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Industry 4.0 and Lean Production

Proposal to change the layout in a job shop environment in a beverage filling machinery industry

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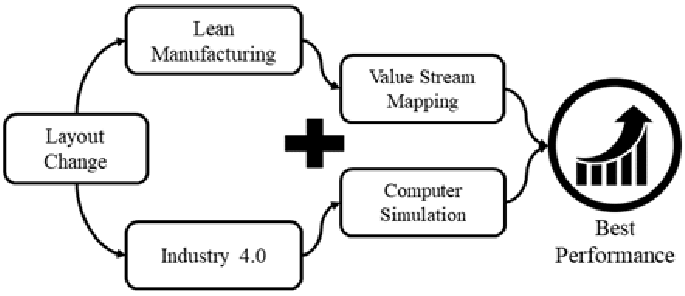

Abstract: The decision-making process in organizations has been the subject of several researchers and managers and much has been explored on the topic, seeking methodologies with a focus on increasing performance and productivity while keeping them competitive in the market. The objective of this work was to apply VSM combined with computer simulation of discrete events as tools to guide decision-making to change the job shop layout of a special machinery company, where the need to make changes in the Welding CDI sector arose, given its importance for the company. Through VSM it was possible to highlight current state problems and seek solutions to correct them. Then, with computer simulation, a scenario was designed in a future state, allowing the results to be compared. As a result, the proposed layout presented a 75% reduction in internal displacement between resources, a 7% increase in the number of packages processed, a 19% reduction in package delivery lead time and a significant improvement in equipment utilization. The application of VSM combined with computer simulation provides greater assertiveness in decision making, as it allows you to identify current problems and test alternatives and future scenarios even before implementing them.

Keywords: Layout, methodologies, simulation, value stream mapping.

Introduction

In the current global manufacturing scenario, every organization wants to meet the needs of its customers to preserve its position in the market [1]. The production layout or physical arrangement of industrial facilities has a great impact on the company's performance. A flexible manufacturing system consists of a movement linking parts to workstations [2]. Industrial production layouts are defined according to the product flow on the production line in four categories: fixed layout, process layout, product layout and cell layout. The process layout (job-shop) is used when many different products are manufactured and when demand is not stable. However, the use of this layout accentuates the increase of losses in the process [3].

Identifying and eliminating activities that do not add value is the key to Lean Manufacturing. Wastes that should be eliminated include overproduction, excess inventory, delay, transportation, rework and underutilization of people and facilities [4]. Industries must focus on minimizing waste to increase their productivity, so Lean Manufacturing provides an extensive set of tools and techniques to achieve this goal [5]. Value Stream Mapping (VSM) is considered one of the most significant methods of Lean Manufacturing, it is based on a visual process that allows the parties involved to visualize and understand the process flows, in order to identify and recognize waste and allow its elimination [6].

The VSM is separated into two stages: current state map and future state map, the current state map is structured after observing current activities and identifying activities that do not add value to the operation. The future state map is structured to show the effect of eliminating losses in the process [4]. With the advancement of computer technologies, several tools have emerged to support manufacturing management, these tools help in data collection, enabling greater assertiveness in project structuring. With the application of the simulation method, more specific data to study the possibilities of future production can be visualized, in order to achieve a more optimized production process [7].

One simulation tool is FlexSim®, designed to evaluate flexible manufacturing systems. It achieves independence between the data model representing the Flexible Manufacturing System (FMS) and the simulation model itself by using a relational database management system to define the system being simulated [2]. In addition, it makes modeling easy and convenient, the basic simulation steps can be divided into six steps: layout construction, definition of process logistics, parameter definition, model execution, simulation and analysis of results [8].

In this scenario, it is important to unify methods to properly design a physical arrangement. Inadequate projects will directly impact the performance of the organization.

The production flow is a challenge for the special machinery sector, as the product is customized according to the customer's needs. This methodology aims to help smooth the production flow, minimizing movement and improving adherence to equipment delivery.

Based on this, this article aims to propose a change in the job-shop layout of a sector of a special machinery industry, using Lean Manufacturing tools such as Value Stream Mapping combined with computational simulation in order to obtain a result more assertive, eliminating process losses and increasing sector availability.

The study in question was divided into 5 sections, namely: introductory chapter, theoretical framework, research method, results and conclusions.

Theoretical framework

Layout

For a manufacturing company to sustain its productivity in a competitive environment and under volatile demand conditions, its production process must be configured correctly. The ability to design and operate manufacturing facilities that can quickly and effectively adapt to technological and marketing changes is becoming increasingly important to organizations' success. Therefore, layouts or physical arrangements must be able to exhibit high levels of flexibility and robustness to deal with significant changes in their operational requirements [9].

Layout is the physical arrangement of the many transformation resources involved in a manufacturing process, and their supporting units. It is the definition of where to place equipment, jobs, people and all facilities [10]. Layout study takes into account the passage of products and/or information from one resource to another, transport alternatives, the priority of interactions and costs. The study also observes the distances between the resources and the production flow in order to avoid the formation of bottlenecks due to arrangements that hinder the flow of products between the resources [3].

According to the needs of the organization and the type of process, it is possible to define the type of layout to be applied. There are several types of industrial layouts, however, they derive from four basic types, namely: (I) Layout in Line or by Product; (II) Functional or Process Layout; (III) Cellular Layout or Manufacturing Cells and (IV) Fixed Position or Positional Layout [11]. Product Layout is used for systems with high production volumes and low product variety. The facilities are organized according to the sequence of successive manufacturing operations. The Layout by Process, also known as Job Shop, groups facilities with similar functions (resources of the same type). This organization is usually considered adequate when there is a wide variety of products. In Cellular Layout, machines are grouped into cells to process product families. In the Fixed Layout, the products generally circulate within the production facilities (machines, workers, etc.), in this type of layout, the product does not move, it is the resources that move to carry out operations on the product [12].

The definition of the ideal type of project layout and execution must be in line with the company's needs, creating an environment where production techniques can be implemented, in order to guarantee business growth. For this, numerous Lean Manufacturing techniques help in decision-making, such as Value Stream Mapping, a method that helps to identify and eliminate losses in the process.

Value Stream Mapping (VSM)

Value Stream Mapping is a method used to analyze and map processes, allowing losses to be reduced [13]. Initially developed with the aim of "helping researchers or practitioners to identify wastes in individual value streams and therefore find a suitable way to eliminate them" [14]. VSM has proven to be a very effective technique, which provides the organization with visualization, analysis and reorganization for planning, helping to organize and manage the principles of lean implementation [1].

The Value Stream Mapping method helps to identify bottlenecks and losses within the process and in the stages of activities [4]. The VSM methodology is used to create a common base allowing production to process and eliminate all operations that do not add value such as overproduction, waiting, transport, unnecessary movement times, unnecessary inventories and defective products [15].

The secret of VSM is in the simplicity of the method. A typical value stream mapping project is carried out in four phases: (I) selection of a product family - a group of products with common or similar process sequences is selected for the mapping procedure; (II) current state mapping – the current process is visualized and analyzed; (III) future state mapping – one or more possible lean process reorganizations are developed and visualized; (IV) definition of a work plan to reach the future state [16]. In this context, the final objective of the VSM is not only to identify the waste evidenced in the current state map, but also to eliminate them through the implementation of its indications to obtain an efficient future map [6]. In this way, the VSM ends up facilitating more thoughtful decisions to improve the value stream [17].

Value Stream Mapping (VSM) is considered essential for Lean Manufacturing, as it is a method that allows the visualization, documentation and understanding of process flows. It also encompasses a variety of management practices, such as just in time, quality systems, supply systems, among others [18]. Despite being fundamental for Lean Manufacturing, the application of VSM has the following shortcomings: (I) it is a static tool and presents a picture of the process on a given day, thus, it tends to vary according to the situation in which the factory is located. finds; (II) the future of VSM is based on the claim that all problems will be solved, however this may not happen in reality; (III) estimated targets may not be achieved [15]. In this context, simulation can contribute to exploring the full potential of VSM, the combination of simulation with traditional value stream mapping techniques makes it possible to assess the performance of a new layout more assertively [19].

Simulation

Industry 4.0 refers to the fourth industrial revolution, which leads to smart, connected and decentralized production. Its purpose is also the integration of intelligent machine tools and industrial robots in flexible production systems and the use of new software for simulation, monitoring and control of production processes [20]. Simulation is a resource widely used in several segments and helps to test hypotheses by evaluating possible scenarios without modifications to the physical system [13].

Using simulation can provide a way to explore the various opportunities for process improvements and verify the impact of proposed changes even before implementation [21]. The application of simulation software can improve the quality of solutions in a short period of time. Simulation is not only able to assess the relative difference between the process in its current and suggested form, but it can also confirm and strengthen our view of all areas that need improvement [22].

Carrying out a system simulation is one of the ways to reduce costs in planning, with the purpose of predicting divergences and understanding the technical and economic feasibility of what is intended to be implemented [23]. Simulation thus becomes an important and efficient method in manufacturing, applied in production systems, simulation can provide crucial answers and can reduce system costs [24]. These particularities end up making the method suitable for evaluating layout changes, as they bring accurate data and can maximize profits [25].

The steps for developing the simulation are as follows: formulating the problem, collecting data, defining and validating the model, building and verifying the computer program, carrying out the pilot project, validating the model, designing the experiments, carrying out the simulation runs, analysis of results and documentation and implementation [26]. The advantages of using simulation are justified by the following factors: (I) productivity gains with the development of projects through simulation; (II) amount of information to enable a simulation analysis of different scenarios; (III) possibility of using animations during the simulation process, in order to facilitate the visualization of what is being modeled; (IV) the simulated model behaves similarly to the real system [13].

The insertion of Industry 4.0 does not replace Lean Manufacturing, but it contributes to increasing the maturity of the program in organizations. VSM is a "paper and pencil" method, both the current state map and the future state map are process models drawn on paper [16]. Industry 4.0 can improve VSM with simulation, helping to reduce movements, reducing lead times, making it possible to test new layouts and verify better ways of production [27].

The simulation of discrete events, integrated with the VSM, makes it possible to determine the limitations of complex systems, also allowing to observe the performance of the proposed solution in relation to the flow time.

Experimental Section

This work proposes, through Value Stream Mapping (VSM) and computer simulation of discrete events, the change of layout of the Welding CDI sector of a beverage filling machinery industry located in Serra Gaúcha, focusing its activities on supplying of complete and customized solutions for its customers.

The proposal aims to identify and eliminate process losses, increasing the availability of operations. The current layout of the sector is Job Shop, which ends up making the process more difficult due to the movement of parts around the sector.

The choice of this sector was due to its importance for the company, basically all parts of all equipment manufactured by the company need to go through the processes that are located in this sector. The sector is responsible for stainless steel welding processes and finishing processes, such as polishing, electropolishing, glass microsphere blasting, shot blasting and painting.

The company uses the package methodology for movement, delivery rhythm and control of parts, as shown in Figure 1.

Figure 1. Parts Pack.

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It is a method based on the concepts of the Theory of Constraints and Continuous Flow, methods used with the aim of reducing bottlenecks and increasing the company's overall productivity. Packages are "clusterizations" of parts with the same DNA. DNA are mapped and strategically defined characteristics for better production flow efficiency, such as: part geometry, raw material, flows, workload and lead time.

With the implementation of this methodology, it was necessary to create an Internal Distribution Center (CDI) for each sector of the company to consolidate the production packages. This also happens with the Welding CDI sector, so every study takes into account the distribution and movement of packages.

In this way, all activities involved in the sector were analyzed by those involved who have roles as process engineering coordinator, production coordinator, PCP analyst and operators, and are described in Figure 2, as follows:

unsystematic observation: the researcher observes and collects current data;

indirect observation: the researcher has no effective participation;

interview: the researcher collects information from the process operators;

analysis of existing documents;

data collection, through chrono analysis and production recording by the system.

The theoretical study was carried out from March 1, 2023 to May 7, 2023, followed by the practical study that took place from May 10 to July 30, 2023.

With the help of the sector's operational procedures, it was possible to describe the internal processes and, based on the established process flowchart, verify the operation on site.

Next, data was collected and grouped (package cycle time, value addition time, availability) through chronoanalysis and production notes recorded in the ERP and MES systems.

With the data, it was possible to draw a map of the current state, and carry out a study of the mapped processes, enabling the identification of losses. Afterwards, a simulation of the future process was carried out, using the FlexSim® software, a tool that met the proposed objective of measuring the rate of movement of packages through the studied sector.

Results and Discussion

The high fluctuation of demands in companies has contributed to decision-making about the manufacturing process, considering the characteristics of flexibility combined with quality, productivity and cost.

Thus, the article has the challenge of finding the best physical arrangement, with the objective of reducing the time for moving packages within the production flow, and consequently increasing the availability of processes.

In this way, a survey was carried out of the equipment with the greatest demand during 1 year of production, namely: Linear Fillers, Rotary Fillers, Can Fillers, Packers, Palletizers, Self-Adhesive Labelers, BOPP Labelers, Washers, Pasteurizers, Boxers, Depalletizers, Wrappers, Tanks and Carbonators. Data regarding the number of packages per equipment are described in Table 1.

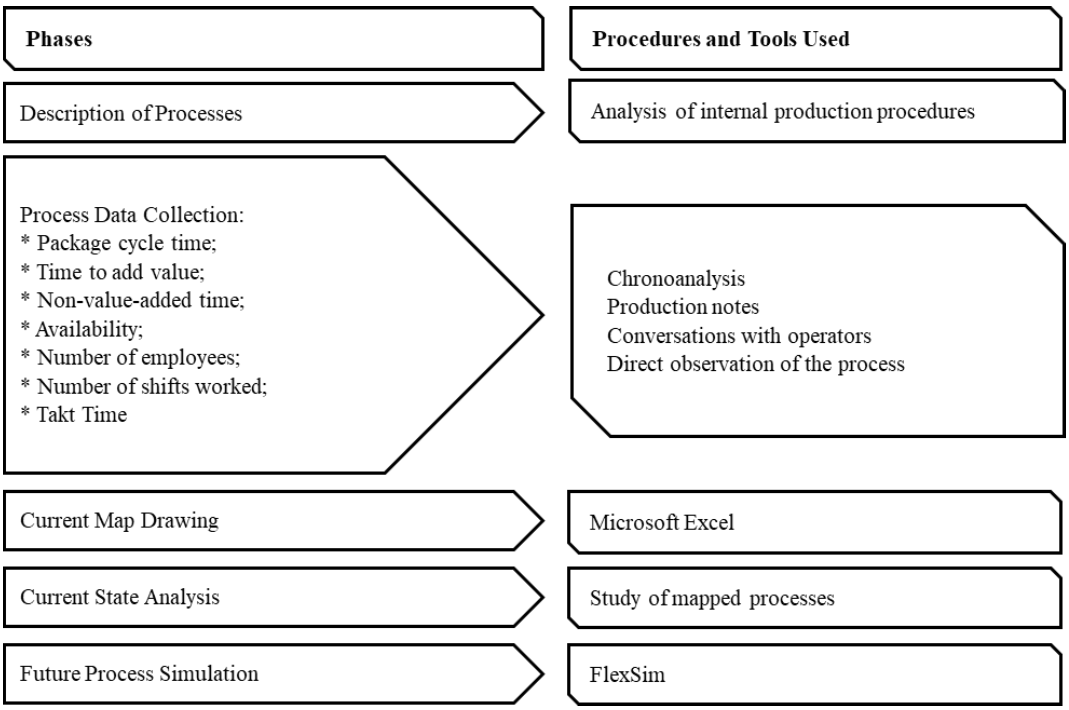

Figure 2. Steps of the methodology used.

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Table 1. Annual package demand.

Product	Annual Demand	Quantity of Packages per Equipment	Package/year	80% Efficiency
Linear Fillers	9	27	243	195
Rotary Fillers	30	27	810	648
Can Fillers	6	27	162	130
Packers	16	16	256	205
Palletizers	5	28	140	112
Self-adhesive Labeling Machines	10	12	120	96
BOPP Labellers	10	12	120	96
Washers	6	9	54	43
Pasteurizers	6	14	84	67
Packing Machines	2	16	32	26
Depalletizers	7	18	126	101
Wrappers	2	20	40	32
Tanks	50	6	300	240
Carbonators	7	4	28	22
		Total Packages per Year		**2013**

The respective values were obtained from the collection of data from the EPR and MES system that monitor production. Other information was collected through visits to the factory floor, to visualize the production process and collect information that complements the research, such as dimensions, displacements between resources, cycle times, in order to cross information with production notes. Conversations with operators and leaders were also held, to understand which factors impact the sector's production process.

Current state drawing

For the elaboration of the current VSM, Excel software was used. The VSM shows that the production flow is composed of nine stations: Package Separation (CDI Solda); Jet shot; Painting; Stainless steel welding; Polishing; Washing; Glass Microsphere Jet; Electropolishing and Consolidation of Packages.

The production flow in the sector happens in a pushed way, in this way, each station performs its operation without making sure that the next operation needs the material. This ultimately results in a large number of in-flow inventory. In Figure S1 (available at supplementary material), the current layout of the sector is shown, where the processes that are part of the studied sector are highlighted in blue. In Figure S2 (supplementary material), the VSM of the current state is shown and in Figure S3 (supplementary material), the critical path of the package is shown, in the same way, of the current state.

As can be seen in Figure S3 (supplementary material), packages that do not have a glass microsphere blasting operation travel 197 meters within the sector. Packaging that has a glass microsphere blasting operation has a displacement of 532 meters, being considered critical packaging. This makes packets a long way to processing.

Often causing lost parts along the way, damaged parts during transit and waiting to be shipped.

As can be seen in Figure S3, packages that do not have a glass microsphere blasting operation travel 197 meters within the sector. On the other hand, the packages that have a glass microsphere blasting operation present a displacement of 532 meters, being considered the critical package. This causes packages to have a high offset until processing. Often, causing loss of parts along the way, parts are damaged during transport, and waits for transport.

Loss analysis

Through the elaboration and analysis of the current state it was possible to identify the losses that occur in the flow. With this, it was possible to draw up the map of the future state, with proposals for layout improvements aimed at reducing displacements.

Due to losses in the process, package delivery adherence is often compromised. The losses identified in the VSM are described in Table 2.

It is possible to identify through table 2 that around 64% of process losses are related to waiting and moving packages. These losses end up directly affecting the sector's package delivery adherence, causing delays in delivery and consequently delays in final assembly of equipment.

Simulation of the current state

The method used in this work was elaborated through Computational Simulation in FlexSim®, which allows simulating the process in a way that approximates the operation of the real flow.

During the construction of the model, simplifications were necessary due to the complexity of the processes, such as

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Table 3, it is possible to verify how the times vary from one package to another.

For this reason, it was decided to adopt average manufacturing times for each job, based on the sector's schedule. The average times were calculated based on the production of one month of work, the same period used for the simulation. It should be noted that in the processes of polishing, electropolishing, washing, glass microsphere jetting, shot blasting and painting, the parts are grouped and processed in a batch. The average times for the stainless steel welding process were adopted based on the programming of parts for specific equipment that was a priority in the analyzed period. Table 4 presents the average times, in hours, used for each productive resource.

Table 2. Losses in the process.

Resource	Losses	Causes
Receiving Packages	Wait	Equipment packages that have assembly replanning end up waiting for release.
	Wait	Packages with a lack of parts end up waiting for the shortages to be later placed in the flow.
	Structuring of Packages	Packages are formed by the product structure and not by processes, so the packages go through all the stations, even without processing.
Polishing	Reworks	Final finishing has a high rework and crossing rate.
Painting	Reworks	Final finishing has a high rework and crossing rate.
	Wait	As the carbon welding sector is located in another pavilion, on rainy days it is not possible to send the parts for painting.
Glass Microsphere Blasting	Movement	Excess movement of parts, consequently parts are damaged and lost.
	Wait	As the glass microsphere sector is located in another pavilion, on rainy days it is not possible to send the pieces for processing.
Package Consolidation	Movement	Excess movement of parts, consequently parts are lost.
	Reworks	Parts are damaged in transit.
	Wait	Packs missing purchased components.

packages with postponed deadlines, scheduled stops such as meetings, and rejected parts due to lack of previous operations, but which do not have a direct impact on the simulation, as The objective of the study is to evaluate the sector's production flow and losses related to package movements. After structuring the model, all input and output parameters are defined [28]. Figure S4 (supplementary material), shows the simulation of the current state.

As already mentioned, the company uses the package methodology for handling, delivery pace and control of parts, so the packages have different parts and production times. In

Table 4. Average operating times.

Resource	Average Operating Time
Polishing	02:20:00
Electropolishing	00:30:00
Washing	00:30:00
Glass Microsphere Jet	00:10:00
Shot Blasting and Painting	00:15:00
Solder	03:56:00

After this definition, the setup and operation times were programmed for each resource. Figure 3 shows the function used to record time in the FlexSim® software.

The simulation data compared to the real one was very close. With VSM, the data found for production was 172 packages per month, while in the simulation it was 168 packages per month, a difference of 2.32%. This small difference is due to simplifications in the structuring of the simulation, but which has no impact for the purpose of the work.

Through the simulation, it was possible to confirm that the packages spend a lot of time in motion, the same information collected in the traditional VSM. Likewise, the values obtained by the VSM and the simulation were approximate.

Table 3. Time difference between packages.

Package	Polishing Time	Electropolishing Time	Washing Time	Jet M. Time	Painting Time	Soldering Time
LR 12.1	00:00:00	00:00:00	00:05:00	00:00:00	00:00:00	00:33:00
ME 30	02:34:00	00:00:00	00:00:00	00:06:00	01:02:00	00:51:00
NB 7.1	00:00:00	00:28:00	00:21:20	00:13:00	00:40:00	00:00:00
NI 10.2	00:45:00	00:19:00	00:16:00	00:41:00	05:43:00	03:36:00
DE 3.2	00:58:00	00:06:00	00:08:00	00:29:00	02:30:00	02:48:00
GU 26	00:00:00	00:00:00	00:27:30	01:11:00	04:43:00	00:51:00
GL 28.1	03:20:00	00:43:00	00:33:00	00:00:00	01:14:00	00:00:00
FT 13	01:25:00	00:12:30	00:00:00	02:30:00	06:16:00	06:14:50
BM 14.2	02:15:00	00:16:00	00:20:00	00:39:30	00:00:00	05:19:30
JW 6	00:36:00	00:05:00	00:09:00	00:41:00	09:21:00	03:05:30

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For the package with Glass Microsphere Jet operation, the data obtained with the VSM was 532 meters of delivery, while in the simulation it was 545,57 meters of delivery, a difference of 2,5%. For packages without Glass Microsphere Jet operation, the data obtained with the VSM was 197 meters of delivery, while in the computer simulation it was 201,25 meters of delivery, a difference of 2,1%.

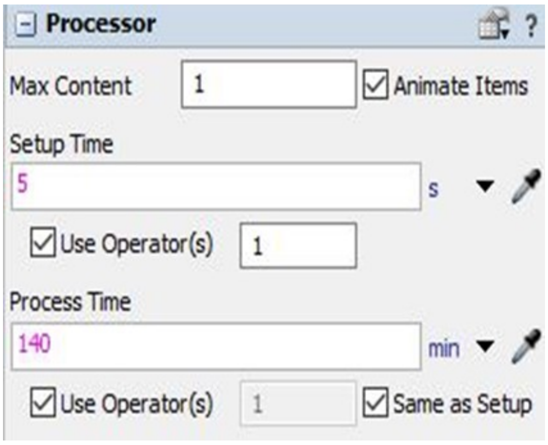

Figure 3. Time recorded.

Regarding the occupancy rate of the jobs, Figure 4 shows that the Shot Blasting and Painting are being well used, since they have an occupancy rate greater than 89%. It also shows that Polishing is being well used, reaching 98% occupancy. At the same time, it demonstrates that the Welding Booth 1, Welding Booth 2, Welding Booth 3, Electro Polishing, Parts Washing and Glass Microsphere Jet have low utilization, since they have a waiting time greater than the processing. This is justified by the displacement in which the packages need to travel within the flow.

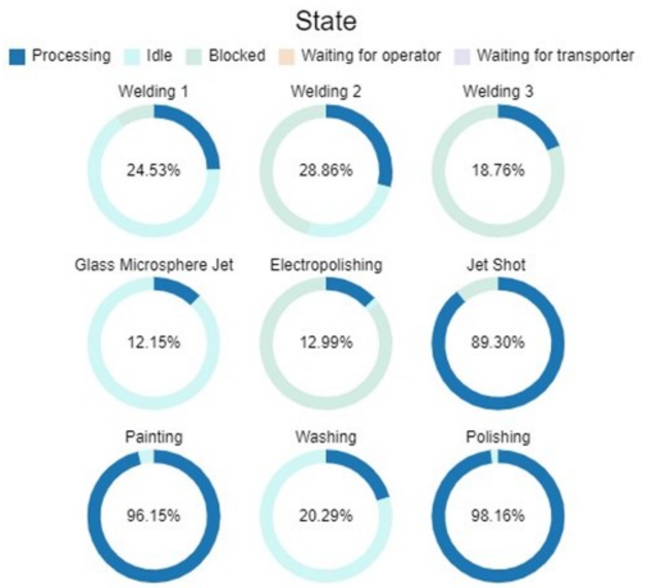

Figure 4. Resource occupancy rate in the current simulation.

As for the lead time of the packages, the results obtained by the traditional VSM and by the simulation had practically the same value on the days that the packages need to be consolidated. In VSM the lead time was 20 days, while the value found in the simulation was 19.52 days.

Future state simulation

From the VSM and the simulation of the current state, opportunities for improvement were raised to reduce the movement of packages and increase the use of equipment. Based on these analyses, a simulation was set up using opportunities for improvements in the physical layout of the sector.

As mentioned in VSM, PERT, and in the current state simulation, the biggest problem with the process is the movement of packages, which need to travel great distances between processes. Therefore, in the new layout, it was proposed to change the location of the CDI, the Glass Microsphere Blasting Cabinet, the Parts Washing and the Package Consolidation. The CDI now occupies an area that is currently free, a location that can be considered prime, since it is located at the entrance to the sector, thus, when packages arrive for processing, they do not need to travel a distance of 33 meters to be separated and prepared to enter the line.

Another proposal for alteration is the glass microsphere blasting booth, which is currently located in another pavilion, causing large displacements for processing. With this change, packages will not need to travel 532 meters to carry out the operation. Parts washing and package consolidation will also have their positions changed, with the aim of making the arrangement more appropriate to the new flow. In Figure S5 (supplementary material), the proposed layout is presented and, next, Figure S6 (supplementary material), presents the simulation of the proposed layout.

Through Simulation in FlexSim®, data were obtained making it possible to compare the current state with the future. The times used for each operation in the future state were the same applied in the simulation of the current state. The production per month found in VSM was 172 packages, in the current state simulation it was 168 packages, while in the future state simulation it was 184 packages per month.

As mentioned earlier, the production increases considerably applying the suggested proposals, if we compare the values obtained in the VSM and the simulation of the proposed layout, the production would have an increase of 7%. This result obtained with the package methodology is very significant for the company, because, as already mentioned, the packages have several components with similar geometries, flows, workload and lead time, and can have up to 50 pieces in each package. Therefore, this change can result in approximately 600 more pieces processed in the month.

As for the displacement of critical packages, that is, which contain glass microsphere blasting operations, it was possible to verify that by making the proposed changes, the movement of packages will decrease considerably. While the movement data found with the VSM and the current state simulation were very close, 532 meters and 545.47 meters respectively, with the proposed changes a movement of 125.13 meters was obtained.

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The suggested changes result in approximately a 75% decrease in package handling with glass bead blasting operations. In addition, the packages will have the same displacement regardless of the parts processes, since all the resources are located in the same pavilion.

As for the use of resources, it also showed gains in relation to the current layout in 6 of the 9 jobs, as can be seen in Figure 5. Shot blasting and Painting had little variation in the occupancy rate. Welding Booth 1, Welding Booth 2 and Welding Booth 3, which showed an occupancy rate of 24.5%, 28.86% and 18.76% respectively in the current simulation, showed considerable improvement, reaching rates of 43, 29%, 43.29% and 60.98% respectively. However, the simulation shows that for the sector's current demand, 3 welding cells would not be necessary, as they have higher waiting rates than processing, and are supplied by receiving packages.

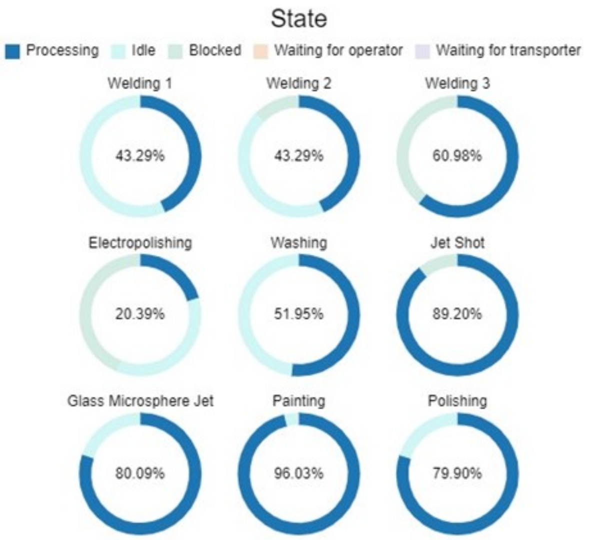

Figure 5. Resource occupancy rate in the proposed simulation.

The Electro Polishing, Parts Washing and Glass Microsphere Jet features increased processing time and decreased waiting time with the changes. While in the current simulation they had rates of 12.99%, 20.29% and 12.15%, respectively, in the proposed simulation they obtained rates of 20.39%, 51.95% and 80.09% respectively. Polishing, on the other hand, was the only resource that showed a drop in the processing rate, going from a rate of 98.16% to 79.9%.

Table 5 presents a comparison of the percentages of resource occupancy in the current process and the proposed process.

As for the lead time of the packages, the results obtained by the current simulation and the proposed simulation had a considerable variation in the days required for processing. In the current simulation the lead time was 19,52 days, while in the proposed simulation it was 16,25 days.

Based on the lead time, it was also possible to calculate the value added rate (TAV) in the current state and in the proposed one based on the cycle time of 25,500 seconds. From the current status to the proposed one, there was an increase of 22.5% in TAV. In the current state, the value-added rate is 0.040, whereas in the proposed simulation it is 0.049.

Table 5. Comparison of the current vs. proposed resource occupancy rate.

Resource	Current State (%)	Proposed State (%)
Welding 1	24,53	43,29
Welding 2	28,86	43,29
Welding 3	18,76	60,98
Electropolishing	12,99	20,39
Washing	20,29	51,95
Jet Shot	89,3	89,2
Glass Microsphere Jet	12,15	80,09
Paintinh	96,15	96,03
Polishing	98,16	79,9

Based on the presented results, changing the layout of the sector allows a considerable increase in the use of resources and a decrease in the movement of packages, being considered a simple change, since it only requires the relocation of existing resources.

This proposal for change is an example of how simulation allows seeking improvements that can bring confirmed results in the computational environment before being carried out in practice.

The integration of the two tools applied in this study presents significant gains in the most diverse types of manufacturing. Using value stream mapping in the application of lean production concepts combined with computer simulation, it was possible to identify bottlenecks in a production process in an automotive industry, enabling the reduction of component lead time [10]. The combination of tools proved to be efficient in identifying the necessary changes in a glass industry before implementation, making it possible to reduce movement costs, as this was the main loss identified [20].

Conclusions

This study aimed to integrate Lean Manufacturing and Industry 4.0 operationalized by Value Stream Mapping techniques associated with Computer Simulation, as decision-making support tools to define the ideal layout for the sector.

Through the VSM of the current state, it was possible to identify losses in the process. With the simulation of the current state, it was possible to confirm the data presented in the VSM. The use of simulation in this study made it possible to test hypotheses and verify whether it presented considerable results before applying it in practice, which allows for better assertiveness and facilitates decision-making. Simulation is one of the pillars of industry 4.0 and allows organizations to visualize possible changes before they are implemented [23]. Simulation brings dynamics to the traditional practice of VSM, promoting agility in decision making and the application of changes to the process [29].

This work showed considerable productivity gains in the company studied, resulting in a 7% increase in the number of packages processed, a 75% decrease in the internal movement of packages, a 19% reduction in delivery lead time, an increase of 22.5% in the value added rate and a significant improvement in the use of resources available in the sector.

The study demonstrates limitations due to having been applied only in one sector of the company. As a suggestion for future studies, a payback analysis is recommended to make the changes proposed by the study economically viable, using application data to make a comparison with the data obtained in the simulation. It is also suggested to use the VSM technique combined with Simulation in other sectors of the company.

Authors Contribution

J. Rubbo: Conceptualization, Writing - original draft; I. Cecconello: Investigation, Writing - review and editing. All authors have approved the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary Material

Supplementary Material associated with this article can be found online at: https://doi.org/10.18226/23185279.e251402.

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