Redesigning the material flow – from receival to assembly

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The high competitiveness and aim to stay ahead of competitors require companies to streamline their value-chain. One of the primary activities of the value-chain is inbound logistics which includes the material flows of a company. Material handling is a part of the material flow and can, for a significant number of manufacturers, account for more than half of the total cost of manufacturing.

**Introduction**
This study is done in collaboration with Haldex Brake Products AB in Landskrona, Sweden and the Faculty of Engineering in Lund, Sweden. Haldex is a world-leading supplier of disc brakes for heavy vehicles. Haldex is expanding and the volumes of disc brakes as well. The material flows are becoming more complex and the need to restructure the material flow resulted in this study.

**Purpose**
The purpose of this study is to identify and evaluate different solutions to feed the assembly lines with materials and to develop as well as implement the most promising one. The solution should improve the ergonomics, the space utilisation in the plant and reduce costs associated with the material flow.

**Methodology**
The purpose of the study is identified as problem-solving. The issue is a real and substantial problem that requires a solution which leads to the conclusion that an action research is best suited as research strategy. A thorough literature review is performed to gather frameworks and important theories relevant to the study. Important concepts are line feeding policies, lean manufacturing and ergonomics. The data is collected using methods such as observations, measurements and unstructured interviews.

**Theoretical framework**
Three line feeding policies are presented: kitting, line stocking, and downsizing. The benefits of implementing kitting are better space utilisation and improved ergonomics. The kitting process is done in a supermarket and the space around the assembly lines is freed up. The ergonomics are improved as a consequence of using smaller unit loads containing less volume. However, implementing kitting increases handling costs significantly.

Line stocking is a line feeding policy where materials are fed to the assembly lines in pallets. The main advantage is the minimal material handling which makes line stocking a very effective line feeding policy. The disadvantage of using pallets is the large space requirements. Line stocking results in occupied space next to the assembly lines which should only be devoted to production and not storage.

The last alternative, downsizing, inherits benefits from the earlier line feeding policies. Downsizing means that materials are repackaged from pallets to smaller unit loads. There is no need for storage at the assembly lines and the use of small unit loads improves ergonomics. The repackaging process can be more costly than using line stocking, however, it is cheaper and more effective than kitting.

Lean manufacturing is an important part of the study. Lean manufacturing minimises waste while increase productivity. Concepts such as milk runs, Kanban, and 5S are used to bring forward a lean solution.
Empirical research
Haldex produces approximately 400,000 disc brakes per year. The brakes are produced in several models but with minor variety. Over 90% of the components are identical. The three assembly lines studied have a combined output of 1200 brakes per shift. The component consumption is distributed according to table 1 below.

<table>
<thead>
<tr>
<th>Assembly line</th>
<th>Comp./hr</th>
<th>Comp./shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tellus</td>
<td>3 180</td>
<td>25 440</td>
</tr>
<tr>
<td>Uranus</td>
<td>2 820</td>
<td>22 560</td>
</tr>
<tr>
<td>Saturnus</td>
<td>1 550</td>
<td>12 400</td>
</tr>
<tr>
<td>TOTAL</td>
<td>7 550</td>
<td>60 400</td>
</tr>
</tbody>
</table>

Table 1: Consumption of components

Haldex uses line stocking and downsizing as line feeding policies. Some components are fed according to line stocking while the remaining are downsized. The downsizing process is performed at the border of the line, i.e. next to the assembly lines.

This arrangement results in large space requirements in the production area. 54 m² of pallet racks holding small components are currently occupying the production area. Same components are stored in two locations. The storage is decentralised and there is a lot of truck and employee movement which increases the risk for accidents. The arrangement does also result in non-ergonomic motions for the line feeder. Long walking distances are performed. Heavy materials are lifted manually, low placed pallets require non-ergonomic waist bending, and high placed pallets are very demanding when picking materials.

The manual material handling activities today includes unpacking and repacking materials, carrying, and loading materials. The research shows that over 60% of the time spent on manual material handling was spent on unpacking and repacking materials. The materials received in bulk are time-consuming and non-ergonomic.

The suppliers use a lot of packaging material such as bags, tape, and cartons for the materials received in boxes. The amount of packaging material and the way the components are packed increases the time spent on handling the specific components.

![Time distribution](Figure 1: Diagram of time distribution)

Analysis
The choice of line feeding policy (LFP) in this study is one of the primary objectives. Earlier studies comparing LFPs suggests that kitting is not suitable in a high-volume production facility with low variety. The number of kits that are needed to cover one shift (eight hours) is the same as the amount of brakes produced per shift, namely, 1200 kits. These kits will add up to 60 400 components per shift that have to be picked manually, more specifically, 126 components per minute. The benefits that kitting offers such as eliminating the need of a stock around the assembly line and the flexibility of using small bins does not offer enough benefits and profit to weigh up the material handling costs associated with kitting.

Line stocking as a LFP is most suitable when the volumes are high and variety low. The material handling is minimal, and the use of original unit load is very effective. However, while it is a suitable solution, it is also contradictory. One of the aims of the study is to free up space around the assembly line. Furthermore, line stocking is the least ergonomic LFP.
The third alternative considered is downsizing. Downsizing inherits two important advantages from the other two LFPs; the removal of stock around the assembly lines and the flexibility of having smaller bins. The implementation of downsizing requires a supermarket for storing the component. Having a compact supermarket will eliminate the excessive walking done by the material feeder today.

The removal of the pallet racks around the assembly lines will create space for improved flexibility and possibilities for increased capacity. The total floor space occupied by pallet racks and stands in the assembly hall is 66.2 m². Moving the pallet racks holding small components will decrease the total storage area by 81.5%. A key factor is the elimination of double storage which reduces the total storage needed and facilitates Haldex FIFO-principle.

Figure 2: Production area before and after the removal of pallet racks

Figure 2 visualises how the assembly hall will look after the removal of the pallet racks holding the small components. The decentralised racks holding the larger components can be centralised between the two large assembly lines. The stock of small components will be moved to a non-utilised area. The proposed design has a capacity of 21 racks which is far more than required. The supermarket holds all components stored at the assembly lines, furthermore, it increases the total storage capacity of the plant. The designed supermarket has three isles, all of them meeting the width requirements applied by Haldex.

The advantages of having the supermarket place in this location are many. Firstly, it is placed in a strategic position, in the centre of the plant. It connects all the other halls and all traffic goes through hall E. Secondly, it reduces a non-value adding activity, the replenishment from the central warehouse to the pallet racks in the assembly hall that is performed today 837 times per month. Having only one concentrated stock for the small components improve the FIFO-principle in the plant. The supermarket will improve the storage and traceability by having correct addresses and control.

The implementation of downsizing as LFP and the supermarket eliminates the stock of components next to the assembly lines. As a consequence, the need of an in-plant material supply system emerges. One of the research questions is how to improve and making the manufacturing process leaner. One part of lean manufacturing is the use of milk runs for material supply.

Determining the frequency of milk runs is a trade-off between train capacity and number of runs. The layout of the plant and the assembly lines limits the number of trolleys to a maximum of three. The trolleys used in the study measures 1200 mm in length and 700 mm in width. The area of each shelf is calculated to 0.84 m². With ten shelves in total, the total area of the trolleys is 8.4 m².

The calculations are divided in two parts, one for Tellus and Uranus, one for Saturnus. The output is changed to 500
brakes for Tellus and Uranus while Saturnus has been decreased to 200 to get an even number and to have the same consumption for Tellus and Uranus. Having the same consumption for the two large lines gives the ability to just split the total consumption on two.

Firstly, the number of bins per shift is calculated using equation 1 for each component.

\[
No. \text{ of unit loads} = \text{Round up} \left( \frac{\text{Consumption per shift}}{\text{Quantity per unit load}} \right)
\]

Equation 1: No. of unit loads per shift

Equation 1 is used to calculate the number of unit loads for Tellus and Uranus combined and Saturnus separately.

Equation 2 below is used to calculate the number of unit loads of each component needed for each run.

\[
\text{Unit loads per run} = \text{Round up} \left( \frac{\text{No. of unit loads}}{\text{No. of runs}} \right)
\]

Equation 2: Unit loads per run

A proposal is to have a run frequency of one hour. According to equation 2, the number of unit loads per run decreases as the number of runs increases. One-hour frequency means that eight milk runs are performed per shift. This results in 118 unit loads with a total area of 6,52 m². The total area is less than the area of the three trolleys.

The unit loads placed on the trolleys have a fixed place. A two-bin Kanban system is implemented. Components 94807 and 94808 will be continuously fed every hour while the other components’ replenishment is controlled by the two-bin Kanban system. An empty bin means that the specific component needs replenishment, and the empty bin is placed on the trolley. The unit loads have a fixed spot on the trolleys for easy and visual guidance. An empty bin of a component means that the specific component needs replenishment.

The creation of a supermarket and a leaner manufacturing will improve ergonomics. Since the storage capacity is increased, it will be possible to move components that are stored in less accessible compartments to more ergonomic compartments. Lifting mechanism for the heaviest components should be installed. The amount of motion done by the line feeder per shift will decrease significantly. The materials will be transported by train which improves the ergonomics of the line feeder. The supermarket will improve the organisation and traceability of components. The FIFO-principle will be actualised, and the components will be easy to trace. Using 5S in the supermarket and the new material flow will make the manufacturing leaner.

The first S, Sort, is implemented by sorting all pallets and removing all unnecessary items from the supermarket. The second S, Straighten, is implemented by putting all necessary pallets in the optimal place for fulfilling their function in the workplace. The third S, Shine, is achieved by cleaning and inspecting the workplace on a regular basis. Containers for different types of waste should be placed in the supermarket. The first three S are improved and strengthened by the two final S, Standardise and Sustain. The routines and rules implemented have to established and sustained by using schedules, audits and training.

**Conclusions**

Redesigning the material flow of small components will require investments in new equipment, time for adaption as well as establishment of routines and procedures. However, the proposed solution will offer benefits and the possibilities it brings along are many. The proposed solution creates a foundation that can be built upon and developed to create a more effective and leaner manufacturing for Haldex.
The most time-consuming activity is handling the components and since it will not be improved in the near future it can be concluded that the labour force will remain the same in line feeding. However, the labour force required from the central warehouse will be decreased as a result of the decreased distance and need for replenishment.

The advantages of implementing the proposed solution are mainly in space utilisation. It will result in a removal of the pallet racks in the assembly hall which will free up valuable space that will most likely be used for expanding the production capacity. The pallet racks from the assembly hall will make part of a new supermarket placed in a non-utilised area. The creation of the supermarket will reduce the transports from the central warehouse significantly and increase the total storage capacity of the plant. The supermarket will have the requisitions needed for creating an ergonomic workplace. There is space for lifting devices and raiseable stands for heavy components. The large storage capacity increases the number of compartments which results in more organised placement of pallets and therefore more ergonomic picking.

The supermarket creates a centralised and compact stock compared to the layout today which reduces the walking done by the line feeder substantially. The implementation of 5S in the material flow contributes to making the manufacturing leaner. The supermarket will be an important part of the lean manufacturing. Implementing 5S in the supermarket creates a cleaner, sorted and organised workplace. A waste handling area should be created for sorting and handling waste picked up during the milk runs.

It is concluded that the milk runs will have a one-hour frequency to minimise the train size and the amount of materials transported in one run. Haldex handles a lot of materials per shift which led to the conclusion that a run every hour will be the optimal solution considering the current layout. The milk runs will also contribute to making the manufacturing leaner by pulling materials according to FIFO and improve the traceability.

**References**

Gashi, K. (2019). *Redesigning the material flow - from receival to assembly*