Process Improvement in Operations Management

The Case Study of SAS interior modules

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Abstract

The automotive industry is recognized as one of the most important industries worldwide, not only for being a reference in terms of technological development, but mainly due to the impact it has on the world economy.

This dissertation focuses on SAS Palmela, the company responsible for the production and delivery of the cockpit and center console modules for Volkswagen Autoeuropa's T-ROC car model. This study arises in the context of continuous improvement and its main objective is to improve SAS's logistics and production processes, by making them more efficient.

Thus, a literature review regarding flow mapping tools was conducted and it was decided to follow a methodology based on the Material and Information Flow Diagram. In this way, the first step was to characterize and to map the current situation of the system in study. Based on the mapped diagram, improvement opportunities were identified, and then each one of them was studied in detail. After this step, each improvement opportunity was evaluated, weighing the obtained savings against the necessary investment and, considering this, the ones that would be accepted for implementation were selected. For the selected improvement opportunities, recommendations of actions to be taken for its implementation were developed. Six improvement opportunities were accepted for implementation, such as the reduction of operator movements, the reduction of handling of materials and the digitalization of paper documents. A total investment of 124,500 € is estimated to allow for a reduction of 190,27% of operator time in total, increasing the efficiency of SAS’s processes.

Keywords: Lean Thinking, Toyota Production System, Material and Information Flow Diagram, Value Stream Mapping, In-house Logistics, Storage Location Assignment Problem.

1. Introduction

The automotive industry is recognized not only for the great impact it has on the world economy, but also for the high competitiveness that exists in this sector. This high competitiveness forces companies, especially those that manufacture components for the automotive industry, to have a constant focus on the continuous improvement of their processes to maintain or gain advantage over competitors. SAS Palmela is responsible for assembling and delivering Just-in-Sequence (JIS) and Just-in-Time (JIT) the TROC car model’s cockpit and center console modules (90% of production volume) and the cockpit module for the Multi-Purpose Vehicles (MPV) car models (Seat Alhambra and Volkswagen Sharan) for its main client, Volkswagen Autoeuropa. In this sense the present work arises, focusing on the improvement of SAS’s logistics and production processes relative to the TROC, since it is the high-runner product.

2. Case Study

2.1. SAS interior modules

SAS interior modules is a key player in the automotive industry's complex interior module assembly, logistics, and Just-in-Time delivery. The company currently employs 4.800 people throughout 22 plants around the globe, including one in Palmela which is the focus of the present article.

SAS Palmela plant, works on JIT, meaning that it is working when its main client is working, Volkswagen Autoeuropa. Besides this main client, SAS also produces the T-ROC Cabriolet model's center console modules for Volkswagen Osnabrück, but in more reduced volumes (less than 10%) when compared to Autoeuropa. SAS Palmela plant, accounts for two independent assembly lines, one for the cockpit modules and the other for the center console modules. In terms of physical space, it accounts for a ground floor area of 7.500m^2 and two additional mezzanines. One of the mezzanines is called the MIKO (German abbreviation for center console) Mezzanine which is where the center console assembly line is present, and the other mezzanine is called the Welding Mezzanine, which is composed of two workstations that make pre-assembly tasks for the cockpit assembly line and one workstation that produces a component, in batch, for the center console assembly line. On the ground floor there are twenty-six workstations which are exclusive for the cockpit assembly line.

It should also be noted that due to the specificity of an assembly plant, SAS deals with a high number of components (more than 600 Part Numbers), which can be assembled in multiple combinations in order to obtain the exact combination required by the end-customer, resulting in a high number of different final products. This, combined with JIS and JIT production, makes both logistical and production processes very demanding, when compared to most component manufacturing plants.

2.2. Problem Definition

The present case study aims to improve the logistics and production processes at the SAS Palmela plant. Thus, it was defined that the best way to approach this project would be through the use of a Flow Mapping tool. This tool would serve for the identification of improvement opportunities, which correspond to waste (Non-Value-Added [NVA] activities) that could be eliminated from the logistics and production processes of SAS. After this identification, detailed studies would then be carried out to make recommendations regarding each of the identified improvement opportunities.

3. Literature Review

3.1. Toyota Production System

Toyota Production System's (TPS) origin dates back to soon after the World War II, where Japan lost the longest war on history and was left in a scenario of destruction. After the war, Toyota was restarting its automotive production and it did not have the same economic power as the American producers, thus it could not invest in the big equipment to produce as many parts as possible (Liker, 2004). This was when Toyota realized that it had the need to search for a new system focused on flexibility and cost reduction through waste elimination, which would allow to produce many models of cars in small quantities (Ohno, 1988).

Even before Toyota existed, Sakichi Toyoda had already invented the first pillar of TPS (Liker, 2004), **Jidoka**, which stands for autonomation, short for automation with a human touch. This pillar aims to equip machines with devices that automatically stop production as soon as they detect any abnormality (Monden, 2011). By introducing the fault detection device, the operator is not needed if the machine is working correctly, but only needs to be present when the machine detects a fault. In this way it is possible for one operator to be allocated to more than one machine and therefore increasing production efficiency (Ohno, 1988).

In 1950, Ejii Toyoda, Sakichi Toyoda's nephew and current president of Toyota, went on a tour to the United States in order to learn from the methods applied in American factories (Womack *et al.*, 1990). Contrarily to what he expected, he was surprised to see several mass production machines producing with many interruptions in the processes, mirrored by huge amounts of intermediate stocks to hide the production problems (Liker, 2004). Ejii Toyoda clearly identified the need to improve this system, and when he returned to Japan, together with Taiichi Ohno, they developed the second TPS pillar, **Just-in-Time**. When applying JIT, products move from one station to the next, only when they are needed and in the quantity required. Even though implementing this system is a difficult task, all flaws are detected, rather than being disguised by intermediary stocks. And as Ohno (1988) stated, the identification of flaws is essential to solving them.

In addition to the two pillars, Monden (1983) has identified three other essential elements: *Heijunka*, *Kaizen* and Standardized Work. ***Heijunka*** is the Japanese word for Levelling. When levelling is applied, the consumption of parts is distributed evenly throughout the days and, with this, instead of having the production concentrated in a short time period followed by a period of no production, the production follows a constant rate allowing for a higher and more constant utilization of machines and human resources (Liker, 2004). ***Kaizen*** is a Japanese expression which can be translated to "continuous improvement", which in this context, is a philosophy focused on enhancing value added activities in the customer perspective and, on the other hand, on removing non-value-added activities (Waste Elimination). Imai (1986) referred to **Standardized Work** as the basis for continuous improvement to occur. This element aims to capture today's best practices, then allow the creativity of workers to improve the standard, and finally incorporate those improvements into the standard so that the learnings can be passed from person to person (Liker, 2004).

3.2. Lean Thinking

The term Lean gained visibility when Womack *et al.* (1990) applied the term "Lean Production" to a production system inspired by the TPS, which is characterized by high efficiency and performance when compared to most traditional systems. The Lean Production was born with the same objective as the TPS: to reduce its production costs while offering a high variety of products at the same time, which would only be possible by minimizing the waste in the production processes (NVA activities) and focusing on what the customer is willing to pay for. Years later, Lean Production would be recognized as one of the most influential paradigms in the automotive industry, thus expanding its applicability from the shop floor to various industries (Hines *et al.*, 2004), becoming a management philosophy called Lean Thinking. Womack & Jones (1997) referred to Lean Thinking as the antidote to waste, and stated that this philosophy is supported by 5 Principles: (1) <u>Specify Value</u> from the customer perspective; (2) <u>Identify the Value Stream</u>, *i.e.*, identify which activities bring value to the customer and eliminate those who do not; (3) <u>Ensure Continuous Flow</u>, which in other words is eliminate the interruptions in the processes; (4) <u>Establish a Pull System</u>, allowing the customer to dictate the production, and therefore to apply JIT; (5) <u>Pursuit Perfection</u>, *i.e.*, while pursuing an ideal scenario for operations, one should focus on small improvements rather than on disruptive ones (*Kaizen*).

3.3. Flow Mapping

By using a Flow Mapping tool, it is possible to better understand the flow of information and material throughout a factory's processes, and with this it to analyze the macro picture of an organization. Flow Mapping is not in itself the tool that improves or optimizes processes, but rather the tool that allows the identification of the weak and strong points of the value chain, allowing to enhance the activities that bring value to the customer, and to eliminate those who do not.

When it comes to Flow Mapping, the most popular tool in Western countries and in the literature is undoubtedly the Lean tool, Value Stream Mapping (VSM) (Chavez *et al.*, 2018; Hines *et al.*, 1998). And thus, it is generally believed that Toyota uses and has always used VSM. However, according to Rother & Shook (1999), VSM is actually an adaptation of the tool invented by Toyota, Material and Information Flow Diagram (MIFD). As both MIFD and VSM are several decades old, one would expect that there would be various cases of their application in the literature. However, at the time of the theorization of the Lean methodology, Lean and the VSM became much more popular, leaving little recognition for the MIFD. Thus, it is noteworthy that there are numerous cases of application of the VSM tool in the literature (McKenzie & Jayanthi, 2007; Singh *et al.*, 2011; Thiede *et al.*, 2016) and none concerning the implementation of the MIFD. Even though both tools have the same objective, they have some differences, being the most noticeable one the level of detail of the information present in the diagrams, with MIFD having a greater detail than the VSM (Chavez *et al.*, 2018). With this in mind, it was decided to use the MIFD approach because more detailed mapping would be beneficial in identifying improvement opportunities.

3.4. Storage Location Assignment Problem

The Storage Location Assignment Problem (SLAP) concerns the allocation of incoming products to storage locations, with the objective of reducing material handling costs and/or reducing space utilization. Gu *et al.* (2007) defined SLAP as a problem that has into account: the physical configuration of the storage area and storage layout; the availability, physical dimensions, and locations of the warehouse department; as well as the physical dimensions, demand, quantity, arrival and departure times of the products to be stored. With this information, the model optimally determines the locations where the incoming products will be stored.

Remembering that the two SLAP objectives are to minimize material handling costs and to minimize space utilization, and that these objectives may be conflicting to each other, here arises the need to balance this trade-off. Given that picking operations account for more than 55% of a warehouse's operational costs (Frazelle, 2002), this is the operation that must be optimized to have a significant impact on total costs. Having said that and given that the material handling cost is frequently represented as a linear function of picking travel distances (de Koster *et al.*, 2007), a literature review on SLAP will be addressed from now on, with a focus on studies that tackle the minimization of the material handling cost. Daniels *et al.* (1998) proposed a model with the objective of minimizing the total material handling cost which simultaneously determines the allocation of inventory to positions and the positions visiting sequence. Chan & Chan (2011) proposed a simulation model that measures the impact of using different storage assignment policies and different routing policies. In this study the authors performed 27 different experiments, in which they combine assignment and routing rules using scenarios with different pick densities. Kovács (2011) addressed the SLAP in a warehouse served with milk-run picking, being therefore a special case designated correlated storage assignment problem. In order to solve this problem, the author proposed a mixed integer programming model that using the class-based storage policy aims to minimize the order cycle time as well as the total picking effort (retrieval and travel times). Later, Ene & Öztürk (2012) developed a storage assignment and order picking system in an automotive industry real case scenario using a mathematical model and a stochastic evolutionary optimization approach. The solution for this problem is obtained in two steps. First a mixed integer linear programming model is modeled to solve the class-based storage assignment problem with the objective of minimizing the total travel distances. Then, in the second step, the authors proposed an integer programming formulation to achieve the optimal solution for the batching and routing problems.

4. Methodology

The methodology pursued in this improvement project is represented in Figure 1, consisting in five steps.

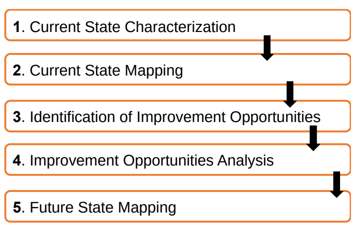

Figure 1: Improvement Project Methodology.

4.1. Current State Characterization

Considering that a factory normally works with a large number of products and components, it is not possible to represent every material in a single diagram. Thus, before the representation of the diagram, the materials in focus were selected based on the materials with most value in stock. Additionally to these, other materials that had distinct flow when compared to the ones already selected were also chosen to be represented.

After this, it comes the collection of information regarding the current state of the material and information flows. In this step, firstly some key questions to characterize the system were identified, and from there, the collection of information started through *Gemba* (Japanese word that means “on site”) walks and through unstructured interviews with people from different departments directly in the shop floor.

4.2. Current State Mapping

After collecting information for the characterization of the plant’s current state, the representation of the plant’s material and information flows follows. The MIFD is composed of flows, symbols and written information.

4.3. Improvement Opportunities

Following the representation of the current state in the MIFD, a multidisciplinary team was established to validate the diagram and to identify opportunities to improve the factory's information or material flows. This team was composed of members from all company’s departments, to ensure that the MIFD accurately reflects the company's reality. After the identification of the improvement opportunities, a detailed study on each of them would be performed in order to analyze if it should be implemented or not.

4.4. Future State Mapping

After the improvement opportunities were identified, the representation of the plant’s future material and information flows follows. Note that, in the future MIFD, all identified improvement opportunities should be represented, regardless of whether they have been selected for implementation or not.

4.5. Storage Location Assignment Problem

This study arises in the context of Improvement Opportunity #2 and its ultimate goal is the minimization of the distances traveled by logistics operators during picking operations. To make this possible, a mathematical SLAP model was developed which considers all picking positions, all decentralized stock positions, all materials that need picking positions, as well as the average number of transportations required for each material per day. With this data as input, the

SLAP model returns the optimal allocation of material-picking position, so that operators walk the shortest possible distance (NVA activity). Note that, due to the orthogonal nature of the plant layout, which has long aisles in both horizontal and vertical directions, the Manhattan Distance was used for the calculation of the distances traveled by the pickers. The following notations were used.

Sets:

- $l \in \{1,2,\ldots,L\}$, set of L I/O points;
- $m \in \{1,2,\ldots,M\}$, set of M materials;
- $p \in \{1,2,\ldots,P\}$, set of P picking positions.

Parameters:

- $HF \in \mathbb{R}_{+}$, maximum distance that an operator is willing to travel for a part to be stored on level 1, instead of on level 2;
- $t_m \in \mathbb{R}_{+}$, average number of transports of material m per day;
- $h_p \in \{0,1\}$, height level of picking position p (h_p=0 corresponds to level 1, and h_p=1 to level 2);
- $r_m \in \{0,1\}$, height restriction of material m (r_m=0 if material m must be stored on level 1, and m=1 if it can be stored on any level);
- $d_{l,p} \in \mathbb{R}_{+}$, distance between I/O point l and picking position p;
- $a_{l,m} \in \{0,1\}$, allocation between I/O point l and material m ($a_{l,m}$=1 if material m has to be supplied in I/O point l, $a_{l,m}$=0 otherwise).

Decision Variables:

- $x_{m,p} \in \{0,1\}$, $x_{m,p}$=1 if material m is allocated to position p, $x_{m,p}$=0 otherwise.

Using the just mentioned sets, parameters and decision variables, the model is proposed as follows:

$$\min z = \sum_{l}\sum_{m}\sum_{p} a_{l,m} \times t_m\left(d_{l,p} + HF \times h_p\right)x_{m,p}$$

Subject to:

$$\left(r_m - h_p\right) \times x_{m,p} \geq 0,\ \forall(m,p) \qquad \textbf{(1)}$$

$$\textstyle\sum_p x_{m,p} = 1,\ \forall m \qquad \textbf{(2)}$$

$$\textstyle\sum_m x_{m,p} \leq 1,\ \forall p \qquad \textbf{(3)}$$

$$x_{m,p} \in \{0,1\},\ \forall(m,p) \qquad \textbf{(4)}$$

The objective function is the minimization of the total traveled distance in picking operations, while penalizing the allocation of materials to level 2 positions for ergonomic reasons (HF). Constraint **(1)** assures that if a given material cannot be allocated to level 2, then that it is allocated to level 1. Constraint **(2)** ensures that each material must, and can only, be allocated to one picking position. Constraint **(3)** guarantees that each picking position can only be empty or allocated to a single material. Constraint **(4)** defines the domain of the decision variables.

Considering that changing a high number of picking positions is a complex process, a sensitivity analysis was performed with the objective of observing the changes in the optimization results when varying the number of allocations (pair material–picking position), when compared to the current allocations. To make this sensitivity analysis possible, the set of picking positions ($\{1,2,\ldots,P\}$) and the set of materials ($\{1,2,\ldots,M\}$) were defined so that $x_{m,p}$=1,$\forall(m,p) \in \{1,2,\ldots,M\}| \ m = p$. Adding to this, a new parameter $n \in \mathbb{Z}_{+}$ was created representing the minimum number of allocations (material-picking position) that should be kept as they are today, that is, the minimum number of picking positions that should remain allocated to the same material they accommodate today. Then, Constraint **(5)** was added to ensure that at least n allocations remain as they currently are:

$$\textstyle\sum_m \sum_p x_{m,p} \geq n, |\ m = p \qquad \textbf{(5)}$$

That said, the Mixed Integer Linear Programming (MILP) model was formulated through the General Algebraic Modeling System (GAMS) Studio 34 software, using IBM CPLEX Optimizer, in a 2x Intel Xeon X5660, 2.8GHz computer with 64GB of RAM, to obtain the results of the SLAP model.

5. Results

5.1. Current State

After answering the identified key questions, it was possible to draw the Current MIFD, which can be seen in Figure 2. Note that the lines and symbols marked in blue refer to the path of the component with the longest lead time, the OCU module (5WA 035 284 E).

Once the Current MIFD was mapped, it was presented to the multidisciplinary team, which validated the diagram. Then, the team started to analyze the flow, and from there the identification of improvement opportunities was conducted.

5.2. Improvement Opportunities

The decision of whether to implement an improvement, or not, is based on the Payback Period, which consists in the time required to recover the investment costs. The team determined that for an improvement to be implemented, it must have a Payback Period of less than or equal to 2 years.

An important aspect to mention is that the benefits associated with the improvements refer to the elimination or reduction of NVA activities. These benefits, although they are not direct gains, should be accounted for, as the Kaizen philosophy suggests that one should focus on several small improvements rather than just looking for big improvements. One final note is that, for confidentiality

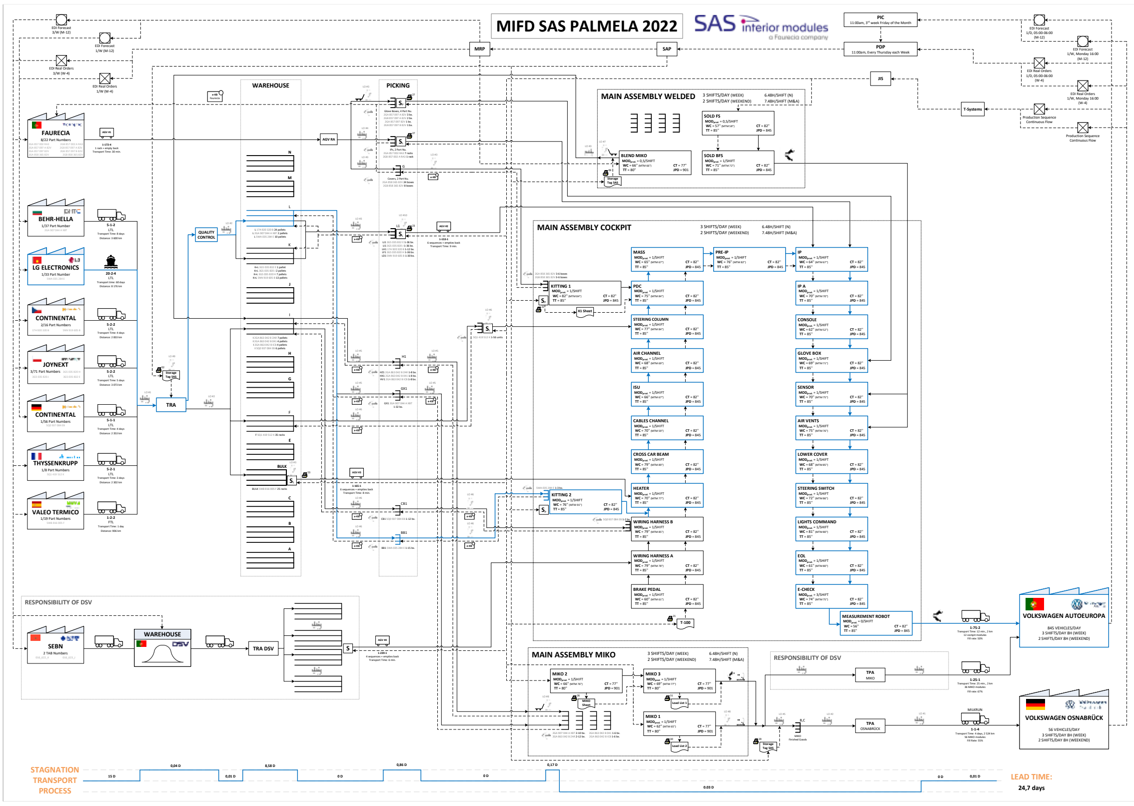

Figure 2: Current state Material and Information Flow Diagram (Current MIFD).

reasons, the cost of an operator can not be shared, and therefore the savings of each improvement opportunity will be presented in terms of operator occupancy percentage (time saved of an operator divided by the total time of an operator).

Improvement Opportunity #1 was thought of with the intent of reducing the lead time of the component that has the longest lead time (5WA 035 284 E). This way, it would be possible to reduce the money invested in inventories while ensuring greater flexibility to adapt to any market changes. Currently this component is received twice a month, *i.e.*, every 15 days, and this improvement opportunity aims to study what the optimal frequency of delivery is. To be able to answer what the optimal frequency is, it was necessary to resort to inventory management, namely to the model of periodic review with variable ordered quantities. From this calculation it was found that the optimal order frequency would be every 11 days. But considering that the boat coming from Vietnam has, at maximum, a frequency of one week, the only possible increase in frequency would be to double it, *i.e.*, every 7 days. Then a comparison of ordering every 7 days and every 15 days was made, and it was found that ordering every 7 days is 13.283,97 €/year more expensive and thus, Improvement Opportunity #1 would not be accepted.

As it was explained in subchapter 4.5, **Improvement Opportunity #2** consisted in the reorganization of the components' picking locations so that the logistics operators travel less during the picking operations. For the sensitivity analysis, the model was computed for different values of n (number of allocations that should remain as they currently are). First the model was computed using n=0, which corresponds to the Optimum Result as it is possible to vary all allocations. Then, n is increased by 10 units and the model is computed again. This process is repeated until n=224 was reached, which corresponds to the Current Scenario, as no allocations change. Since it is not known how many changes in the warehouse the decision maker (SAS Logistics Director) is willing to make, or how much distance reduction she wants to achieve, the author decided that his suggestion would be made based on efficiency (*i.e.*, how much distance can be reduced per allocation that can change). That said, the graph representing the total reduction of distance travelled during picking operations as a function of the number of allocations that can vary (the total number of allocations minus the number of allocations that cannot vary [parameter n]) was plotted and can be seen in Figure 3.

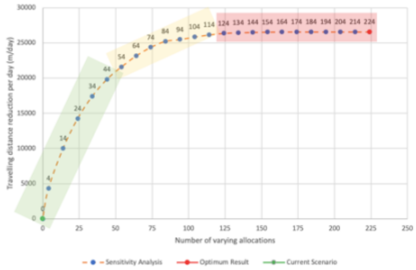

Figure 3: Reduction of distance travelled as a function of the number of allocations that can vary.

This graph is divided into 3 efficiency ranges: Green Range for points with efficiency higher than 175m/day per allocation, Yellow Range for points with efficiency between 175 and 25m/day per allocation and Red Range for points with efficiency lower than 25m/day per allocation. Thus, three suggestions were made, one for each efficiency range, and will be presented in descending order of efficiency: varying 44 allocations (n=180), resulting in a total distance reduction of 19,941 m/day; varying 114 allocations (n=110), resulting in a total distance reduction of 26,151 m/day; varying 174 allocations (n=50), resulting in a total distance reduction of 26.569 m/day. After showing the results to the decision maker, she opted for the second suggested solution, *i.e.*, varying 114 allocations to achieve a total distance reduction of 26.151 m/day. In this way, it would be possible to almost achieve the maximum distance reduction (26,151 m/day instead of 26,569 m/day [98%]), by changing 51% of all 224 allocations. As this solution has no significant investment costs (the only cost is the time invested for changing the positions) but brings significant savings to the plant's operations (25,75% of operator time), Improvement Opportunity #2 would be accepted to be implemented.

Improvement Opportunity #3 consists in the reorganization of the layout of the Kitting 1 supermarket so that the operator travels less during its operations. With the current layout, the operator sequences two cars at each time. The kitting boxes are placed in a kart, with which the operator visits all four racks and returns to the starting point. By observing its operations it was realized that he spent too much time walking (NVA activity). For this, a new layout was purposed, as can be seen in Figure 4. With this, the operator would be in Area 1 more than 90% of the cycles (T-ROC), and would only have to visit Area 2 when sequencing for MPV (less than 10% of cycles). This improvement would allow for a reduction of 21,40% of operator time and, as the only investment for this was the time to physically change the layout, Improvement Opportunity #3 would be accepted to be implemented.

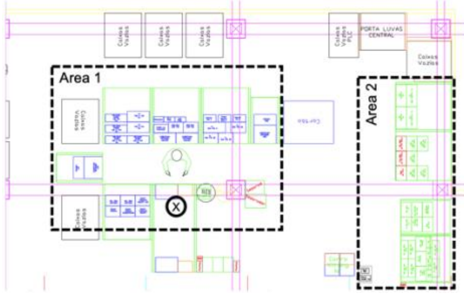

Figure 4: Future Layout of the Kitting 1 supermarket.

Improvement Opportunity #4 consists in the digitization of the T-100 sheet. The T-100 sheet, is a paper document which has the list of components that will be assembled into one cockpit, and is therefore essential for the production operations. Before the assembly operations start, one operator is responsible for retreiving the sheet from the printer and to place it on its position in the cockpit trolley. In the end of the assembly process, the last operator takes the sheet from the trolley and places it in the paper garbage can. The objective of this improvement opportunity is to use eInks tablets to show the essential informations, replacing this way the paper sheet and eliminating the handling of the document (NVA activity). The invesment needed in eInks tablets and trolley supports, would account for 10.500 €, with an additional cost of 100 €/year in batteries. On the other hand, it would allow for the elimination of the costs of printing in paper, which account for 3.016,80 €/year and would allow for a reduction of 8,49% of operator time, as the handling of the document is eliminated. Taking the investment and the savings generated into account, the payback period was calculated and, as its result was less than 2 years, Improvement Opportunity #4 would get the approval to be implemented.

Improvement Opportunity #5 consists in the elimination of the IP Stock to reduce an handling (NVA) activity. Currently, the IPs are transported in metal containers on top of an AGV from the supplier directly to SAS. When the rack gets to SAS, one operator using a forklift, takes the container and places it in the IP stock. In return it takes one empty container and sends it by AGV to the supplier. The sequencing of IPs is done with the inventory in the IP stock. The idea of this improvement opportunity is to sequence directly from the top of the AGV, eliminating this way the handling of the IP's containers. For this, it is necessary to invest in one conveyour belt for the IP transportation from the AGVs to the assembly line, one plantform for the operator to handle the IPs from the top of the AGV, and two additional AGVs to ensure that there is always a rack available for the operator to pick IPs from. With this, the handling of the containers will not be needed (87,10% of operator time), and the sequencing activity can be allocated to other operator. Having the total investment (68.000 €) as well as the associated benefits (87.10% of operator time) into account, the payback period was calculated, and as it is lower than 2 years, Improvement Opportunity #5 would be accepted to be implemented.

Improvement Opportunity #6 arises to counteract the main root cause of the assembly line stoppages that currently occur, *i.e.*, the delay in receiving orders from the customer. On the customer's assembly line, the Point Of Fit (POF) of cockpits occurs in one of the first workstations. This means that there is little time from when a particular car starts to be produced by the customer until the respective cockpit is inserted into the customer line. Thus, for SAS, the number of customer orders waiting to start being produced is always low and can even reach 0 if the customer is late in sending information regarding the production sequence. When this happens, it means that there is no information for the production of SAS's assembly line and therefore the production line stops. SAS's assembly line carousel has capacity for 35 trolleys (or equivalently, cockpits) at all times, however, since there are only 28 workstations the carousel this means that in each cycle there are 7 trolleys along the carousel that are not being worked on. By moving 2 of these trolleys that are not being worked on to the beginning of the line, it is possible to add approximately 3 minutes (2 cycle times) for the customer to send information regarding the products before the line stops for lack of information. This means that, with this improvement, the stops due to this root cause that were shorter than 3 minutes would be completely eliminated, and the stops that were greater than 3 minutes, would be reduced in 3 minutes for each time the line stopped. This results in a reduction of 0,92% of operator time of innactivity (NVA activity) per operator, and given that there are 27 operators in the assembly line, this result in a reduction of 24,84% of operator time in total. Besides this, with the physical changes in the layout, the Kitting 2 operator would no longer be able to move the heaters to the heaters table, and therefore this would have to be automatically done by a karakuri system, which costs 40.000 €. With this, there is a reduction of 1,17% of operator time that could now be allocated to other activities. To conclude, with an invesment of 40.000 €, it is possible to reduce 26,02% of operator time in total. Since the payback period was lower than 2 years, Improvement Opportunity #6 would be accepted to be implemented.

Improvement Opportunity #7 consists in the minimization of transport of materials. Currently, the MIKO 1 workstation is physically present in the MIKO Mezzanine. Even though the operations that occur in this workstation are basic, the transport of components to this workstation is time intensive due to two factors: the big dimensions of the components demand for a high number of transportations per day, and the long time it takes to transport this containers to the mezzanine. The idea behind this improvement opportunity is to occupy the ground floor area relative to the Brake Pedal workstation, once the production of the MPV models end. When the MPV production ends, the Brake Pedal workstation will no longer be needed as this operator only works for the MPV models. Thus, the solution for this is for the MIKO 1 workstation to physically work on the ground floor when it is producing for the Autoeuropa customer (approximately 95% of the day) and to physically work on the MIKO Mezzanine only when it is producing for the Osnabrück customer (approximately 5% of the day). With this it is possible to eliminate the movements of the components to the upper level and the movements in the upper level, which correspond to 21,51% of operator time. Besides moving the physical stock, which has no significant costs, the only investment required for the implementation of this improvement opportunity is a Clever station, which is the information system that assists the operator in its production activities. This would cost approximately 6.000 €. By considering this cost and the total savings of this solution (21,51% of operator time), the payback period was calculated and as it was lower than 2 years, Improvement Opportunity #7 would be approved to be implemented, once the production of the MPV models ends.

Improvement Opportunity #8 arises with the objective of simplifying the flow and eliminating part of the handling of the MIKO cover components. The MIKO covers are produced in the only workstation that produces in batch, the Blend MIKO workstation. This workstation is present in the Welding Mezzanine and it produces pallet by pallet. When a pallet is finished, it is lowered to the ground floor, and stored in the warehouse. When it is needed in the MIKO Mezzanine, it is moved up from the warehouse to the mezzanine. The proposal for this improvement is to install a gravity ramp with an individual lane for each of the three most requested references (high-runners) which would directly link both mezzanines. This way, instead of the stock travelling from the Welding Mezzanine to the warehouse (clocked time of 180 seconds per transportation), and then from the warehouse to the MIKO Mezzanine (clocked time of 200 seconds per transportation), these references would always have their stock at the gravity ramp. This way, it would eliminate 1,77% of operator occupancy time in total. However, when estimating the cost associated with implementing a gravity ramp between the two mezzanines, it was concluded that this solution has a cost of €40,000, which is too heavy when compared to the total savings associated with this solution (1,77% of operator time). Since the calculated payback period was greater than 2 years, Improvement Opportunity #8 would not be accepted.

Considering only the six Improvement Opportunities that were accepted, it can be concluded that, through a total investment of 124.500,00 €, it is possible to reduce the operational costs by 2.916,80 €/year and to reduce 190,27% of operator time. Although this does not mean that the factory can directly reduce two operators per shift, this means that a significant amount of time that is used for NVA activities (waste) can, with the implementation of these improvements, be allocated to other VA activities.

5.3. Future State

After the improvement opportunities identification, it was possible to draw the Future MIFD, which can be seen in Figure 5. This Future MIFD aims to show how the flow of material and information within the factory would be, if all improvement opportunities were implemented, and to demonstrate the impact of these changes in the lead time of the component with higher lead time.

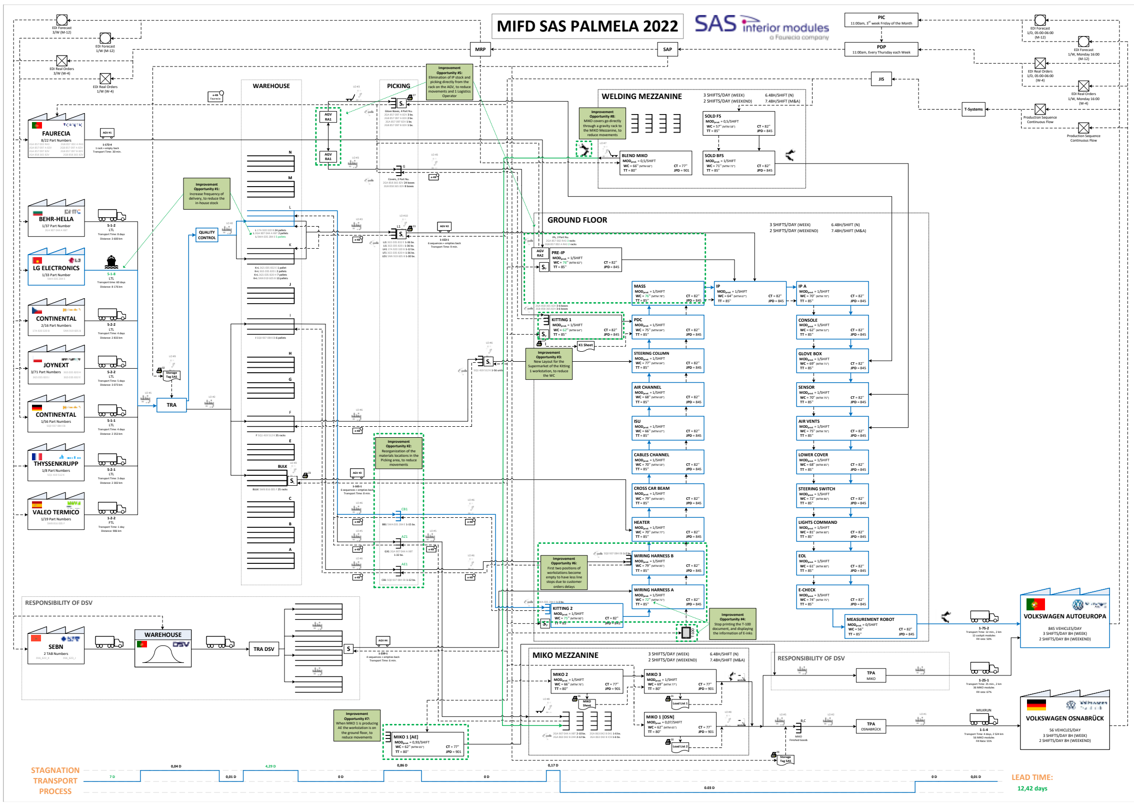

Figure 5: Future state Material and Information Flow Diagram (Future MIFD).

6. Conclusions

The main objective established for the present work was to improve SAS's production and logistics processes, by improving its processes' efficiency through the elimination of waste activities. For this, all processes were mapped, a first identification of improvement opportunities was done, and then subsequent recommendations were made regarding actions to improve the processes. Taking into account that the factory works 24 hours a day and that the implementation of the improvements would have to occur during the summer break, the author was not able to observe the results in the shop floor. Nevertheless, the impact of each improvement opportunity was estimated and it is possible to state that, after the implementation of the six improvement opportunities, and through a total investment of 124.500 €, it will be possible to reduce 190,27% of operator time in total that, until today, is used for NVA activities. In this way, it can be stated these work's objective has been achieved. By cutting waste activities, SAS's logistics and production processes become more efficient.

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