to the use of large pallets to present a large amount of the different part numbers. Different part numbers can generally be presented much more space efficiently in smaller containers, compared to on pallets: several containers can be presented in the same amount of space as one pallet. The other main reason why the average distance between different parts was long was that a long distance had to be traversed between the section of the storage where pallets were stored and the section where the plastic containers were stored.
In total, 6 operators worked in parallel preparing different types of kits within the plant. (In total, 20 different types of kits were prepared and delivered to different sections of the assembly plant.) Within the company, it was found to be relatively easy to achieve a high utilisation of each of the operators, and to maintain it when production volumes changed.

4.3.6 *Quality in case 3*

As in the other cases, it sometimes occurred that the wrong parts were picked into the kits. Normally, these mistakes were discovered at the assembly line, before the parts were assembled. In order to replace a faulty part, the assembler reported the problem, either in a computer system or by telephone. Normally within 5-8 minutes (and, according to company guidelines, within a maximum of 15 minutes), the faulty part was then replaced by a new part from the storage area. Replacement of faulty parts was not performed by assemblers or operators responsible for preparation and delivery of kits, but by separate support staff.

4.3.7 *Ability of continuous improvement in case 3*

The company was working systematically with continuous improvements, where the operators of both the assembly and the materials supply divisions of the company contributed regularly. When suggested changes would affect both the assembly and the materials supply divisions within the company, there were sometimes difficulties getting all parties to agree on a solution.

5. ANALYSIS

The current section provides a cross-case analysis linking the performance of the in-plant materials supply in the different cases to the location of the kit preparation. Using the theoretical framework as a basis, each of the seven performance areas identified there is analysed.

5.1 **Amount of transportation**

In all three cases studied, the kits contained on average fewer parts than the part number specific unit loads in the respective kit preparation area. As found in the theoretical framework, this then indicates that the amount of transportation could be lower the closer the kit preparation area is to the assembly line. A further aspect that should be considered is that having a separate kit preparation area between storage and assembly line results in an extra transportation of each part, compared to when the kit preparation is performed either in the storage area or in direct association with the assembly line.

5.2 **Inventory levels and space requirements**

In all three cases, it seems that the location of the kit preparation does not have any significant impact on the overall inventory levels within the respective plant. In the cases, overall inventory levels were based mainly on other aspects than in-plant materials handling and storage cost. However, it seems that the space requirements for preparing the kits can differ. In case 3, where kits were prepared in storage, no more space was consumed than had the parts been supplied to the assembly line without first being kitted (e.g. had they been supplied by continuous supply instead of kitting). In cases 1 and 2, instead, the kit preparation required an area in addition to the area in the main storage.

5.**3 Potential for visual control**

As indicated in the theoretical framework, the distance between the kit preparation and the receiving assembly station affects the potential for visual control over the inventory levels. In cases 1 and 2, where kit preparation was performed close to the assembly line, visual control was used to regulate the pace of the kit preparation in relation to the pace of the assembly operations. In case 3, where the distance was much longer and made visual control impossible, it often occurred that kits were delivered to the assembly line before they were due, which then resulted in problems with overfull buffers.

5.4 **Flexibility**

As indicated in the theoretical framework, the flexibility in terms of variations in production volumes and product mix was in the cases found related to the space available for expanding the kit preparation area. In case 2, where the kit preparation area was located in direct association with the two assembly stations it was supplying, the possibilities to expand the kit preparation area were limited, as the size of the area was strongly linked to the size of the assembly stations. In cases 1 and 3, instead, there was a higher flexibility for expanding the area used for kit preparation.

5.5 **Efficiency of the kit preparation**

The efficiency of kit preparation is dependent on a large number of aspects that are not directly linked to the location of the kit preparation. A general differences could, however, be discerned in relation to the level of

freedom to design the kit preparation area to support efficient kit preparation. In case 1, where the kit preparation was performed in a separate area, not linked to either storage or assembly line, there was a relatively large freedom to design the kit preparation area. In cases 2 and 3, where the assembly line and the storage layout, respectively, had to be considered, the freedom to design the kit preparation area was more restricted.

As indicated in the theoretical framework, for decentralised picking areas, there could be difficulties achieving and maintaining a high level of utilisation of the operators in the kit preparation area when production volumes changed. This was, to some extent, confirmed by the cases. In case 1, where kit preparation was performed in a decentralised location, between storage and assembly line, there were indeed difficulties achieving a high level of utilisation of the operators, whereas in case 3, where kit preparation was performed in a central storage, it was easier to balance the workload between different operators. However, in case 2, where kit preparation was performed in direct association with the assembly line, the potential difficulties were counteracted as subassembly tasks, that were possible to perform off-line, were transferred back and forth between the assembly line and the kit preparation area when production volumes changed, thereby increasing flexibility.

5.6 **Quality**

Like the efficiency of the kit preparation, the quality of the kit preparation depends on a large number of aspects in addition to the location of the kit preparation. A difference between the cases could, however, be identified in relation to the ability to respond to quality deficiencies and replace faulty parts. In cases 1 and 2, where the kit preparation was performed close to the assembly line, the replacing of a part was much quicker than in case 3, where the kit preparation was performed in a storage area further away from the assembly line.

5.7 **Ability of continuous improvement**

The findings from the three cases support the notion that continuous improvements are easier to achieve when the same operators are responsible for both assembly and kit preparation. Based on the cases, it seems that continuous improvement work can be facilitated both by the fact that the operators then have an understanding of both assembly and kit preparation, and by having potential changes and reorganisations taking place within the same organisational unit of the company.

6. DISCUSSION AND CONCLUSIONS

Based on the findings of the paper, it is clear that the location of the kit preparation affects several performance areas of the in-plant materials supply. Each of the three different locations for kit preparation studied in the paper was associated with both benefits and drawbacks. Within industry, these benefits and drawbacks need to be taken into consideration when decisions are made regarding where the kit preparation should be performed.

It should be acknowledged that each of the studied cases is part of a larger system and that it can be difficult to link the performance within the cases directly to the location of the kit preparation. For example, as noted in section 5, the efficiency of the kit preparation (for example in terms of average picking time per part) is dependent on a large number of aspects, of which the location of the kit preparation is but one. Nevertheless, the level of detail with which the three cases were studied, and the theoretical framework upon which the analysis was based, made it possible to discern general differences related to the location of the kit preparation.

Some aspects of performance were difficult to study fully, based on the three cases available and could be subject to further studies. Among these aspects are the quality of the kit preparation and the inventory levels. Furthermore, the paper has only considered potential locations of kit preparation within the assembly plant. It is possible to perform kit preparation in locations outside the plant, such as at a supplier or in an off-site warehouse. The use of locations like these could be studied in future research.

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Lokacija za pripremu kita za montažu – Uticaj na performanse snabdevanja materijalom unutar pogona

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Rezime

Ovaj rad teži da utvrdi kako lokacija pripreme kita za montažu utiče na performanse snabdevanja materijalom unutar pogona. Da bi se to postiglo, identifikovana su tri različita slučaja, gde u osnovi različite lokacije za pripremu kita mogu da se prouče i uporede: (1) na montažnoj traci, (2) u glavnom skladištu pogona za montažu, i (3) u posebnom prostoru za pripremu kita između skladišta i montažne trake. Uz pomoć teorijskog okvira koji je razvijen u radu, napravljena je analiza kako su performanse snabdevanja materijalom u ovim slučajevima povezane sa lokacijom pripreme kita.

Ključne reči: *Oprema, lokacija za pripremu kita za montažu, snabdevanje materijalom unutar pogona*