Application of Lean Methodologies in the Improvement of an Automotive Supplier's Operation

The SMP Portugal Case Study

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Abstract: The Portuguese automotive industry is part of a globalized industry, with a complex value chain, from both an organizational and technological point of view. There is an important component supplier industry in Portugal, which is subjected to a strong supplier competition. This leads to finding more efficient ways of operating. In this sense, lean manufacturing plays an important role in reaching the desired goal. This methodology, developed through its application in the automotive industry, is one of the most used in improving production processes.

The present work focuses on Samvardhana Motherson Peguform, in Portugal (SMP), an automotive component supplier for Autoeuropa (AE), and its need to increase its efficiency through the implementation of the lean methodology. SMP's operation works according to strict specifications, demanding a high degree of coordination between their operational areas, and a constant need to assure the value chain flows efficiently, since they work Just-in-Time.

The study of SMP's operations using lean methodologies, led to the design of three value stream mappings (VSM), of the bumper, the frontend, and the door panel production lines. The use of lean tools and the analysis of the current VSM's led to the identification of improvement opportunities which were, later, implemented in the design of the future VSM's. The analysed results revealed improvements in the lead time and in the decrease of inventory costs.

Keywords: Lean Manufacturing; Value Stream Mapping; Automotive Industry; Supplier Industry; Just-in-Time.

1. Introduction

The automobile industry is one of the most important industrial activities in the world, linking many industrial sectors (Inteli, 2005). It was in the automobile industry where the great eras of industrial development were reflected. From mass production to lean production, not forgetting the origin of manufacturing and practices such as total quality management (Womack, Jones, & Roos, 1990). Nowadays the automobile is a product from a global industry with a structured value chain and has become a necessity in the running of the day-to-day lives in most communities.

Given recent increases in global competition, scarce resources, and fluctuating economies, it is not surprising that lean production has become critical to long-term survival of today's manufacturing organizations (Scherrer-Rathje, Boyle, & Deflorin, 2009). In this sense Samvardhana Motherson Peguform (SMP), a supplier for components in the automobile industry, decided on creating lean departments in all their factories globally and are developing the Peguform Production System (PPS).

This work intends to support SMP in Portugal through the use of lean methodologies, by identifying its value added activities and eliminating waste along the value chain of their three main production lines, namely, the bumpers, the frontend and door panel production lines. For this purpose an internship was carried out during a period of 4 months.

1.1. Introduction to SMP Portugal

SMP is a leading specialist for automotive exterior and interior modules in the automotive industry. The company supplies plastic components to customers across the globe, as well as complete systems and modules for the interior and exterior of vehicles, such as door panels, cockpits, bumpers and spoilers. Their main clients are Audi, VW and BMW. The company is present in Europe, Asia and South America having over 7000 employees worldwide (SMP, 2013, 2014).

The modules assembled by SMP for AE are presented in Figure 1 with indication of the car model they are produced for, on the left. The modules are assembled from a set of auto components, some of them produced by SMP.

The modules are described in more detail below:

- The front and rear bumpers are, respectively, the front-most and rear-most part of a car. They are designed to mitigate damage to the car structure in case of an accident.
- The frontend module is located in the front part of the car and is composed by many auto components. The Kum is the central metallic structure of the frontend, on which the rest of the components are assembled.
- The door panel is the plastic panel attached to the interior part of the car structure which

holds electric components, such as, speakers and window switches. It also has an aesthetic function.

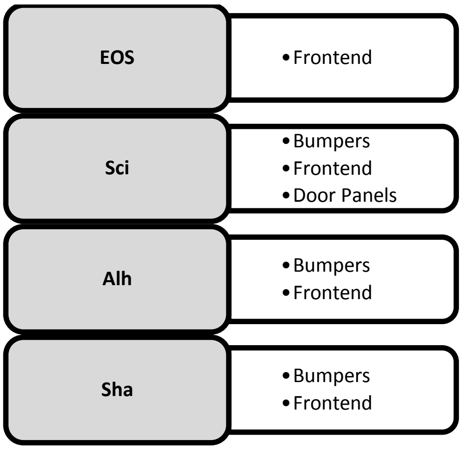

Figure 1 - Components produced for each model by SMP

1.2. Plant Overview

This section describes the production areas and the operational functions in the SMP plant. The layout of the plant is shown in Figure 2 in order to visualise each area more clearly. The description of the areas is structured in the following sequence: injection moulding area (shown in blue), painting area (marked in red), and finally the assembly area (in green) which is divided in three assembly lines. Each area is described in more detail as follows. Note that all areas work according to AE's production and if AE has a down day the production areas will also have a down day.

Injection Moulding Area

The injection area works continuously 5 days a week, 3 shifts per day. M1, M2, M3 refer to moulding machines used to produce different parts.

The moulding area also has machines for the punching of the Sci bumpers (M4) and a machine used for the pre-assembly of the Sci frontend Kum (M5). There is also a storage area for all the raw material (RM) received for the production of the modules, and a storage area for the moulded bumpers, Kums, spoilers and diffusers[1] (Racks).

[1] The spoilers and diffusers are air dams for the front and rear bumpers, respectively.

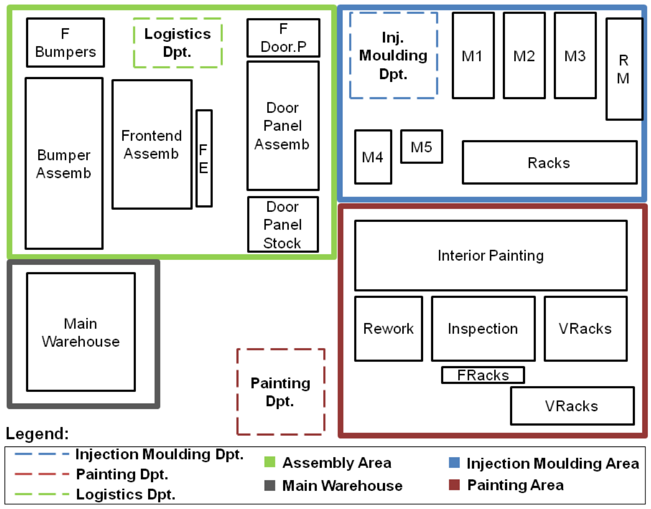

Figure 2 - Layout of the SMP plant

Painting Area

The modules painted in SMP are bumpers and other smaller components, such as sensors. The painting area works continuously 5 days a week, 3 shifts per day. It is divided into two separate areas:

- The interior area, also called the black box, containing 26 painting circuits which differ in the capacity of paint each circuit holds;
- The exterior has an inspection area where the bumpers are inspected after exiting the black box and a rework area where immediate work is done on bumpers with painting defects. There is also a storage area for bumpers incoming from the injection area to be painted (VRacks).

After the bumpers are inspected and placed in racks (FRacks) a forklift truck takes the full racks (each can take 6 to 9 bumpers) to the main warehouse located before the bumper assembly area.

Assembly Area

The assembly area is divided into three distinct areas. Each area works 5 days a week, 2 shifts a day. There is an assembly area for the bumpers, another for the frontends and a smaller assembly area for the door panels.

2. Value Stream Mapping

A value stream consists of all the steps from the suppliers to the final product including the non-value added activities. It provides a pictorial view of what elements of the process are value-added and the customer is willing to pay for (Tapping & Shuker, 2003). Rother and Shook (1999) defined VSM as a powerful tool that not only highlights process inefficiencies, transactional and communication mismatches, but also guides about the improvement. Jones and Womack (Jones & Womack, 2003) describe VSM as the process of visually mapping the flow of information and material as they are, and preparing a future state map with better methods and performance. Defined by Voelkel and Chapman (2003), VSM is the simple process of directly observing the flows of information and materials as they now occur, summarizing them visually, and then envisioning a future state with much better performance. A successful attempt to use VSM has been made by Seth and Gupta (2005), as a technique to achieve productivity improvement in production output per person, reduction of work-in-process, and finished goods inventory.

The process of designing a VSM itself is very simple and straightforward, using pencil and paper, and doing a Gemba walk[2]. Starting from the customer delivery end point, and working back through the entire process documenting the process graphically, and collecting data along the way until reaching the suppliers. It results in a single page map containing data, such as, cycle time, work-in-process (WIP) levels, equipment performance data, and also the flow of information within the system (Singh & Sharma, 2009). Besides this information the VSM identifies the value added activities and non-value added activities, adding up to the total lead time of production.

The steps taken in Value Stream Mapping, according to Lasa et al. (2008) and ITC (2004), are described as follows:

1. **Select** the product or product family you want to map;
2. Draw the current state value stream map;
3. Draw the future state value stream map;
4. Implement the action plan;
5. Achieve the action plan.

Terminology used in Value Stream Mapping is described in Table 1.

Table 1- Terminology used in the VSM design (Singh & Sharma, 2009)

Takt Time	The rate at which a company must produce a product to satisfy its customer demand. It is calculated dividing the available working time per day by the customer demand per day.
Production Lead Time	The total time a component takes through the shop floor, from point of arrival as raw material until shipped as finished goods to the customer.
Value Added Time	The time during which value is added to the product. Everything the customer pays for.
Current Value Stream Map	Describes the current state of the value chain from the arrival of raw material until the shipment to the customer.
Future Value Stream Map	Describes the proposed future state map of the value chain after improvements have been identified to eliminate waste activities.

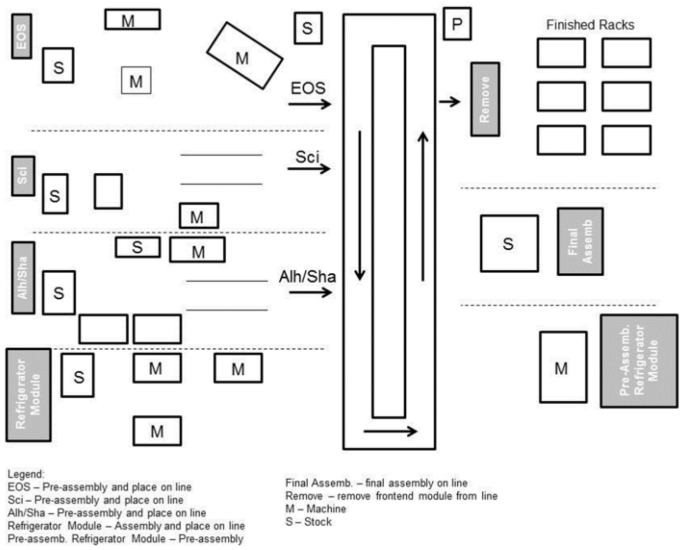

Figure 3 – Frontend assembly process layout

3. SMP – The Current Status

In this chapter the current VSMs are designed, through the collection of relevant data and the

[2]Gemba walks denote the action of going to see the actual process, understand the work, ask questions, and learn. It is known as one fundamental part of the Lean management philosophy

analysis of the information and material flow throughout the production lines.

The timed data needed to calculate the total lead time along each production line was gathered by using a chronometer, timesheet tables, and a pencil. The data was later analysed using a spreadsheet. The detailed data is not part of this document due to the confidentiality nature of the information.

Each process presented in the value stream map contains activities which can be divided into tasks.

Data from all production lines was obtained. However, in the present document, only the frontend production line is analysed in detail.

3.1. Frontend Production Line Data

1. Injection Moulding Area

The frontend production line starts in the moulding area. Machine M3, as shown in 2.2.2., moulds the Kum for the Sci and the EOS frontend modules. The Kums for the Sha and Alh are supplied externally, and are stored in the storage area.

The times measured in the moulding area are of the machine cycle times, the manual inspection time after the Kum is moulded, and the time taken to place the Kum on the rack.

In Table 2 the total average time of the moulding of the Kums is shown. All times are in seconds.

Table 2 – Frontend injection moulding data (in seconds)

Machine	Cycle Time	Inspection	Storage	Total Time
M3	73	15	7	**95**

After the racks are complete, a forklift truck stores them in the storage in the injection moulding area or transports them immediately to the assembly line, depending on the production schedule that is being followed.

Note that the Alh and Sha Kums supplied externally are stored in the storage area near the frontend assembly area. The Kums are supplied to the assembly area when needed.

2. Assembly Area

The frontend assembly process has 7 different activities, as follows:

- EOS pre-assembly;
- Sci pre-assembly;
- Alh/Sha pre-assembly;
- Refrigeration Module;
- Pre-assembly Refrigerator Module;
- Final Assembly;
- Remove Module.

The layout is shown in Figure 3 to have a clear image of the process.

The central part of the assembly area is a moving assembly line with metal robust holders to place the pre-assembled Kums on. The holders are integrated into the assembly line.

The label printer, P, which receives JIS information from AE, is located at the end of the assembly line. The operator on the final activity glues the labels on the metal holders after he has taken the finished frontend module off the holder.

The metal holders then move on to the next activities, which consist on placing the pre-assembled Kums on the holders. From this point on, all the following activities consist of assembling parts on the Kum whilst it is on the line. When the assembled Kum reaches the final activity, the operator takes the finished frontend off the line and places it in a rack. All the pre-assembly activities are external and do not have interaction with the assembly on the line.

Each rack holds 6 frontend modules. The dispatch racks are then transported to the waiting area by forklift truck.

Table 3 – Frontend module assembly data (in seconds)

Model	Pre-assembly(*)	Assemble on Line	Refrigerator module	Final assembly	Take-off line	Total Assembly Time
EOS	1 158	75				**1 463**
Sci	988	68	63	101	66	**1 286**
Alh/Sha	697	50				**977**

(*) external to the assembly line

The times measured at each activity along the frontend module assembly process are detailed in Table 3. Note that the pre-assembly of the refrigerator module present in the layout is not included in the time measurement, as this is an external activity, and will not influence the calculation of the average time the frontend takes on the line.

Table 3 shows the total average time for each frontend model to be assembled in the assembly process. The table is divided by activity and frontend model. The times measured start with the pre-assembly of the Kums, at their designated work station. Followed by the time to place and assemble the Kum on the line. The following three activities measured are of the time for parts to be assembled on the Kum whilst it is on the line. These times are the same for all models. All times are in seconds.

3. **Waiting Area**

The waiting area is located between the frontend assembly area and the AE truck loading area. The truck arrives every 2 hours, and loads all the racks which are finished.

3.2. Spaghetti Diagram

A spaghetti diagram was designed to enable a clear vision of the material flow throughout the plant. In this case the factory layout is designed as the background, and the three production flows are identified in different colours. The image may be found below, in Figure 4.

The design of the material flow using a spaghetti diagram is important to design before the current VSM to have a clear vision of the flow the production lines follow in the VSM.

from the client to the logistics department and to the frontend assembly area electronically.

The average total demand information is sent to the logistics department and the logistics team sends the information electronically to the suppliers, and manually to the injection moulding department.

The information sent to the frontend assembly area is JIS and the modules are assembled as soon as the order is received.

3.4. Frontend VSM Lead Time Analysis

Each process identified along the frontend current VSM is presented in the figures found below. The figures are of the value added and non-value added lead time. The time is presented in days. Figure 5 shows the non-value added time and Figure 6 the value added time.

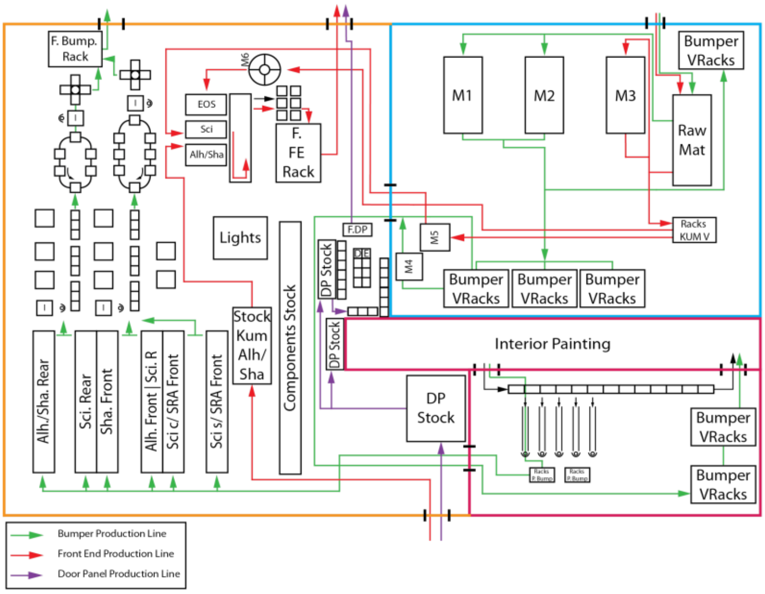

Figure 4 – Spaguetti diagram layout

3.3. Frontend Current VSM

The frontend current VSM is designed below in Figure 9.

Material Flow Analysis

The material flow the frontend production line follows in the VSM is the same as shown in the spaghetti diagram, in Figure 4. The current frontend VSM process description is found below, in Table 4.

Note that the racks with the Kums are transported to the frontend assembly area by forklift truck, as needed. For that reason the transport is shown directly from the supplied Kums to the assembly area.

Information Flow Analysis

The information flow throughout the frontend current VSM is electronic and manual. The information is sent

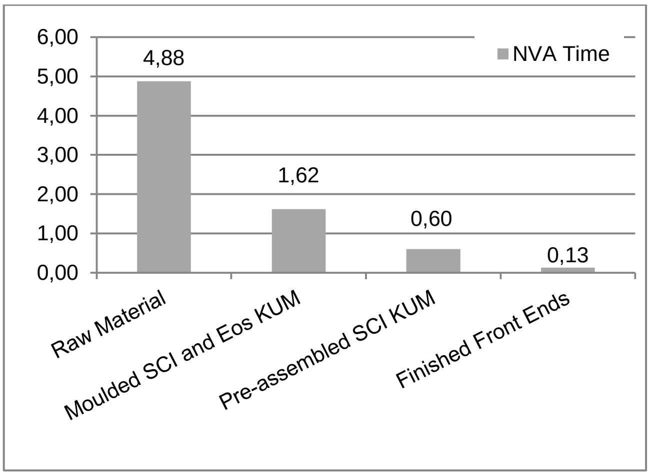

Figure 5 – Non-value added time in the frontend VSM

Table 4 – Current frontend module VSM process description

Process	Description
Unload Raw Material and Alh/Sha Kums	The raw material arrives from the suppliers and is unloaded in the injection moulding area. The Alh/Sha Kums are unloaded at the unloading dock near the main warehouse.
Store Raw Material and Alh/Sha Kums	The raw material is stored in the designated storage area in the injection moulding area, and the Alh/Sha Kums are stored in the designated area in the main warehouse.
Mould Sci and EOS Kums	The Sci and EOS Kums are moulded in M3 in the injection moulding area.
Store Moulded Sci and EOS Kums	The moulded Sci and EOS Kums are stored in the designated storage area in the injection moulding area.
Assemble Sci and EOS Kums	The Sci Kum is assembled in M5 in the injection moulding area, and the EOS Kum is assembled in M6 in the frontend assembly area.
Store Assembled Sci and EOS Kums	The assembled Sci and EOS Kums are stored in the designated storage area in the injection moulding area.
Assemble Frontend Modules	The frontend modules are assembled in the frontend assembly area.
Store Finished Frontend Modules	The finished frontend modules are stored in the dispatch area near the designated loading dock.
Load Finished Frontend Modules	The finished frontend modules are loaded and transported to the client.

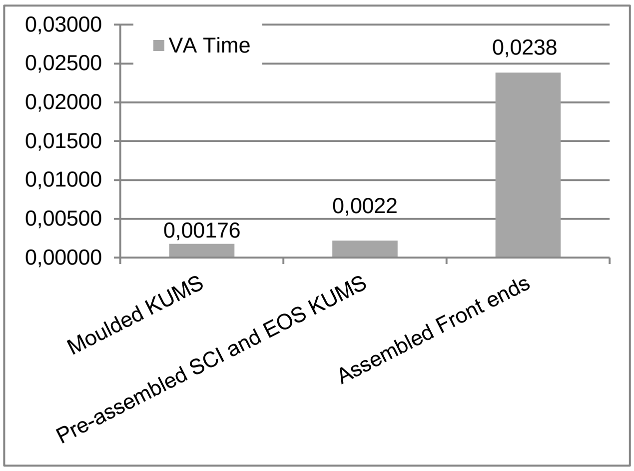

Figure 6 – Value-added time in the frontend VSM

Through the comparison of the value added and non-value added processes it is possible to identify space to improve. In Table 5 the total lead time for each figure is shown.

Table 5 - Total lead time of the current frontend VSM (in days)

	NVA Time	VA Time
Total	12,4	0,028

4. SMP - Improvement Proposal

The future VSM design starts with the identification and analysis of opportunities for improvement.

In order to define improvement opportunities the 7 deadly wastes are identified along the current VSM. The non-value added and value added processes are analysed, and wastes are identified throughout the production line.

4.1. Opportunities for Improvement

Along the current VSM it was possible to identify the following wastes:

- **Defects** – raw material may be stored for a long time leading to decrease in material quality;
- **Inventory** – non-value added processes located in the raw material storage, and between the injection moulding and the assembly processes;
- **Over-production** – located in the storage areas, which leads to high inventory levels;
- **Waiting time** – identified on the assembly line.

In order to eliminate these wastes, the following measures are suggested:

- **Review Supplier Contracts**

The supplier contracts should be reviewed in order to achieve a lower inventory of raw material. This suggested measure will not be used in the design of the future VSM, due to limited access on supplier contracts information. These values could not be estimated for the future VSM.

- **FIFO Lane**

Introduce a FIFO lane for the raw material in the injection moulding area. The raw material has a lot number and a date. Sometimes problems may occur with the quality of the raw material and in this case the entire lot should be sent back to the supplier as soon as the problem is found. Introducing a FIFO lane will guarantee the raw material is used as it arrives, first in first out, and possible quality problems with the raw material can be solved soon after the lot has arrived.

- **Signal Kanban System**

Introduce a Kanban production system working between the supermarket and the injection moulding process. The frontend assembly process takes Kums from the supermarket as needed, and when the reorder point is triggered, the Kanban signal is sent to the injection moulding process to produce more. The Kanban card contains information on the Kum model and the number of Kums to be produced. In this sense, by introducing a Kanban system the injection moulding process of the Sci and EOS Kums will be pulled by the assembly process as they consume the Kums. This leads to less inventory levels, a reduction in lead time and a reduction in inventory costs.

- **Supermarket**

Introduce a supermarket between the injection moulding and frontend assembly processes. The injection moulding process supplies the supermarket which feeds the assembly process. Supermarkets contain the right-sized amounts of inventory that allow seamless production flow to occur when it is not possible to physically link processes and achieve flow.

- **Line Balancing**

The frontend module assembly process has many activities which are not balanced. Meaning some operators are idle, whilst others are busy. SMP decided to implement the line balancing improvements during the development of this study. Therefore the line balancing results have been analysed and are detailed in the following section.

4.2. Future VSM

The frontend current VSM has alterations that can be identified in the future VSM Figure 10. Other improvements applied to the processes can be identified in the lead time.

Material Flow Analysis

A FIFO lane was introduced in the moulding area to control the supplied raw material.

A Kanban system was introduced between the injection moulding process and the supermarket located between the injection moulding and the assembly process. A signal Kanban signals when a reorder point is reached and another batch needs to be moulded. In more detail, as the assembly area consumes the moulded Kums from the supermarket, a signal is sent to the moulding area for another batch to be moulded. When the injection moulding area receives the Kanban signal card it contains all the necessary information on how many Kums are to be moulded and which models.

The pre-assembly of the EOS and Sci Kums are not mapped in the future VSM as this is now included in the moulding process as a one-piece flow system.

A supermarket has been introduced between the injection moulding process and the assembly process. This supermarket holds the moulded Kums. It works together with the Kanban signal system.

Information Flow Analysis

The load levelling icon continues to work JIS with the assembly process as in the current VSM. However the information from the logistics department to the injection moulding department has been eliminated due to the introduction of the signal Kanban. The need for production is passed on to the injection moulding process through the signal Kanban card.

Lead Time Analysis

The lead time presented is estimated according to the improvements implemented in the future VSM.

The inventory levels presented in the moulded Kums supermarket follows the two day minimum stock specification ordered by AE. The inventory also has a safety factor to prevent any variation in demand or quality problems that may occur.

The assembly process time has decreased due to the balancing of the line. The detailed analysis is found as follows.

Line Balancing

This improvement opportunity, identified in section 4.1, was implemented during the design of the future VSM and as such can be considered as real data.

In assembly line balancing the objective is to meet the required production rate and achieve a minimum amount of idle time. Each activity in the assembly process should have, approximately, the same amount of work time.

The problem identified along the frontend module assembly line was the variation in the workload throughout the activities. Some operators were idle and others were busy. By analysing the assembly line using time measurements and breaking down each activity into standardized tasks it was possible to quantify the line unbalance.

4.3. Frontend Improvements Analysis

The results obtained from the improvement analysis on the frontend future VSM focus on the inventory and its cost, and also the improvement achieved through balancing the frontend assembly line.

Figure 7 presents the improvement obtained in the inventory of the moulded Kums due to the implementation of a supermarket and a Kanban system. The values are presented in units.

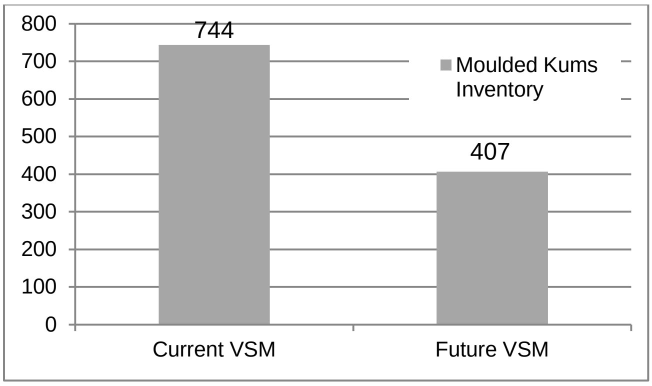

Figure 7 - Results analysis of the frontend moulded Kums inventory (in units)

The improvements in the future VSM lead to a reduction in the moulded Kums inventory of 45%.

Figure 8 presents the improvements obtained in the frontend assembly line resulting from the line balancing. These improved values are the actual current values, as the improvement proposal was implemented during the development of this study.

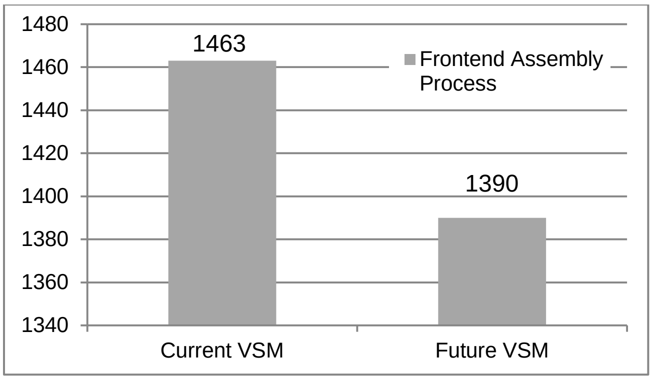

Figure 8 – Actual improvement results on the frontend assembly line (in seconds)

The improvements resulting from the line balancing lead to a reduction of 5% in the total assembly process lead time.

It was possible to obtain the costs to hold a moulded Kum in inventory. The values are not the actual values due to confidentiality policies, but their nature is equivalent. In Table 6 the cost analysis and the overall improvement is presented.

Table 6 – Frontend moulded Kum inventory cost analysis (in €)

Inventory	Current VSM	Future VSM	Savings (daily)	Δ
Moulded Kums	33.480 €	18.315 €	15.165 €	**45%**

The savings presented in Table 6 are daily.

The line balancing also resulted in a saving of one operators wage on the frontend assembly process, as one operator was taken off this line. These values are not available. This improvement also decreases the total operator idle time by 38%.

In Table 7 the improvement in total lead time on the frontend production line, from supplier to client, is presented.

Table 7 – Frontend VSM lead time improvement (in days).

	Current VSM	Future VSM	Δ
Total Lead Time	7,3	5,9	**19%**

5. Conclusions

The present work focuses on the implementation of lean methodologies in SMP, an automotive supplier in Portugal, with the aim to improve its productivity. The methodology followed was based on the design of the value stream mappings for three production lines, namely, the bumper, the frontend, and the door panel production lines.

The study began with the design of the current VSM's through the analysis of the data collected along all the processes. The wastes were identified, which led to the development of opportunities for improvement. These opportunities were designed in the future VSM's, and are as follows:

- Implement a Kanban system between consecutive production processes;
- Introduce a supermarket which pulls the Kanban system;
- Balance the frontend assembly line;
- Redesign the door panel layout.

After the design of the future VSM's, the lead time and savings were analysed. The results are as follows:

- Savings in daily bumper inventory costs of, approximately, 44.000 €;
- Improvement in bumper production line lead time of 15%;
- Savings in daily Kum inventory costs of, approximately, 16.000 €;
- Improvement in frontend production line lead time of 19%;
- Improvement in door panel production line lead time of 4%.

The results obtained from the future VSM's show an improvement in terms of lead time and savings, which is encouraging. Therefore an implementation strategy was defined, following a PDCA managing system.

In conclusion, the application of lean methodologies in manufacturing processes was very efficient in obtaining improvements. This is aligned with the results described in the literature. Therefore, the study of the lean methodology in a Portuguese case study has contributed positively to this research area.

This study has managerial implications for the successful lean implementation in SMP. There has to be visibility throughout the whole supply chain, and as SMP's production is completely dependent on the orders issued by AE, it is of utmost importance to know in advance the production plan. Presently, the accurate production plan issued by AE is known only 24 hours in advance, which leads to poor predictability and therefore great amounts of inventory. If AE allows its production plans become more visible, its suppliers can become lean and achieve better production results.

Throughout this work, some limitations were found. There is a lack of detailed information on the production plans, which limits the amount the VSM's can be detailed, such as defining the Kanban signal.

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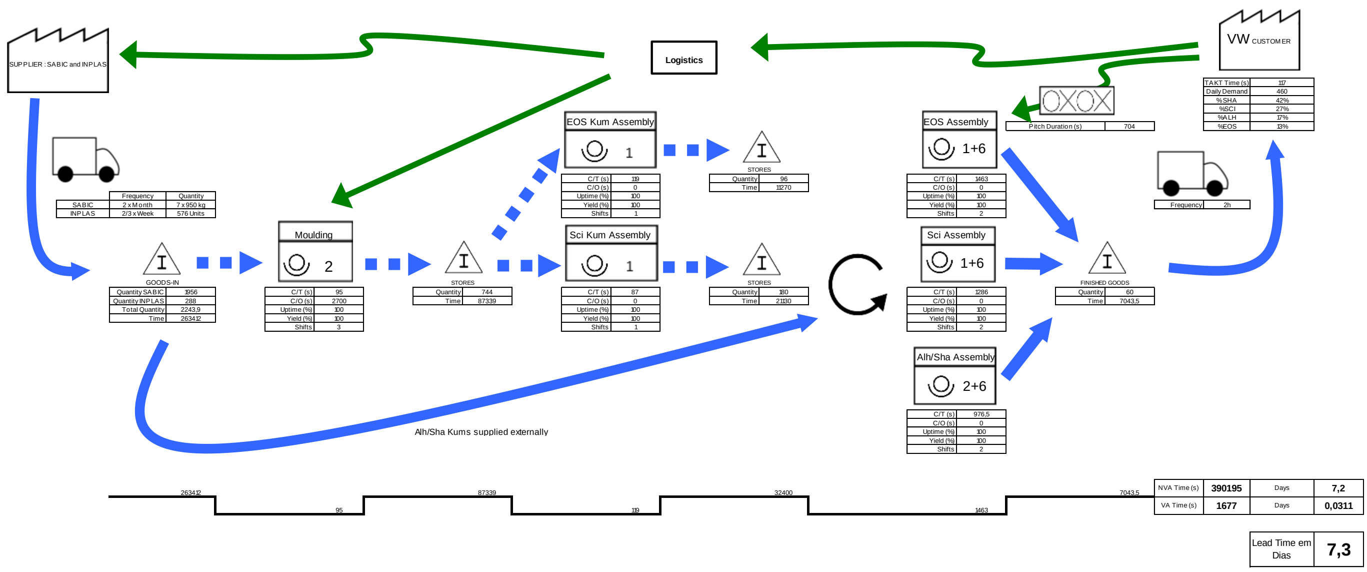

Figure 9 - Frontend Current VSM

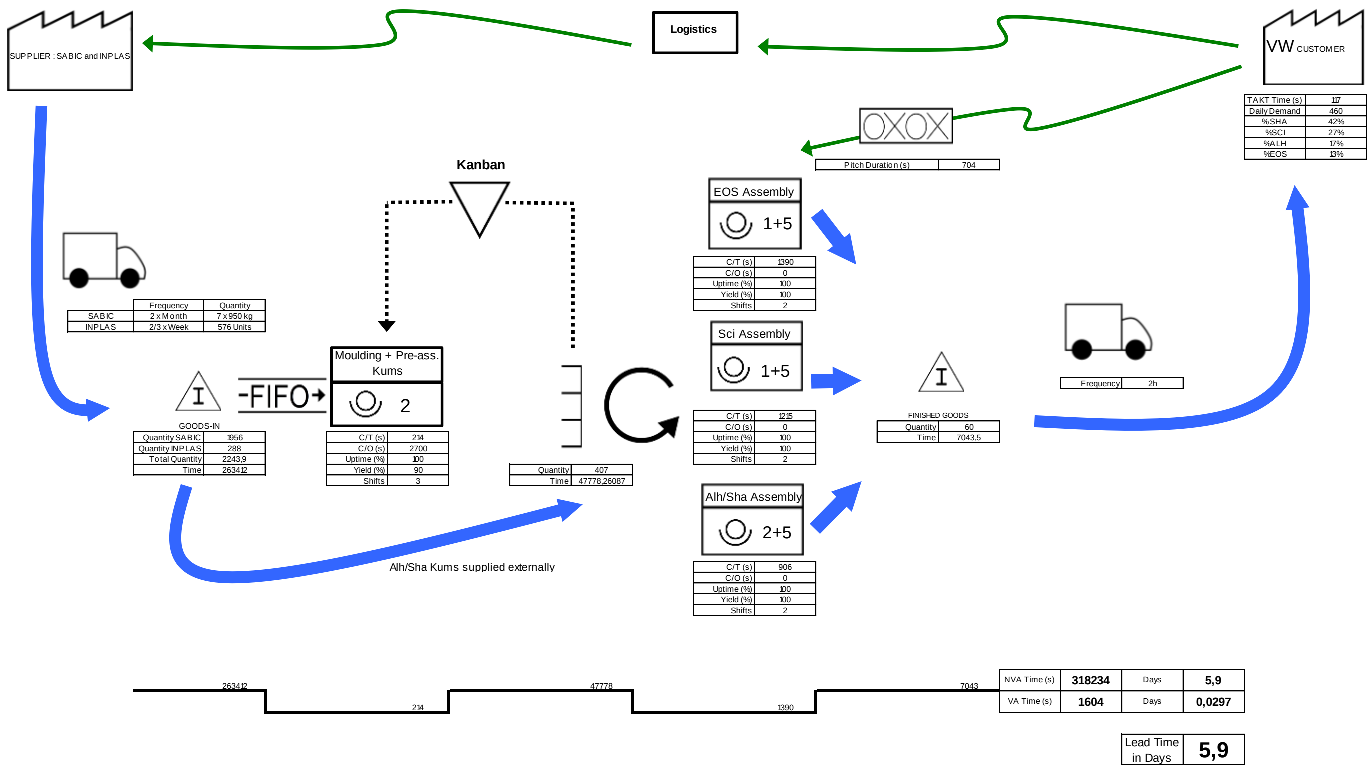

Figure 10 – Frontend Future VSM