Improving Internal Logistics of a Bus Manufacturing Using the Lean Techniques

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Abstract

Purpose: This study aims to improve the reception and positioning of materials in the warehouse, as well as the internal logistics of a bus manufacturing company by acting upon the processes of supply line management.

Methodology: This study is based on the Action Research methodology which, through a practical approach, intends to generate transferrable knowledge to other organizations whose situations are similar to that of this study. The practical actions and the knowledge acquired co-create the changes needed for the improvement processes.

Findings: Through these improvements, it is possible to standardize supply and eliminate the retention of picking carts on the line, simplify the management of materials provided in supermarket boxes, improve the control of materials, and facilitate the process of picking and materials storage. A *Kanban* card-based supply system was also expanded to the bus assembly line, allowing more control over valuable materials.

Originality/value: This study has demonstrated how the implementation of Lean techniques on a bus assembly line can lead to increased consistency of supply to the line and improved working conditions, both in the production and warehouse areas. Furthermore, it has set a new standard of the internal logistics processes and the inclusion of process recording in the working instructions.

Keywords: Lean, Internal logistics, Bus manufacturing, *Kanban*, Warehouse, Logistics.

1. Introduction

The productivity of bus manufacturers in Portugal has dropped by 45% between 2015 and 2018, due to ever-increasing competition in the automotive sector. The low level of automation in most bus manufacturing processes requires well-trained workers to maintain a continuous flow of production and organization of the workspace. Despite this, the number of public transport passengers in Portugal has increased by 12%, as the need for public transportation is ever-present (Institute of Mobility and Transports, 2019).

Bus manufacturing is an activity which requires a lot of components and complex coordination processes to keep the buses flowing along the production line. The manufacturing process also demands an excellent internal supply chain to fulfil everything needed at the line side at the right time. Delays in the supply chain may cause bottlenecks, resulting in unnecessary waste, hence costs. As the delays affect the delivery times, bus manufacturers are under pressure to avoid penalties that add costs and risks of the deterioration of the company's brand image.

This paper was based on a study carried out at a bus manufacturing company located in Vila Nova de Gaia, Porto, in Portugal. The company experienced various operational issues affecting their competitiveness. The purpose of the study was to improve the internal logistics of the company through the review of different methods to supply material to the bus assembly line. The goal was to reduce the waste, enhance visual control of the line supply flow and reformulate the method used to identify warehouse stock sites. It was hoped that by effectively redesigning the line supply method, the frequency of material detours between workstations, as well as the material damage during transport, could be minimized.

This paper is organized into ten sections: Section 1 describes the context of the study undertaken and the objectives to be achieved; Section 2 presents the state of the art of the research, which includes the theoretical bases and bibliographic review; Section 3 focuses on the research methodology used; Section 4 describes the approach to data collection; Section 5 presents the analysis carried out in each process; Section 6 discusses the results obtained from the analyses; Section 7 describes each intervention that was undertaken and presents a detailed account of the solutions proposed; Section 8 details the results obtained by implementing the solutions; Section 9 highlights the discussion and Section 10 presents the conclusions.

2. Literature Review

In order to gain a fundamental understanding to support this study, bibliographic research was carried out in the focused area of process analysis and improvement, from which several relevant case studies were extracted. The aim was to better understand the implementation of Lean techniques to improve the internal operation of companies in various sectors of activity. The review was focused on the suite of tools and techniques used in the development of the work described in this paper, that have also been successfully implemented in different contexts.

The Lean techniques consist of a conceptual approach which encompasses an entire set of approaches and methodologies (Abbas, 2015; Dias *et al.*, 2019). These offer a way to reduce one or more types of waste in a production process, thus generating a competitive advantage for a company. This philosophy particularly impacts on the areas of product development, as well as management of the supply chain and shop floor and, in some cases, after-sales services (Nenni *et al.*, 2014).

The application of 5S, *Kanban* and visual management for a continuous reorganization of space and production tasks can provide significant improvements in the production performance and working conditions. The work performed by Kumar et al. (2014) shows 5S procedures that were applied to the operating range of a process that manufactures automotive parts. This led to the elimination of unnecessary tasks and a consequent increase of 50% in process productivity. Ribeiro et al. (2019) applied some Lean tools such as 5S, Visual Management, SMED and Standard Work to improve the processes and workflow in a company devoted to the production of plastic parts. They showed some saving of about 70% in the travel time into the painting production line and an increased OEE (Overall Equipment Efficiency) by 16% to 18% in four different areas within the production plant. Veres et al. (2018) used 5S to improve processes in an automotive cables production plant, concluding that a direct correlation between the 5S technique application and an increase in productivity is real, showing how this Lean tool is essential in creating the necessary frameworks, discipline, cleanliness and work organization.

Moreover, they showed that through the application of 5S technique, the company became a safer place for the workers, as detecting and preventing problems also became easier. Also, the product quality has been improved, the waste of time and cost has been reduced, and the final product meets customer requirements, thus improving the overall operations within the production plant. Mascarenhas et al. (2019) also refer that 5S implementations can induce better workers' involvement in the company's overall goals. Moreover, after the first implementations, the workers are requesting more formation in 5S techniques to enhance the whole process, providing new ideas on how to improve their workstations voluntarily. This change allows workers to acquire greater self-confidence and self-control, which enables them to start and maintain a positive cycle of continuous improvement, as the workers themselves want to know the results of the audits and be an active part of the results continuous improvement. Monteiro et al. (2017) also refer the workers' satisfaction as one of the main factors achieved through the implementation of the 5S technique together with other Lean tools such as Poke-Yoke, Visual Management and Standard Work, that proved to be efficient to achieve substantial savings in the logistics department responsible for providing raw materials to a production line.

Indeed, the 5S technique has been applied in many cases. An example of this is the work developed by Weigel (2016), who used 5S technique to redesign an airway cart. The results were clear; the airway equipment was initially stored in 4 different locations, being reduced to a single difficult airway cart. The total of parts constituting that equipment was reduced by 89%, and the cost of inventory dropped by 81%. Moreover, the equipment setup during a difficult airway scenario showed a 39% reduction in equipment set up time, as well as a 77% reduction in non–valued-added setup time, and a 74% reduction in walking distance. Thus, it remains clear that 5S is a simple technique with the potential to promote an improvement in the most diverse scenarios and sectors of activity. Indeed, as referred by Costa et al. (2018), 5S technique is the foundation of the Lean production systems and comprises five main factors. When properly implemented and put together, it will sort, straighten, shine, standardize and sustain the work environment and corresponding procedures, fostering the workers' satisfaction and work effectiveness.

When one of the main concerns is the operations within a manufacturing company, Lean has some essential tools that can help organize tasks and improve processes. The inclusion of graphical tools, such as flowcharts and spaghetti diagrams in process mapping, adds more details to their description, thus provides better support in decision-making (Domingos et al., 2016). A flowchart is typically used to translate a particular sequence of tasks or procedures in a structured way, allowing a better understanding of the whole process, even when several decisions can be taken during that process. Santos et al. (2017) used a flowchart to describe the procedure to be followed in order to decide if a heavy component part of a truck can be changed by a lighter one. By using the flowchart, the analyst or practitioner can determine whether the component can be redesigned and changed, allowing the use of other lighter materials and expeditious manufacturing processes, leading to an overall weight reduction in trucks. The different subsequent steps are shown in the flowcharts highlighting the decision paths followed in each situation through different decision steps and actions, from a starting point to the end of the process, covering all the possible scenarios considered in a system. Reniers et al. (2013) used this to show the sequence of actions and decisions to design a Threat Assessment Review Planning (TARP), making it easier to carry out the problem-solving of a company's security management. Osman et al. (2019) also take advantage of the flowchart's objectivity to illustrate a configuration and change management approach of different chillers into the same family of products. Using a flowchart, the designers can quickly reach more efficient solutions in the design of chillers, obtaining solutions to save energy, presenting smaller dimensions and producing less noise, among other features. Neves et al. (2018) and Tavares et al. (2018) also used flowcharts to illustrate procedures able to solve problems in the textile industry, both in terms of managerial concerns, as well as in the manufacturing process. Moreover, flowcharts are also insistently used in computer science to describe procedures. Fitzgerald et al. (2019) have taken advantage of the use of a flowchart to describe the steps and learning curve necessary to generate a Color Magnitude Diagram of stellar objects.

As stated by Gladysz et al. (2017), Spaghetti diagrams are a useful tool to reduce waste of time in production systems or warehouses and other time-consuming tasks which illustrating a static situation, but not describing the dynamics that usually affects the logistics systems. Thus, they proposed a dynamic Spaghetti diagram that can overcome the inconvenience, which could work together with a Real-Time Locating System supported by appropriate hardware and software. In the study performed by Silva et al. (2018), the elaboration of spaghetti diagrams to observe the flow of the picking of materials at a textile industry warehouse allowed for a consideration of the features which had to be thought in the restructuring of the storage space layout. Hys and Domagala (2018) used the Spaghetti diagram to reorganize a worksite in a company related to the automotive industry in Poland, drawing the workers movements before and after some improvements performed on the shop-floor, verifying that there were a lot of unnecessary movements performed by the workers in the initial process. The time saving was about 28.5%, and the workers' satisfaction increased due to unnecessary efforts being eliminated after the analysis of the situation and the elimination of futile movements. Senderska et al. (2017) considered the spaghetti diagram as an essential tool for tracking the movement of workers and products, allowing the identification of non-value adding activities, which could then be reduced or eliminated. Reis et al. (2016) have also applied some Lean tool to rationalize the shop-floor of a German manufacturer of electric and electronic components for the automotive industry located in Portugal, having as well used the Spaghetti diagram as a part of the solution to overcome some wastes of time found in the manufacturing process. The actions done allowed a substantial reduction (46.59%) in the time spent by the *Mizusumashi* in operations carried out in the warehouse. Moreover, these problems can be mainly related to warehouses' management, where manual picking procedures have been explored using several techniques.

As stated by Powel (2018), *Kanban* methodology integrates the Lean manufacturing tools in such a way that allows the just-in-time (JIT) production to be materialized. *Kanban* works like an order card which can be used together with standard parts supermarkets. In these supermarkets, the quantity of parts in inventory is proportional to the time needed to send an order back to the production, produce that quantity and replenish the stock. Thus, the system works based on the principle of "take one, made one", and also means that when a certain quantity of products is spent, a *Kanban* card is sent to the production in order to start producing the same parts at the desired quantity. Naufal et al. (2012) applied the *Kanban* methodology in a Malaysian company, concluding that it leads to the reduction of the lead time, minimizing as well the inventory of parts or components on the shop-floor, leading to the optimization of the storage area. As demonstrated in the work of Apreutesei et al. (2010), a successfully implemented *Kanban* card system can provide a standardized flow of supply, empowering a low inventory policy and just-in-time delivery of products, resulting in a substantial reduction of waste of time and stocks. However, the *Kanban* methodology has been adapted to other environments due to its usefulness, flexibility and easiness of implementation. Thus, there is myriad of work referring its applications, for instance, in the software development projects (Lei at al., 2017), or hospitals (Aguilar-Escobar et al., 2015), although the primary applications of *Kanban* remain in assembly lines (Yang and Zhang, 2009) and supply chains (Nakashima and Gupta, 2012).

Rosa et al. (2017a) also applied the Plan Do Check Act (PDCA) tool to monitor the manufacturing process of the production line of Bowden cables in order to illustrate the implementation of a continuous improvement cycle beginning from planning a new idea (P - Plan), implementing it (D – Do), controlling the process after implementation and comparing it with the initial solution, before getting as well new ideas (C - Check), and developing a new process (A – Act). Through a redefinition of the process, the production line achieved a 41% increase in productivity and a 29% reduction in cycle time, with the payback time being estimated at four months. However, PDCA cycle has found in many sectors that support continuous improvement processes. Prashar (2017) used PDCA to optimize the energy consumption in SMEs, achieving a saving of 0.3 GJ/t per year in the first round of improvements as a result of improvements in the vacuum system of a paper's machine. However, the actions planned in the second round of improvements, resulted in savings of USD 26,900, as a consequence of the improvement in the steam and condensation system. Tye and Wheeler (2007) also used PDCA cycle to improve the patient meal service practices in a medical center, through the analysis of the patient satisfaction with factors such as the food temperature, flavor, quality and presentation. The first plan to increase the formation of the people responsible for the meals' preparation increased the training from 27% to 73% from 2006 to 2007, also resulting in the standardization of the meals' presentation to go further to the next levels. The training sessions have evolved all process of meals' preparation, and one of the last rounds of improvements was focused on the meals' temperature. A survey carried out in the medical center allowed for concluding that the patients' overall satisfaction with meals' temperature, quality, presentation and flavor had increased significantly, but the continuous improvement process should lead to even better results in the future.

Several Lean tools have been used in previous studies, whose sequence of implementation can be deliberated to solve the existing problems. In this paper, the main problems related to materials supply process to an assembly line, quantity of material stored on the side of the assembly line, as well as the positioning of the materials into the warehouse will be investigated and improved using the appropriate Lean tools.

3. Methodology

In order to perform this study, the Action Research (AR) methodology has been selected. AR consists of seven steps: (1) Selecting the focus of the study; (2) Selecting and dissecting theories; (3) Developing research questions; (4) Collecting data; (5) Analyzing data; (6) Reporting results, and (7) Taking actions based on results (see Figure 1). These steps will be elaborated throughout the study, allowing a good match between each stage of the work and the corresponding methodology step. AR focuses on the construction of research theories which can be applied to real situations in order to respond to the needs of an organization (Eden and Ackermann, 2018; Thornhill *et al.*, 2009). These actions are then implemented, and the ensuing results are assessed. The first three steps of the AR methodology previously described will be discussed in this section, and the remainders in later sections.

Regarding the first step, clearly, the focus of this work has been defined as the improvement of the assembly lines workflow in a bus manufacturer. To achieve this goal, theoretical support has been searched, as the second step of the methodology described. Taking into account that several inefficiencies and non-value adding activities from the warehouse to the assembly lines have been previously identified and reported, some Lean tools have been established as the proper support to the solution. In this way, 5S, *kanban*, visual management and PDCA cycle have been identified as key tools to help in finding the best solution to the problem, together with other tools, such as flowcharts. The combined application of these tools will enable the attainment of the desired improvement of the assembly lines. The selection of the tools underlaid the third step of the methodology, which was the development of the research questions.

The remaining four steps of the AR methodology will be described in the next sections.

Figure 1 – Action Research Cycle (Counterclockwise direction).

4. Data Collection for Processes in Internal Logistics

4.1. Data Collection - Supply Management to Production Lines

In order to understand and document the material supply process, data regarding each supply model implemented in the production environment, as well as its general layout and work conditions, was collected.

The assembly line within the bus manufacturing plant can be divided into the body assembly to chassis, painting and finishing. Each area consists of three production lines with several workstations dedicated to the production of specific models for urban transport, tourism or airport services.

These production lines use different supply models that are decided according to the characteristics of each type of material supplied. Various factors may influence this decision, for instance, the weight and size of the material, the amount consumed, and the conditions required upon delivery to the line.

Four supply models are used to feed materials/components to the lines: picking carts, Kanban supermarket, Kanban cards and ship-to-line.

Picking materials are delivered to the line by conveyors called picking carts. These carts are filled and supplied periodically according to the specified production plan for each bus.

A Kanban supermarket supply model is suitable for small-size components such as screws, washers or nuts, which are usually consumed in large quantities. These are placed in standard-sized boxes arranged in different positions on supermarket shelves at the sides of the line. The empty boxes are moved to the last shelf on each rack; these are collected and replaced periodically by the logistics train (*mizusumashi*).

The Kanban card system is used to control adhesive materials such as glue or tapes, as well as long materials such as rubber or tubes. Each production workstation has a Kanban board, where two order cards are placed for the supply-to-the-line of each material. These are inserted into a slot on the respective board. The materials in question are stored in closed cabinets; the collection of cards and replacement of material are carried out on the same route for the collection and replacement of supermarket boxes.

The ship-to-line model allows materials to be fed directly to the line (direct line feed) by one or more warehouse operators. This usually occurs one day before they are required. Depending on their characteristics, the materials may be taken to the line using transport carts or forklifts. Some of these materials are extremely large and are delivered directly to the line by the supplier so that they never enter the warehouse. In contrast, others are supplied by the warehouse.

4.2. Data Collection – Material Reception and Storage

With regards to the material reception and storage process, the central warehouse can be divided into areas according to the various codes chosen by the section supervisors. The warehouse stored, treated, and subsequently dispatched the materials to the assembly area. Each stock location was provided with rails or identifying labels in order to define the exact position for each type of material. For instance if, for one of the lines on a picking list, a specific type of material was identified as being located at the stock site "3.50.21.F2", then the warehouse worker responsible for refill the stock would successively have to look for: area 3, rack 50, module 21, sixth shelf (F) of the module and, finally, the second position on that shelf (2). The absence of a standardized method for identifying stock sites, as well as the lack of identification in some of them, had led to inconsistent records and the difficulty in locating stock areas in the warehouse, adding the time needed by warehouse operators for picking and storage, hence increased cost.

5. Data Analysis for Processes in Internal Logistics

5.1. Data Analysis - Supply Management to Production Lines

In each of these supply models, shortcomings were identified through frequent observation. Various unassembled materials supplied through picking were often retained at the side of the line due to the mixing of materials for different workstations in each picking cart, which made the identification and segregation of these materials much more difficult. Moreover, in the current picking supply method, picking carts were supplied arbitrarily depending on each workstation, leading to a non-standardized flow of materials.

Several components supplied via supermarket Kanban boxes often underwent many detours between workstations, making it difficult to control the flow of supply. Furthermore, adhesive and long materials were supplied directly to the line whenever necessary, in the absence of a Kanban card system, suffering frequent shortages and being prone to detours between workstations. In the case of large parts such as fibers, panels and roof racks supplied directly to the line, the records of which workstations these materials were supplied to and whether they were being supplied, were often inconsistent with the reality of the production line.

This constant occurrence of shortages, detours and other time-consuming impediments made it more difficult for the company to maintain its competitiveness, in terms of productivity and profitability. While the airport services line had already been subject to several 5S interventions and supply process reworks, due to its high export demand worldwide, the urban transportation line still experienced long delays and complications in material management and transport which led to an insufficient supply, thus making it the primary target of improvements made in this work.

To address each shortcoming, continuous improvement initiatives were carried out over a period of 9 months by the logistics team, in coordination with both the production and warehouse management teams. The logistics team, along with the production planning and process engineering teams, was in charge of the planning aspects of material supply to each line as well as managing those aspects with the production and warehouse management teams. The production and warehouse management teams were in charge of operationalizing changes in each environment by aligning them with the supervisor of each workstation, who would then propagate this information to each member of the workforce.

In order to simplify and standardize the process of material supply, by means of picking, to a line with a particular multiplicity of models (line 2 of the finishing sector), an analysis of the advantages and disadvantages of selecting the most suitable method was carried out by the logistics team. Three supply methodologies were then chosen: the supply of material to each workstation for each vehicle (Single Bus Supply); the current material supply method for two vehicles, used in the case of one or more stations (Two Bus Supply); and the supply of material by FLK (Follow Lead Kit), consisted of a set of trailer carts containing materials for all the workstations, and which would then follow the bus from one workstation to the next workstation. Table 1 shows the comparison of the three supply methods.

Having undertaken an analysis of the resources required to implement each method, the next stage was to establish the picking supply method to be implemented, in order to calculate the necessary warehouse space for the picking carts. The decision matrix in Table 2 sums up the point-based assessment made of each supply method. A scoring system was agreed upon by the logistics team, to determine how significantly the supply methods have contributed to each objective, and this is represented by three different scores: 0 being ‘does not contribute’, 1 being ‘contributes moderately’ and 2 being ‘contributes fully’.

Table 1 – The pros and cons of each supply method considered

Supply method	Advantages	Disadvantages
Single-Bus	Greater control of the process (how many components in each cart per workstation)	Larger parking area is required for carts in the warehouse, regarding Two-Bus supply
	Increased visual control of unassembled components at production workstations	

	Immediate identification of route errors (task allocation)	*Mizusumashi* routes with more trailer carts (5 carts), in comparison to Two-Bus supply (3 carts)
	Less likelihood of damage to materials/components	
Two-Bus	*Mizusumashi* routes with fewer trailer carts, regarding Single Bus supply (3 carts)	Material for two different vehicles at different workstations (unnecessary material on the line)
	Need for fewer carts on the side of the line, regarding Single Bus supply (3 carts)	Less control of the process, due to a higher probability of material detours
	Need for a smaller parking zone for carts in the warehouse	More complex flow for the replacement of carts
FLK	Space gained on the side of the line (carts circulate on the line itself)	Difficult to implement on lines of great variability due to the need to design very compact carts for the specific model (all the material is supplied at once)
	Simplified *mizusumashi* routes (deliveries to one single station)	Implementation implies increased stock volume and WIP (Work-In-Progress)
		Greater probability of damage to materials (large volume of materials on conveyors)
	No need for the parallel management of components mounted along the production line	Higher probability of detours and of exchanged materials between different vehicles
		Need for more carts to ensure flow, given the high retention time in production

Table 2 – The assessment of each supply method against the objectives

Objectives	**Score**		
	Single Bus	Two-Bus	FLK
Freeing up space reserved for the supply of picking materials, thus eliminating excessive stock of material	2	0	1

Control, on the factory floor, of what was supplied, the amount, which vehicle it was sent to and whether it was assembled or not	2	0	1
Creation of standard supply flows to the line that is easy to control visually	2	1	1
Reduction in material detours by standardizing and controlling flows	2	1	1
Reduction of the damage of materials/components by enhancing picking carts, as well as the storage of components on the side of the line	1	1	1
TOTAL	9	3	5

A review of the materials supplied in supermarket boxes to the various workstations on assembly line 2 was also undertaken. The purpose was to ensure compliance with the requirements of each station, avoiding materials and components in excess on the line.

With the assistance of the work team, a review of card *Kanban* material supply in each workstation on assembly line 2 was carried out. The space dedicated to each material was estimated by considering the amount of each type of material, and the volume it occupied per unit. These volumetric needs were calculated and a clearance of 35% of that value was added in order to oversize the space and take care of future needs.

Once the review of the *Kanban* method was undertaken, the materials supplied directly to the assembly line in order to update the lists of material were then verified. This verification confirmed the materials registered on the list of materials and components generated by the ERP system software (SAP), through the contact with production and the warehouse managers. The unloading position of the material on the assembly line and the workstation to which it was attributed at the time was subsequently recorded.

5.2. Data Analysis – Material Supply and Storage

Due to the absence of a universal method for stock location identification in the warehouse, when checking-in materials from suppliers, the attributed stock locations often did not follow a logical coding sequence. This led to the unnecessary multiple coding processes, often selected without any clear criteria. These faulty identifications were then printed out on the picking and storage lists, making it more difficult for the warehouse workers to identify stock locations.

In order to quantify the overall lack of identification and based on the survey of identified and unidentified positions, the proportion of inexistent identification for a sample of five racks in a given storage area was calculated. While this measurement was being undertaken, the movements of warehouse staff during their activities of tidying and supplying was also analyzed by constructing a spaghetti diagram.

6. Reported Results for Processes in Internal Logistics

6.1. Reporting Results - Supply Management to Production Lines

Considering the described objectives, it was concluded that the Single Bus supply was the most suitable option, having scored the highest total points on the decision matrix. By supplying the material for each vehicle to each individual workstation, unassembled material is instantly identified at the side of the line and no space is wasted due to retention of picking carts. Moreover, the supply of materials can be standardized for all workstations (Figure 2), hence reducing the possibility of detours.

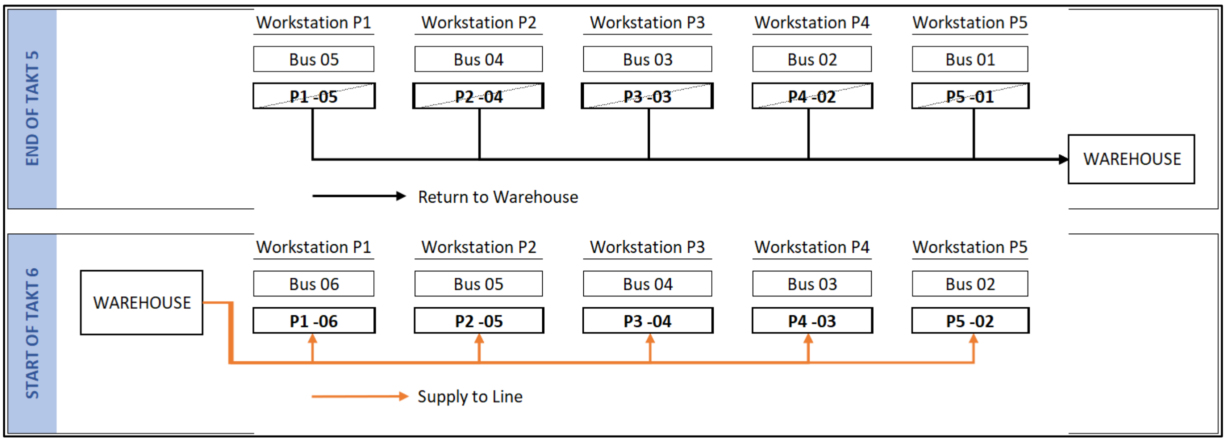

Figure 2: Example of Supply flow in a Single Bus picking methodology

From the previous resource analysis conducted for each supply method, the Single-Bus supply model would require five picking carts for each workstation to maintain a proper supply flow, for a total of 25 picking carts. Under this new method, each cart would supply a much lower volume of materials to each workstation, despite the need for more picking carts than the current two-bus supply model.

Moreover, the analysis of the number of *Kanban* cards needed has resulted in the decision to employ three closed *Kanban* cabinets, which would cover all production workstations in line 2 of the finishing section.

According to the analysis of the list of materials directly fed to the assembly line, only half (47%) of the material being registered on the schedule of demand corresponded to the actual supply. Similarly, 17% of the materials were allocated to a wrong workstation on the assembly line. Beforehand, the materials were attributed to a workstation where they were temporarily stored on the side of the line. It was therefore concluded that approximately 36% of the materials registered should be removed from the list, either because they are no longer consumed at a given workstation or because they are not supplied directly to the line. Nine types of material were supplied directly to the line but not included in the lists. These constituted 30% of the total of materials supplied in this manner.

6.2. Reporting Results – Material Supply and Storage

From the analysis of unidentified positions for a sample of five racks in a given storage area, it was found that approximately 64% of all the positions in this sample were identified inadequately. In addition, when measuring the time needed to locate stock sites in the warehouse, during the put-away and picking of materials, an average identification time of 6.52 s was recorded, with several outliers reaching up to 41s, which were found to be rather high (Table 3). As expected, these outliers belonged to stock locations nearly devoid of identification, requiring workers to search materials individually by reference tags.

Table 3 – Sample of measured stock location identification times in picking or put-away materials

STORAGE DATA COLLECTION - STOCK LOCATION IDENTIFICATION TIMES				
Storage Nº	Date	Material Reference	Stock Location	Identification Time (s)
1	11/12/2018	53882301	3.50.27.C2	4
2	12/12/2018	53812901	3.50.24.F4	4
3	13/12/2018	53906901	3.50.24.B	15
4	14/12/2018	53822601	3.50.28.C	15
5	15/12/2018	51976302	3.50.25.F	2
6	16/12/2018	53843901	3.50.25.F3	9
7	17/12/2018	53814201	3.50.24.B	26
8	18/12/2018	53822601	3.50.25.F2	10
9	19/12/2018	53761001	3.50.25.F2	5
10	20/12/2018	53302408	1.1B	41
11	21/12/2018	53812802	1.1A	1
12	22/12/2018	53770805	3.10.1.B	4
13	23/12/2018	59122071	3.30.8.D23	3
14	24/12/2018	53104603	3.30.8.C	3
15	25/12/2018	59118319	3.30.8.E9	2

The Spaghetti diagram in Figure 10 shows the movements of warehouse staff during their activities of tidying up excess components and supplying new components to the assembly lines.

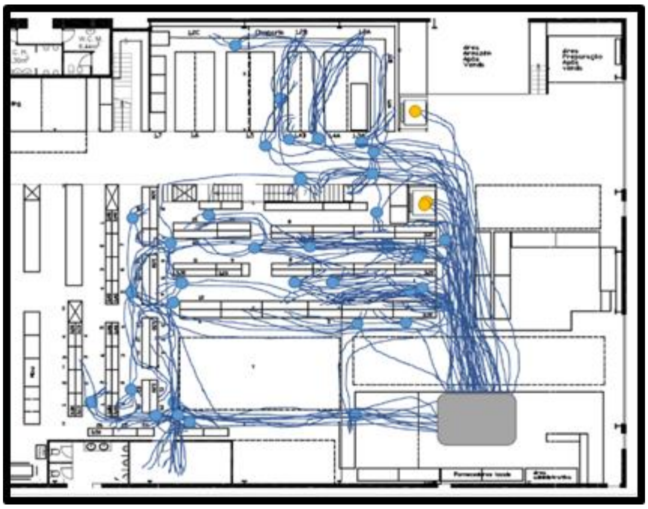

Figure 10: Spaghetti diagrams explaining movements during the operations of picking and storing the materials and components.

On the spaghetti diagram, the blue dots refer to the locations where support tables were positioned. The yellow dots indicate the use of freight elevators to transport material to the upper floors. It can be seen that a great deal of movement was detected in rack areas 3.10, 3.20 and 3.30, where smaller standard parts are stored.

7. Actions Taken for Processes in Internal Logistics

7.1. *Actions Taken – Supply Management to Production Lines*

Given the need for conveyors to suit the typology and quantity of materials/components that would now exist at each workstation on assembly line 2, the drafting and internal designs of these were executed. Considering the area occupied by each new picking cart, it was concluded that 40 m^2 of the additional warehouse storage area was deemed necessary. To free up this space, 5S interventions were implemented by the logistics team over several months, focusing on the reorganization of the warehouse layout to clear out a dedicated area for picking carts.

An area near the production line exit corridor, used mostly to temporarily store materials that require repacking (see Figure 3), was identified as the optimal location for picking cart storage. In order to clear out this area, repacking materials were then moved to warehouse area 5 (see Figure 4), located on the upper floor, from which they could be easily transported to the after-sales handling zone via a lift. As such, 5S efforts were made to: remove unnecessary materials from the repacking area; move and reorganize repacking materials on the upper floor (area 5); clean up the new picking cart storage area and upper floor repacking area; and markdown rows for each workstation and specific positions for each picking cart, enforcing a standard procedure for moving picking carts in and out of this dedicated area.

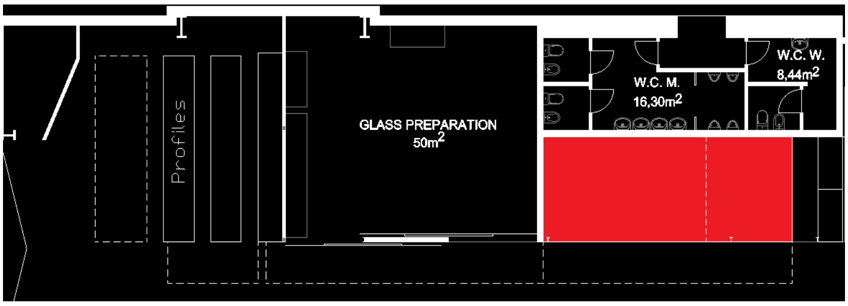

Figure 3: Area previously occupied by repacking materials and later repurposed for storing line 2 picking carts

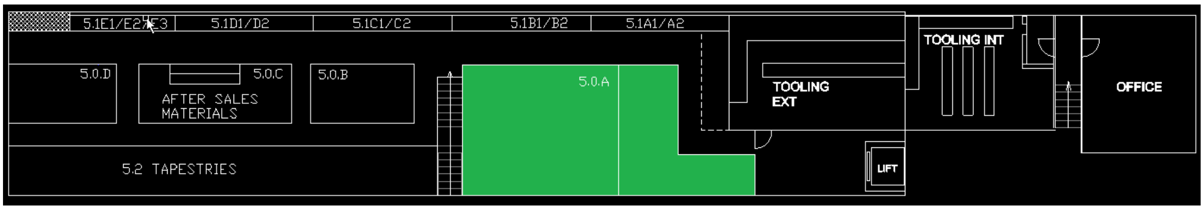

Figure 4: New area for repacking materials (warehouse 2nd floor – area 5)

On arrival at the warehouse, each cart was appropriately identified, according to the workstation and assembly line to which it was dedicated. Therefore, each cart was then positioned in the warehouse area reserved for picking carts. In order to control the unused picking material/components at each workstation, these materials/components were immediately separated at the end of each shift according to a standardized flow of picking cart collection and supply.

Closed cabinets were installed and positioned on the side of the line to store unused materials. After discussing this issue with the heads at each workstation, it was concluded that, because of the current volume of unused material at each station, two cabinets with the same dimensions would be required. Each of these would store the material coming from three different workstations. The layout of the assembly line was then updated to include the overall positioning of equipment on the side of the line (Figure 5), and positions were later proposed for the placement of these cabinets.

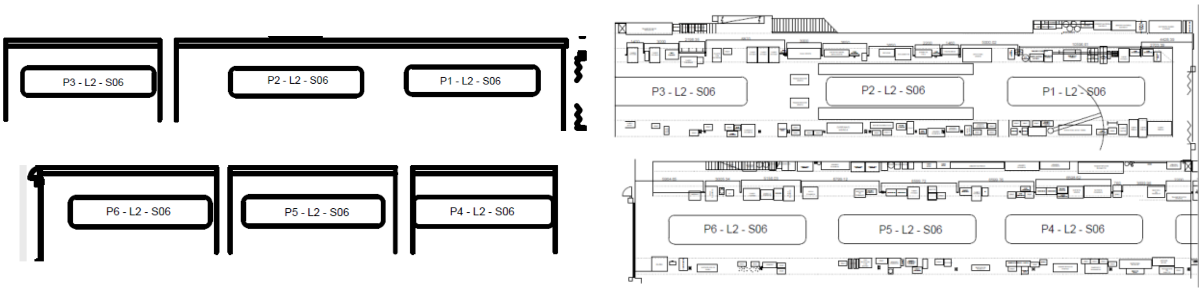

Figure 5: Old layout (left) and updated layout of production line 2 (right)

Following the review of materials supplied in supermarket boxes to the various workstations on assembly line 2, the heads of each workstation were called to define the right needs in terms of standard components for each bus model, including a small quantity for eventual damages or losses during the assembly process.

As a consequence of this intervention, more than 60 unnecessary boxes from the supermarket shelves on assembly line 2 were removed. This is equivalent to approximately 17% of the total number of boxes on the line. In order to ensure the control of the supermarket boxes, a checklist was created to record which boxes could be found in the warehouse and which were on the assembly line. The boxes were identified by their colored labels, indicating the assembly line, workstation, rack and position assigned to those boxes. The checklist was updated daily until the circulation of all the boxes had been confirmed.

In order to automate and simplify the process of consulting and managing the materials supplied by supermarket *Kanban*, with the intervention of assembling and logistics teams, respectively, a new database was also developed. Besides acting as an updated collection of information of all the materials supplied by the supermarket, several sets of subroutines were added in the form of buttons or templates, thus enabling a series of automatic operations, such as:

- Review of materials according to the line, section, workstation or reference;
- Insertion (Figure 6) or justified disposal (Figure 7) of supermarket materials, indicating which spaces are available for the placement of material on each shelf at each station, and maintaining a record of changes with the associated reason;
- Automatic preparation of data for the subsequent printing of labels for supermarket boxes.

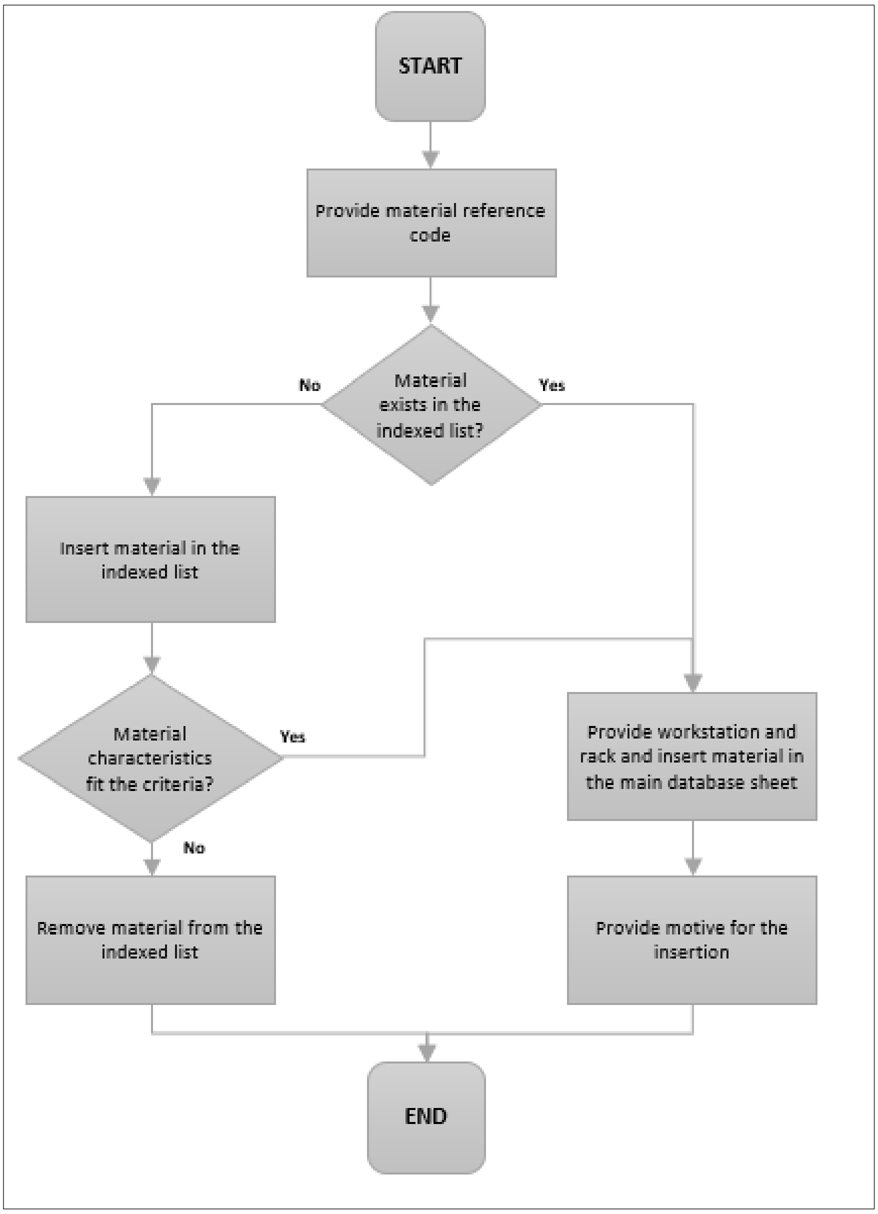

Figure 6: Flowchart for the material insertion process in the new supermarket database

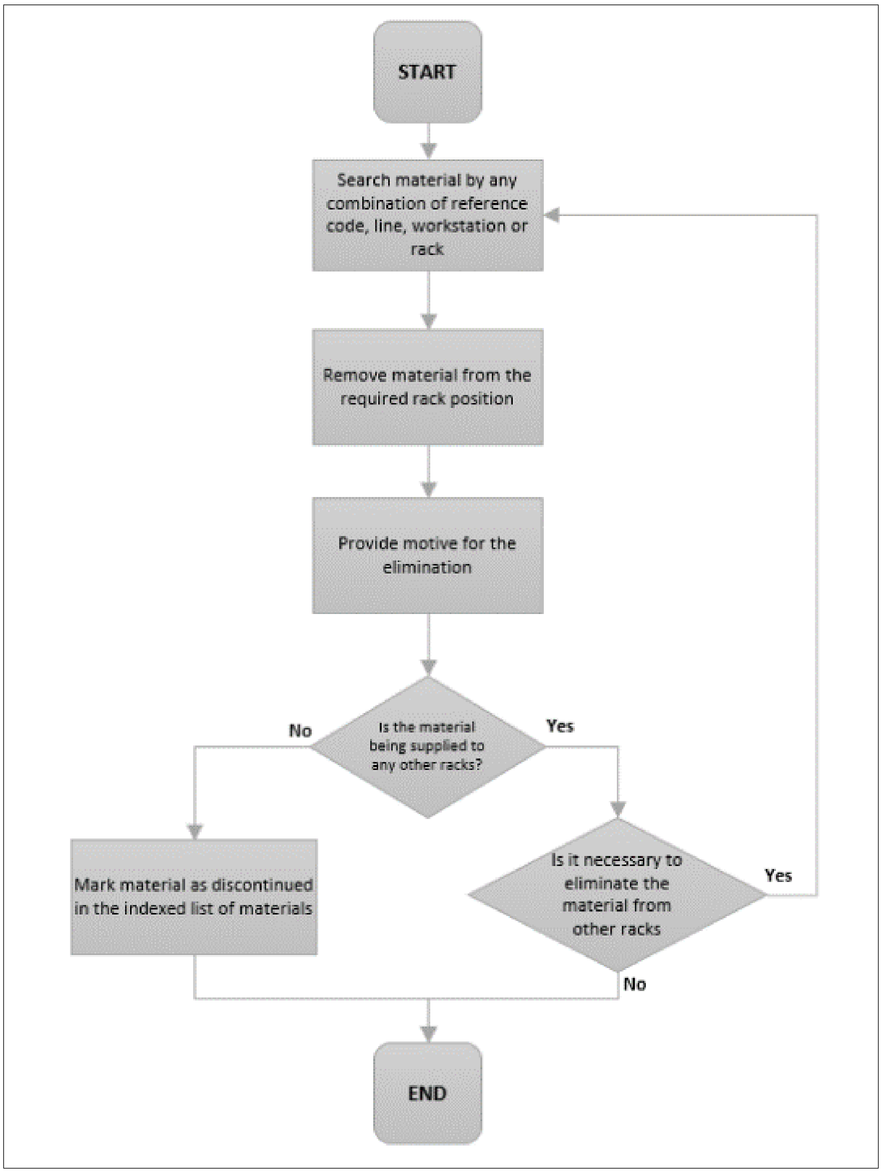

Figure 7: Flowchart for the material disposal process in the new supermarket database

Once the design of the card Kanban cabinets was completed, the cabinets were labelled; the positions for each type of material were labelled on the six shelves of each cabinet, as well as on the outer hooks for pipe and rubber placement. In addition to the closed cabinets, three *Kanban* boards were also requested for the card placement. A blue bag was attached below the board for the placement of cards, which will be collected by the *mizusumashi*. In the same manner, other information labels were placed, which are related to requirements pertaining to health and safety in the workplace, such as the use of chemical and adhesive products. Figure 8 displays one of the *Kanban* cabinets developed and its *Kanban* board.

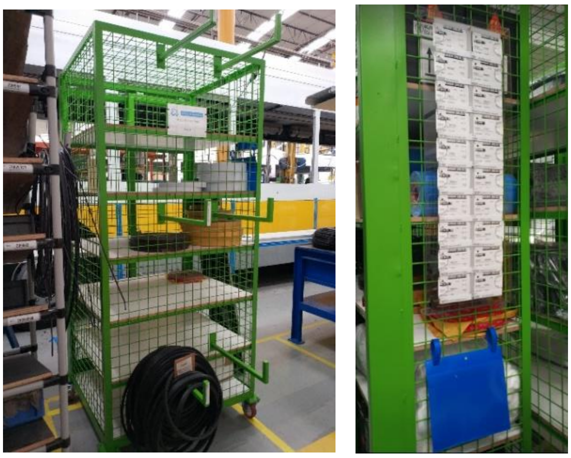

Figure 8: Example of a *Kanban* cabinet and its *Kanban* board, designed internally

Finally, a complete proposal of new lists of ship-to-line materials, for each workstation on assembly line 2, was then presented to the warehouse managers so that their records could be updated.

7.2. Actions Taken – Material Supply and Storage

In order to standardize the method for identifying stock locations, a new coding method was proposed as shown in Figure 9.

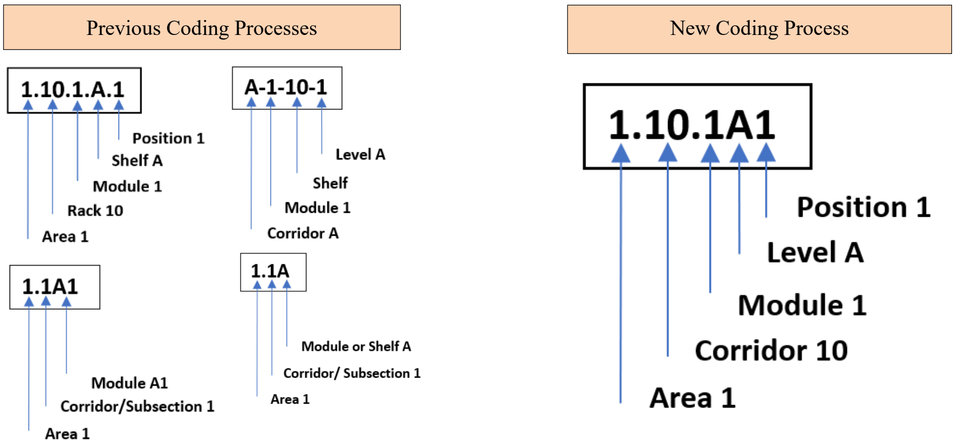

Figure 9: Old coding processes (left) and new universal coding process for warehouse stock locations (right)

Once this new coding method was fixed, and so that it could be presented to the logistics and warehouse managers, the warehouse layout was updated through *Draftsight*® software, with additional explanations provided about the new coding for each stock site.

Having been accepted by the warehouse supervisors, the 5S intervention was done in each production area over several months, where excess or unused materials were eliminated. At the same time, the positions of each type of material in all the stock locations were identified, according to the new stipulated coding, leaving additional space in each position for possible stock fluctuations.

In order to record all the positions which were unidentified in each stock location, a review of these was carried out. This was later followed by drawing a list of the size of labels required, and whether these relate to a position, corridor or module. Following the logical sequence of the survey of unidentified stock locations, a list of the quantities of plastic racks and labels needed to identify the remaining positions was made and then ordered from an external supplier. As soon as all the required materials had arrived, the implementation of new identification was carried on. This was then accompanied by the 5S interventions at the various stock sites. Figure 11 shows an example of a stock site provided with new plastic racks and appropriately identified positions.

Figure 11: Rack shelves on the upper floor of the warehouse, with appropriately identified positions.

In order to simplify the process of the visual detection of corridors and storage areas, identification plates and labels were also implemented to highlight these locations. Figure 12 shows the assembly and final appearance of some corridors.

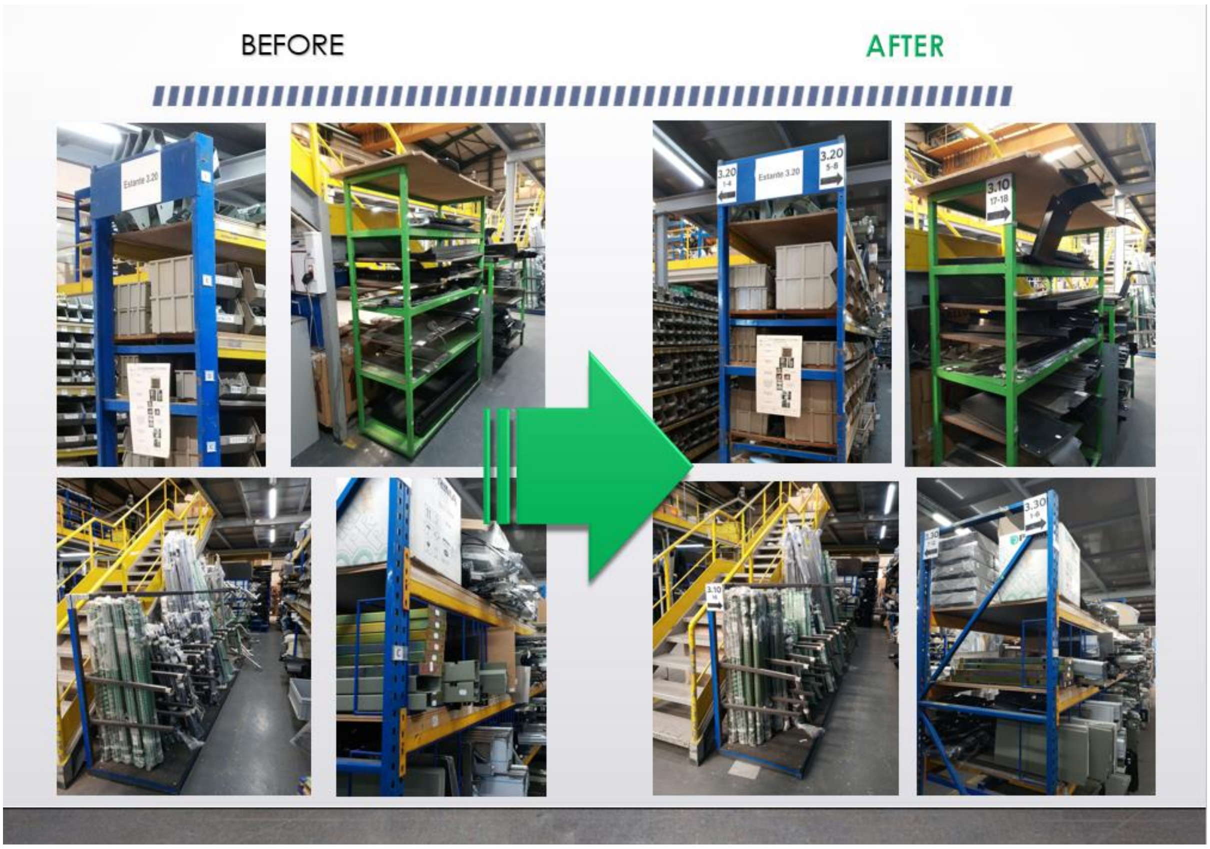

Figure 12: Final appearance of some of the corridors after new labelling has been implemented

8. Analysis of results

By implementing a new method, based on picking to supply assembly line 2, a single cart (instead of two or three previously) is always available at each workstation. This cart will be retrieved at the end of the shift. Given the space required for picking carts on the line has now been reduced, and combined with the placement of new cabinets to separate materials, a total area of about 4.32 m^2 was cleared (about 6.8% of total space on the side of the line). This was considered to be significant due to the lack of available space in the assembly area. As requested by the workstation staff, the unused picking material has now been collected in a separate cabinet, thus assuring a standard flow of parts through the production line.

The new *Kanban* system implemented in the finishing section did not exhibit any problems in the first few weeks of implementation and was fully managed in accordance with the method already used in the body assembly area. Once the proposal for changes to the method of coding stock was accepted, the reorganization of stock locations in the warehouse was subsequently done. New positions were determined for each type of material, and these were then identified after each area has been tidied-up. Since all the stock locations that need tidying-up have been mapped out, as well as all the types and quantities of labels needed for the identification process, a great deal of time was saved in this analysis, which warehouse supervisors would otherwise have had to carry out themselves. Table 4 summarizes the qualitative benefits obtained by each of the improvements implemented in this study.

Table 4 - Benefits verified in the implementation of the solutions

Improvements	Benefits
Reformulation of assembly line 2 supplying procedure through picking	▪ Standardization of material supply flow ▪ Reduction of possible damage ▪ Reduced probability of detours
Application of 5S methodologies on the side of the line	▪ More free space and improved use of the line side ▪ Better organization of storage sites on the line
Design and implementation of closed cabinets for unused picking material	▪ Improved visual control of unused material on the shop floor ▪ Disposal of waste by keeping picking carts on the side of the line
Development of a database to manage consumed material	▪ Easy consultation of information related to materials consumed and management thereof
Review of the supply of consumed material and of material supplied on demand	▪ Elimination of waste on the line and updating of records relating to the supply of materials
Extension of the *Kanban* supply system to line 2 of the finishing area	▪ Better control of adhesive or extremely long material supplied to the line
Proposal of a new method to identify stock locations	▪ Standardization of the method to identify stock locations in the warehouse
Preparation and implementation of means to identify stock locations	▪ Easier tracking of materials in the respective stock locations
Preparation and implementation of means to signal areas and corridors	▪ Easier identification of areas and corridors in the warehouse

9. Discussion

Akin to this work, several studies can be found in the literature, where the application of lean techniques has contributed to the improvement of internal logistics (de los Mozos et al, 2020; Martins et al., 2020; Freitas et al., 2019). Most of the times when warehouses experience problems with space or product rearrangement, complicated algorithms are often not needed, but rather a rudimentary reorganization of space, which is easily achieved through the application of 5S techniques and *kanban* methodology (Pena et al., 2020; Freitas et al., 2019).

As stated by Kumar et al. (2014), where 5S and *kanban* were applied in the context of automotive parts to streamline processes, the simplification of internal logistics led to an overall increase in productivity. Furthermore, the standardization of production flow by implementing a *Kanban* card system had a similar effect in the work of Apreutesei et al. (2010), with the advantage of minimizing stock retention and waste in the production line.

Close cooperation between employees and managers has contributed significantly to the continuous improvement of the internal processes, thus helping the company align their vision and objectives to the operational management. However, the resistance to change depicted by the workers is commonly referred to as a difficulty to overcome (Pinto et al., 2020). It is worth to note as a well-known principle that any process requires constant monitoring and improvement.

Some problems in logistics usually stem from the lack of space, thus requiring the application of Lean tools or the development of new management techniques in order to save space and avoid the undue immovability of components and materials inside the warehouse (de los Mozos et al. 2020). Our approach to solve this common problem was different from de los Mozos's work (de los Mozos et al., 2020), however, both methods were found effective in solving the same problem.

Industry 4.0 has gain importance in terms of the information management related to industrial operations and corresponding warehouses (Woschank and Pacher, 2020). However, Pinto et al. (2019) suggested that Lean and other tools that eliminate waste in the process and to optimize resources should be done before the implementation of Industry 4.0 principles.

If more detail is put into predicting possible post-implementation outcomes, then the process is bound to require less subsequent monitoring efforts. It is, therefore, imperative that Lean techniques and continuous improvements be part of the company's business philosophy and day-to-day operations management strategy.

10. Conclusions

This study has demonstrated how the use of Lean techniques on a manual assembly line can lead to improved working conditions, both in the production and warehouse areas. Furthermore, it has promoted the standardization of the internal logistics processes and the inclusion of procedure records in the working instructions, akin to that of Greenough & Tjahjono (2007).

Through the application of Lean tools in the context of a bus manufacturing, significant improvements have been achieved in terms of the consistency of supply to the line and the amount of material on the line side. In addition, the new procedure for the stock sites identification has substantially simplified the work of warehouse managers and operators. The practical contributions of this study are the following:

- Implementation of a standardized system to supply picking materials;
- Improved organization and conditioning of materials and conveyors, both in the production area and in the warehouse;
- Creation of procedures to enable a visual identification and management of unused materials;
- Development of an intuitive tool for the consultation and management of supermarket materials;
- Implementation of a rapid detection system of stock locations, areas and corridors in the warehouse;
- Implementation of a standardized method to identify areas and stock locations in the warehouse.

Within the company's operational scope, workers no longer needed to worry about retention of picking carts at the end-of-line or detours between workstations, as well as uncoordinated *mizusumashi* supply routes leading to lack of material in some workstations. The added simplicity in detecting warehouse stock locations and material positions, paired with a lower probability of lack of materials in stock locations due to a better organization of supply flow, allowed warehouse workers to focus more on increasing their productivity, rather than being interrupted to address numerous issues brought about by improper management or communication.

As for the management scope, the task of supervising and visually managing material flow in the production environment by both the logistics team and the heads of production was made much simpler and more effective. With standardized operational systems and tools for managing supermarket Kanban and card Kanban materials, any future manager could have a clear vision of the exact location of each material, as well as numerous other important decision-making facts about material management.

However, a persistent lack of space for operations, both in the corridors as well as on the line side, and the overall disorganization of means and equipment, were still apparent, despite many notable refinements. An additional 5S intervention is, therefore, deemed beneficial and should be complemented by the implementation of Kaizen projects. Likewise, since the warehouse stock locations are often overcrowded, and there is limited space to install conveyors and room for forklifts to maneuver, it is advisable to continue the implementation of 5S to eliminate waste and reorganize stock locations. If these prove to be insufficient, the extension of the warehouse itself may provide better storage capacity to address the growth of demand in the future, through the continuous effort of both the logistics and warehouse management teams.

In the context of the improvement of the supply process, a supply system using Kanban cards can be extended to the remaining assembly lines. If this proves to be beneficial, the single bus picking supply could also be implemented on Line 1 of the finishing area. Cabinets to separate unused material and to standardize supply and enable the visual control of material on the line could also be added by the logistics team.

As the materials tend to accumulate in the picking cabinets due to routing issues that occurred during the project, the PDCA approach is essential for maintaining a steady and uninterrupted flow of parts, which consequently will further improve control of materials picking carried out by the production and engineering teams.

An RFID system could be used to control the Kanban supermarket and identify entry into the warehouse and exit from supermarket boxes, thus eliminating unnecessary costs and ensuring a faultless supply of materials.

Bearing in mind that the automotive industry is dynamic, with a constant need to meet increasingly higher levels of demand, there will be a greater tendency for the automation of the production process by means of the implementation of cyber-physical systems, which will be integrated within a digital network. The emergence of the fourth industrial revolution (Industry 4.0) will inevitably generate a substantial impact on the manual work currently undertaken on assembly lines. To raise the workers' awareness of Industry 4.0, and prepare them for the implementation of new technological means in the workplace, it would be useful to organize training sessions or informative seminars. Continual skill development and training of shop floor personnel is a vital catalyst to increased competitiveness of today's manufacturing organizations (Tjahjono, 2009).

Moreover, the continuous and smooth workflow will increase the satisfaction of the workforce, improve their relationship with their fellow workers and stimulate their contribution to continuous improvement initiatives. This would represent a better state of mind, which could subsequently be conveyed to the society, thanks to the improved work-life balance. The improvements can also help the workers acquire new skills and transfer their knowledge acquired through this work, and further disseminate these principles in other organizations.

11. References

Abbas Mahmoud, M. (2015), “Just in time (JIT), Lean, and Toyota Production System (TPS)”, University of Technology Baghdad – Iraq.

Aguilar-Escobar, V. G., Bourque, S. and Godino-Gallego, N. (2015), “Hospital kanban system implementation: Evaluating satisfaction of nursing personnel”, Investigaciones Europeas de Dirección y Economía de la Empresa, Vol. 21 No. 3, pp. 101-110.

Apreutesei, M., Arvinte, I. R., Suciu, E. and Munteanu, D. (2010), “Application of kanban system for managing inventory”, Bulletin of the Transilvania University of Brasov. Engineering Sciences. Series I, Vol. 3, No. 52, pp. 161-166.

Costa, C., Ferreira, L. P., Sá, J. C. and Silva, F. J. G. (2018), “Implementing of 5S methodology in a metalworking company”, DAAAM International Scientific Book 2018, Chapter 01, pp. 001-012, B. Katalinic (Ed.), DAAAM International, ISBN: 978-3-902734-19-8.

de los Mozos, E. A., Lopez, N. G. (2020), “Short-term logistics management at a multinational corporation”, Procedia Manufacturing, Vol. 51, pp. 1696-1702.

Dias, J. A., Ferreira, L. P., Sá, J. C., Ribeiro, M. T. and Silva, F. J. G. (2019), “Improving The Order Fulfilment Process At A Metalwork Company”, Procedia Manufacturing, Vol. 41, pp. 1031-1038.

Domingos, D., Respício, A. and Martinho, R. (2016), “Using resource reliability in BPMN processes”, Procedia Computer Science, Vol. 100, pp. 1280-1288.

Eden, C., and Ackermann, F. (2018),”Theory into practice, practice to theory: Action research in method development”, European Journal of Operational Research, Vol. 271 No. 3, pp. 1145-1155.

Fitzgerald, K., Browne, L.-M. and Butler, R. F. (2019), “Using the Agile software development lifecycle to develop a standalone application for generating colour magnitude diagrams”, Astronomy and Computing, Vol. 28, 100283.

Freitas, A. M., Silva, F. J. G., Ferreira, L. P., Sá, J. C., Pereira, M. T., Pereira, J. (2019), “Improving efficiency in a hybrid warehouse: a case study”, Procedia Manufacturing, Vol. 38, pp. 1074-1084.

Greenough, R. M., & Tjahjono, B. (2007). An interactive electronic technical manual for an advanced aerospace assembly machine. The International Journal of Advanced Manufacturing Technology, Vol. 33 No. 9-10, pp. 1045-1055.

Hys, K., Domagala, A. (2018), “Application of spaghetti chart for production process streamlining. Case study”, Archives of Materials Science and Engineering, Vol. 89 No. 2, pp. 64-71.

Institute of Mobility and Transports. Statistical Yearbook of Mobility and Transports. Available at http://www.imt-ip.pt/sites/IMTT/Portugues/BibliotecaeArquivo/RepertorioIMT/Estatisticas/Paginas/Estatisticas.aspx (accessed December 2019)

Kumar, M. K., Rajan, A. J., Navas, R. K. B. and Rubinson, S. S. (2014), "Application of lean manufacturing in mass production system: A case study in Indian manufacturing unit", In 2014 IEEE International Conference on Industrial Engineering and Engineering Management (pp. 702-706).

Lei, H., Ganjeizadeh, F., Jayachandran, P. K. and Ozcan, P. (2017), "A statistical analysis of the effects of Scrum and Kanban on software development projects", Robotics and Computer-Integrated Manufacturing, Vol. 43, pp. 59-67.

Martins, R., Pereira, M. T., Ferreira, L. P., Sá, J. C., Silva, F. J. G. (2020). "Warehouse operations logistics improvement in a cork stopper factory", Procedia Manufacturing, Vol. 51, pp. 1723-1729.

Mascarenhas, R. F., Pimentel, C. and Rosa, M. J. (2019), "The way lean starts – a different approach to introduce lean culture and changing process with people's involvement", Procedia Manufacturing, Vol. 38, pp. 948-956.

Monteiro, J., Alves, A. C. and Carvalho, M. S. (2017), "Processes improvement applying Lean Office tools in a logistic department of a car multimedia components company", Procedia Manufacturing, Vol. 13, pp. 995-1002.

Nakashima, K. and Gupta, S. M. (2012), "A study on the risk management of multi Kanban system in a closed loop supply chain", International Journal of Production Economics, Vol. 139 No. 1, pp. 65-68.

Naufal, A., Jaffar, A., Yusoff, N. and Hayati, N. (2012), "Development of Kanban System at Local Manufacturing Company in Malaysia–Case Study", Procedia Engineering, Vol. 41, pp. 1721-1726.

Nenni, M. E., Giustiniano, L. and Pirolo, L. (2014), "Improvement of manufacturing operations through a lean management approach: a case study in the pharmaceutical industry", International Journal of Engineering Business Management, Vol. 6, No. 24.

Neves, P., Silva, F. J. G., Ferreira, L. P., Pereira, T., Gouveia, A. and Pimentel, C. (2018), "Implementing lean tools in the manufacturing process of trimmings products", Procedia Manufacturing, Vol 17, pp. 696-704.

Osman, K., Tomaš, Z. and Pervan, D. (2019), "Configuration and Change Management Approach in Product Variant Design of Chillers", Procedia CIRP, Vol. 60, pp. 464-469.

Pena, R., Ferreira, L. P., Silva, F. J. G., Sá, J. C., Fernandes, N. O., Pereira, T. (2020), "Lean manufacturing applied to a wiring production process", Procedia Manufacturing, Vol., 51, pp. 1387-1394.

Pinto, B., Silva, F. J. G., Costa , T., Campilho, R. D. S. G., Pereira, M. T. (2019), "A Strategic Model to take the First Step Towards Industry 4.0 in SMEs", Procedia Manufacturing, Vol. 38, pp. 637-645.

Pinto, G., Silva, F. J. G., Baptista, A., Fernandes, N. O., Casais, R., Carvalho, C. (2020), "TPM implementation and maintenance strategic plan – a case study", Procedia Manufacturing, Vol. 51, pp. 1423-1430.

Powell, D. J. (2018), "Kanban for Lean Production in High Mix, Low Volume Environments", IFAC-PapersOnLine, Vol. 51 No. 11, pp. 140-143.

Prashar, A. (2017), "Adopting PDCA (Plan-Do-Check-Act) cycle for energy optimization in energy-intensive SMEs", Journal of Cleaner Production, Vol. 1451, pp. 277-293.

Reis, L., Varela, L.R., Machado, J. M. and Trojanowska, J. (2016), “Application of Lean Approaches and Techniques in an Automotive Company”, The Romanian Review Precision Mechanics, Optics & Mechatronics, Vol. 50, pp. 112-119.

Reniers, G., Herdewel, D. and Wybo, J.-L. (2013), “A Threat Assessment Review Planning (TARP) decision flowchart for complex industrial areas”, Journal of Loss Prevention in the Process Industries, Vol. 26 No. 6, pp. 1662-1669.

Ribeiro, P., Sá, J. C., Ferreira, L. P., Silva, F. J. G., Pereira, M. T. and Santos, G. (2019), “The Impact of the Application of Lean Tools for Improvement of Process in a Plastic Company: a case study”, Procedia Manufacturing, Vol. 38, pp. 765-775.

Rosa, C., Silva, F. J. G. and Ferreira, L. P. (2017), “Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry”, Procedia Manufacturing, Vol. 11, pp. 1035-1042.

Santos, J., Gouveia, R. M. and Silva, F. J. G. (2017), “Designing a new sustainable approach to the change for lightweight materials in structural components used in truck industry”, Journal of Cleaner Production, Vol. 164, pp. 115-123.

Senderska, K., Mareš, A. and Václav, Š. (2017) “Spaghetti Diagram Application for workers`Movement Analysis”, UPB Scientific Bulletin, Series D, Vol. 79 No. 1, pp. 139-150.

Silva, T., Pereira, T., Ferreira, L. P. and Silva, F. J. G. (2018), “Improving the Multi-Brand Channel Distribution of a Fashion Retailer”, Procedia Manufacturing, Vol. 17, pp. 655-662.

Tavares, C., Silva, F. J. G., Correia, A. I., Pereira, T., Ferreira, L. P. and de Almeida, F. (2018), “Study On The Optimization Of The Textile Coloristic Performance Of The Bleaching Process Using Pad-Steam”, Procedia Manufacturing, Vol. 17, pp. 758-765.

Thornhill, A., Saunders, M., and Lewis, P. (2009), “Research methods for business students”, Prentice Hall: London.

Tjahjono, B. (2009). “Supporting shop floor workers with a multimedia task-oriented information system”. Computers in Industry, Vol. 60 No. 4, pp. 257-265.

Tye, M. J. and Wheeler, W. E. (2007), “Applying FOCUS-PDCA Methodology to Imrpove Patient Meal Service Practices”, Journal of the American Dietetic Association, Vol. 107 No. 8, A71.

Veres, C., Marian, L., Moica, S. and Al-Akel, K. (2018), “Case study concerning 5S method impact in an automotive company”, Procedia Manufacturing, Vol. 22, pp. 900-905.

Weigel, W. A. (2016), “Redesigning an airway cart using lean methodology”, Journal of Clinical Anesthesia, Vol. 33, pp. 273-282.

Woschank, M., Pacher, C. (2020), “Teaching and Learning Methods in the Context of Industrial Logistics Engineering Education”, Procedia Manufacturing, Vol. 51, pp. 1709-1716.

Yang, L. and Zhang, X.-p. (2009), “Design and Application of Kanban Control System in a Multi-Stage, Mixed-Model Assembly Line”, Systems Engineering - Theory & Practice, Vol. 29 No. 9, pp. 64-72.