World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:15, No:6, 2021

Lean Manufacturing: Systematic Layout Planning Application to an Assembly Line Layout of a Welding Industry

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***Abstract*—**The purpose of this paper is to present the process of elaborating the layout of an assembly line of a welding industry using the principles of lean manufacturing as the main driver. The objective of this paper is relevant since the current layout of the assembly line causes non-productive times for operators, being related to the lean waste of unnecessary movements. The methodology used for the project development was Project-based Learning (PBL), which is an active way of learning focused on real problems. The process of selecting the methodology for layout planning was developed considering three criteria to evaluate the most relevant one for this paper's goal. As a result of this evaluation, Systematic Layout Planning was selected, and three steps were added to it – Value Stream Mapping for the current situation and after layout changed and the definition of lean tools and layout type. This inclusion was to consider lean manufacturing in the layout redesign of the industry. The layout change resulted in an increase in the value-adding time of operations carried out in the sector, reduction in movement times between previous and final assemblies, and in cost savings regarding the man-hour value of the employees, which can be invested in productive hours instead of movement times.

***Keywords*—**Assembly line, layout, lean manufacturing, systematic layout planning.

I. Introduction

LEAN manufacturing strengthened in after-war considering that the Japanese reality demanded methodologies which accelerate the country's economic recovery. Also known as Toyota manufacturing system, lean manufacturing can be defined as a set of combined techniques that allow the decrease or elimination of super production, waiting, transport, process, inventory, movement, and defects wastes [1].

To improve a company's layout is highly important to reduce the time from customer placing orders and receiving them – lead time. The inadequate position of equipment, machines, workstations, and other necessary resources can impact the organization performance about its productivity and compliance in delivery dates, besides in decreasing the added value in operations. By improving layout, it is possible to achieve moving economy and waste elimination [2].

When discussing about lean manufacturing and layout, it is common to associate to cellular layout considering its main characteristics of positioning all necessary resources for the assembly of a product part and, combining all these parts, the final product. However, according to the company's context, cellular layout cannot be the selected one, even if the main driver is lean manufacturing.

For this paper, the industry used as a study case is a German multinational company which is in the welding segment and has a factory in the state of Rio de Janeiro, Brazil. Divided into two pavements, the machining and packaging sectors as well as the warehouse are on the first floor and the assembly line in the second, being necessary transporting products, parts, and components through an industrial elevator.

On the second floor, its assembly line is divided and identified by signs of three product lines – Meta Inert Gas/ Metal Active Gas (MIG/MAG), Tungsten Inert Gas (TIG) and Robot torches and cables. There are pre-assembly cells of components and cables which are used in assembly cells of torches or are sold as spare parts. Despite being divided by these signs, the positioning of cells does not follow completely this separation. This fact, besides visually not being in accord to the signs, results in the need of operators move themselves between cells to arrange finished products or gather components. These shifts are considered movement times and are included as non-productive hours in the factory's productivity indicators. These indicators are calculated considering productive hours and hours when employees remain without Production Orders (PO). Since operators invest time in movements, which are non-productive hours, the results of the indicators decrease by 10% in relation to the hours available. In addition, it was identified by time studies that the assembly times are correct compared with the effective time invested by employees. However, the total production time is increased in 28% by movement times for torch assembly, caused by the current layout. Therefore, this paper approaches the question of redesigning layout using Lean manufacturing as the main driver.

II. Methodology Selection

The project behind this paper followed the PBL methodology, which consists in a way of students to control the learning process by engaging themselves in a real problem and research good practices on literature to solve it [3].

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A. Literature Review

The objective of this stage was understanding concepts related to lean manufacturing and layout and lean tools indicated for designing layouts. Also, the objective was identifying methodologies for layout planning and which one was the most suitable one considering lean manufacturing as the main driver.

The procedures used in the literature review were based on the systematic literature review model [4] composed of five stages: search, organization, and selection, reading, annotation and critical analysis and writing.

B. Evaluation Criteria

To evaluate the methodologies for layout planning and select the most relevant to be used in the welding industry, a relationship matrix was used, whose criteria were -:

1) Have bibliographical references been identified with specific examples of application of the methodology for the layout elaboration in industrial assembly lines?
2) What is the relevance of the methodology in relation to the number of quotations?
3) How detailed is the methodology evaluated?

In order to quantify the degree of relationship between the methodologies for layout planning with the defined criteria, it was used the relationship degree scale of "0 – none", "1 – weak", "3 – moderate" and "9 – strong" [5].

C. Analysis and Methodology Selection

After the literature review, 16 methodologies for layout planning were identified, in which their occurrences on Google Scholar, Web of Science and CAPES Portal were counted and compared.

The methodologies with the highest percentage of occurrence and with a moderate or strong degree of relationship in relation to criterion I were selected and evaluated in the other two criteria (see Table I).

TABLE I
EVALUATION RESULT OF LAYOUT PLANNING METHODOLOGIES

Criteria / Methodologies	Have bibliographical references been identified with specific examples of application of the methodology for the layout elaboration in industrial assembly lines?	What is the relevance of the methodology in relation to the number of quotations?	How detailed is the methodology evaluated?	Total
Systematic Layout Planning [6]	3	9	9	21
Slack & Chambers Proposal [7]	3	3	9	15
Favaretto Proposal [8]	3	1	9	13
Silva and Rentes Proposal [9]	3	3	9	15
Pache Proposal [10]	3	1	3	7
Urban Model [11], [12]	3	9	1	13

Considering the result of the evaluation, the Systematic Layout Planning (SLP) was the one selected to orientate the re-planning of the assembly line layout.

D. Application in the Welding Industry

The research of this study is classified as a case study which represents the most appropriate strategy when asking questions such as "how" and "why", when the researcher has little control over events and when the focus is on contemporary phenomena inserted in some context of real life [13]. Therefore, this work can be classified as an exploratory case study, where through documentary analysis, interviews and observations it is possible to determine the current scenario, propose improvements and simulate the situation after layout changed.

The data were collected in oral interviews with employees in the assembly sector, as well as the Production Planning and Control (PPC), Logistics, Production Support and Industrial Management department. Data were also collected from company documents and databases, as well as from observations made during visits to the company.

III. SLP AND LEAN MANUFACTURING

The SLP methodology has great applicability in planning and redesigning the layout [6]. It is composed of a model of procedures and conventions for identification, evaluation and visualization of the elements and areas involved in the planning of a layout. These procedures are described as [14], [15]:

1) P, Q, R, S, T & activities analysis: Data collection – volume of products (P), quantity of batch (Q), route (R), support equipment (S) and setup, movement, and activity times (T).
2) Flow of materials: Flow intensity of a product between equipment is defined.
3) Activity relationships: The activities are analyzed according to their importance, classifying them into A, E, I, O and U, where A represents the most important and U the least important. This stage result is the input to the next one.
4) Relationship diagram: This is a quantitative analysis that helps to place the equipment considering the frequency of the product flow.
5) Available and required space: The available and necessary space for equipment and its auxiliary resources is measured.
6) Space relationship diagram: This is an initial layout design, which tries to work out the final layout.
7) Modifying constraints: Layout operators and users must be interviewed, and their needs considered in the proposed layout.
8) Practical limitations: Each need and suggestion may have a practical limitation that must also be analyzed for layout planning.
9) Evaluation: All layout alternatives must be analyzed.

The application on the assembly line of the welding industry used the nine steps of the SLP methodology, plus three steps related to the principles of lean manufacturing, following Fig. 1, where the added activities are highlighted with dashed lines.

The first step added was the elaboration of the VSM for the current layout. The second step included was the definition of the layout type and tools of lean manufacturing which helps in proposing the new layout for the assembly line. The third stage included was the elaboration of the VSM regarding the layout of the proposed situation.

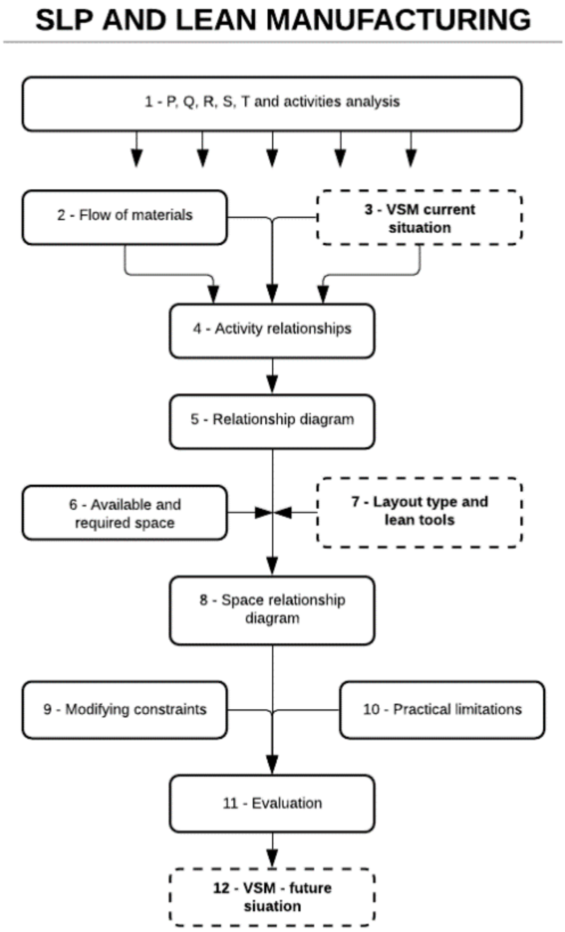

Fig. 1 SLP and lean manufacturing

IV. Analysis

A. P, Q, R, S, T and Activities Analysis

For this analysis, all the welding torches assembled in the industry were surveyed, as well as the demand of the last three years, ordering them by highest to lowest production.

After ordering the torches from highest to lowest demand, the first three standard torches were selected, that is, primary torches in the company's product mix. For these torches, volume of products per month (P), quantity of batch (Q) and setup, movement, and activity times (T) in minutes were the support equipment and route traveled were listed (see Table II).

The MIG/MAG torch does not have a defined batch, as PO are issued in specific quantities to meet the order point of this company's product line. It is worth mentioning that components used in the assembly of torches are considered as pre-assembly.

TABLE II
Prioritization of Highest Demand Torches

Product	Volume of product/month (piece)	Quantity of batch (piece)	Movement time (min)	Assembly time (min)
TIG torch 3,5M 13MM	84	31	1,50	5,00
TIG torch 3,5M	61	31	1,50	5,00
MIG/MAG torch 3M	23	0	2,00	5,00

The route (R) for all the three torches is the same: PO printing and booking – gathering materials for pre-assembly (kanban), pre-assembly of components, storage of components finished on the kanban shelves, PO printing and booking – assembly, materials gathering for assembly (kanban), assembly and testing, packaging and placing the finished torches in specific area. The routes of both models are the same, since the assembly of the torches, in essence, is similar, differing only in components because they are applied to different welding processes. The assembly of TIG torches has less support equipment compared to the MIG/MAG torches, as there is only one pre-assembly, considering that its components are mostly purchased.

The support equipment for TIG torches are device for cutting cables, crimping device, screwdriver, continuity test device, flow meter, general tools and movement trolley. And the support equipment for MIG/MAG torches are device for cutting and striping liners, bending and fixing torch necks, cutting monocables, fixing plugs, crimping device, screwdriver, continuity test device, flow meter, general tools and movement trolley.

B. Flow of Materials

Once the monthly volume and product route had been analyzed in the previous step, the grouping of products into families considered the two product lines - MIG/MAG and TIG line. The implementation of the kanban in the assembly line is in progress, in which the inputs are available in supermarkets, but not yet at workstations. In addition, the current layout has the 5S tool fully implemented.

Considering the route indicated in the previous step and detailing the flow of materials, for the assembly of MIG/MAG torches first the PPC department needs to print POs for the pre-assembly of components. The PO is issued by the Enterprise Resource Planning (ERP) system from the need for production. The company is in the implementation phase of the Overall Labor Effectiveness (OLE) project, which consists of providing tablets to operators so that the POs, drawings, and work instructions needed for the assemblies are displayed, eliminating the need for printing. Afterwards, it is responsibility of the PPC department to deliver the POs to employees so that they collect the necessary inputs and start the pre-assembly of the liner, monocable, plug and torch neck. Once finished, the liner and monocable are stored in the supports and the plug and the neck in the kanban supermarket.

The ERP issues the need to produce torches, the PPC department prints the POs again and delivers them to employees. To assemble the torches, it is necessary to collect the liners and monocables on the supports, in addition to the other components in the supermarket. After assembly, the torches are tested in the workstation itself, taken to another bench for packaging and, finally, moved to the finished product area.

The flow of materials for the assembly of TIG torches is similar to MIG/MAG, except for the fact that there is only one pre-assembly of power cables, which after assembled are stored in supports.

C. VSM: Current Situation

In this step added to the methodology, the VSM of the current situation was elaborated with the objective of using it as a comparison parameter for the proposed layout (see Figs. 3 and 4). For the development of the VSM, the second was used as a unit of measurement and the legend represented by Fig. 2 the symbols.

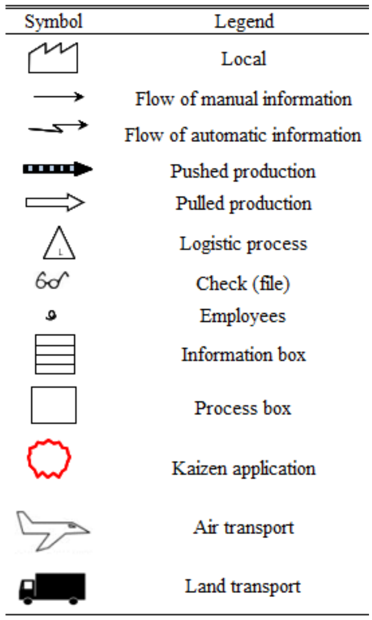

Fig. 2 VSM legend

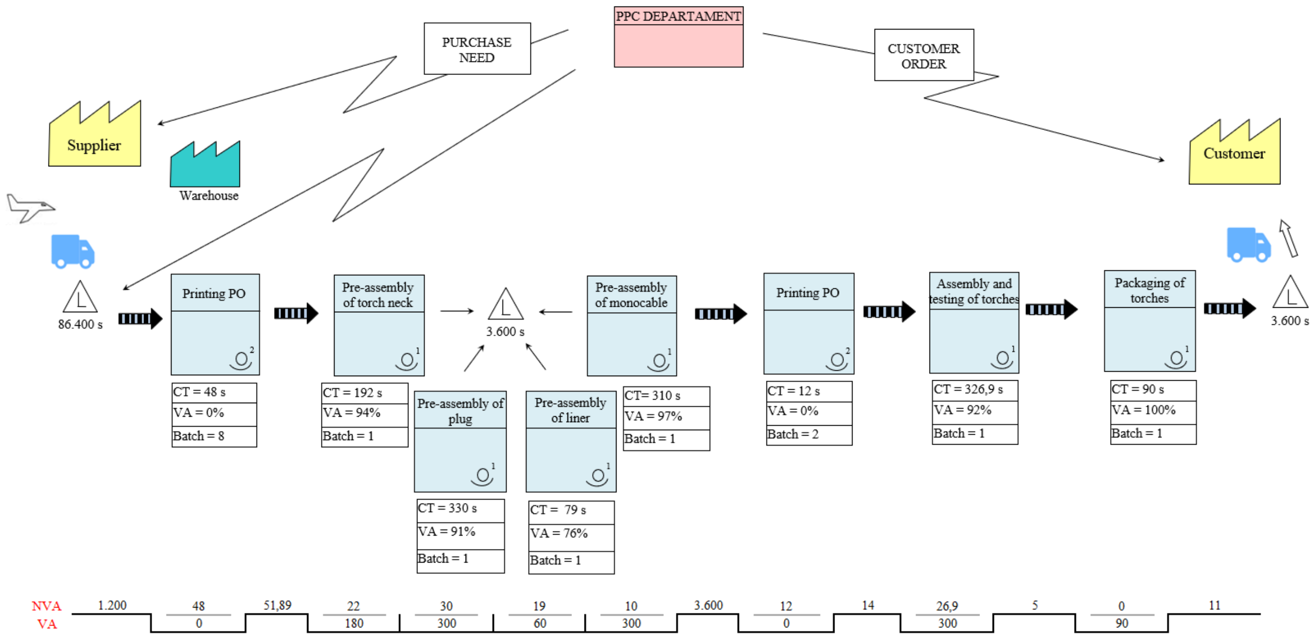

Fig. 3 Value Stream Mapping of MIG/MAG torches – current situation

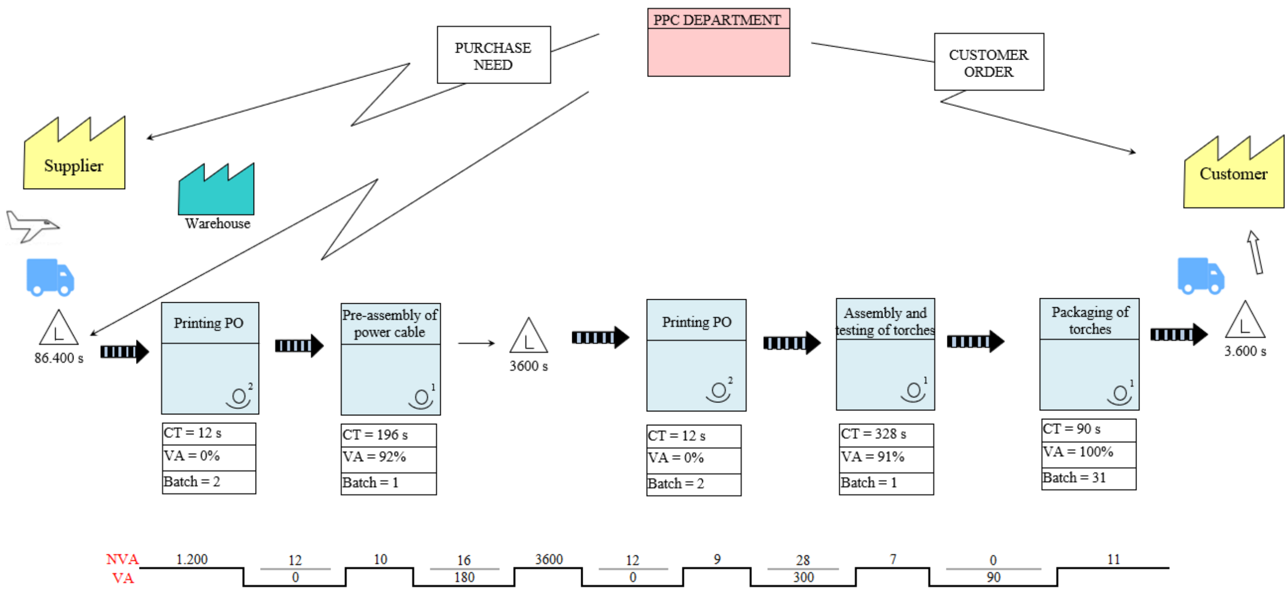

Fig. 4 Value Stream Mapping of TIG torches – current situation

Cycle time (CT), value-adding time (VA), non-value-adding time (NVA), lead time and the percentage of value-added were used as parameters of analysis [16]. Both VA and NVA were resulted from time studies using chrono analysis as methodology [17]. The results of the VSM of the current situation for the MIG/MAG and TIG torch lines are shown in Table III.

TABLE III
VSM RESULTS OF CURRENT SITUATION

Parameter	MIG/MAG	TIG
CT (s)	1.397,9	638,0
VA (s)	1.230,0	570,0
NVA (s)	5.049,8	4.905,0
Lead time (s)	6.279,8	5.475,0
Value-adding (%)	24%	12%

D. Activity Relationships

For the diagram of MIG/MAG torch assembly relationships, four proximity reasons were used: reducing travel distances, independent processes, no possibility of layout changing and grouping pre-assembly process. The number three reason, "no possibility of layout changing", applies only to the relationships between the "Printing PO" and the others, since there will be no change in positioning in the PPC department office. For the A classifications, priority was given to directly related activities, such as the collection of liners and monocables for torch assembly, since these components are used in torches.

For the diagram of TIG torch assembly relationships, since there is only one pre-assembly activity, which is the power cable, "group pre-assembly process" was not considered for the analysis. The classification of proximity used the same criteria as for MIG/MAG torches.

E. Relationship Diagram

Based on the activity relationships, the analysis was performed using the relationship diagram to position the equipment and workstations in terms of proximity classification. The main objective of this diagram is to assist in redesigning the layout, since through it there is the visual positioning according to the classification performed in the previous step.

The relationship diagram must be made listing, initially, the activities whose relation was classified in A [6]. Then, the relations with classification E must be added, including any new activity involved and redistributing those classified in A in order to arrange them respecting the relationships. In the same way, it is performed with the relations I, O and X, and those classified in U, unimportant, are not represented in the relationship diagram.

For the MIG/MAG torch relationship diagram, the torch-related activities, with the pre-assembly components already available, are those that have the highest priority in terms of proximity, being classified in A, and are related for the reason of reducing travel distances. The activities whose relationships were classified in E and I are related to the reason of grouping pre-assembly processes and/or reducing travel distances. And the activities whose relations were O received this classification because they are independent processes.

The TIG torch relationship diagram follows the same reasoning as MIG/MAG torches.

F. Available and Required Space

This step aims to measure the space available and necessary for the equipment, workstations and auxiliary resources, in order to make the proximity indicated through the relationship diagram. The plant drawing of the assembly line was used for this analysis and the available space was considered sufficient for the layout changes.

G. Layout Type and Lean Tools

This step was added to the SLP methodology so that the layout planning would be carried out using the principles of lean manufacturing as the main driver.

For the definition of the layout type to be considered in the layout redesign of the assembly line, the type of manufacturing process of the welding industry was defined as a batch process, which consists of "a wider range of volume levels and variety than other types of processes" [7]. In other words, whenever there is a need to produce a product model, more than one unit is produced, with the batch being two or three products. Thus, the assembly operations are repeated whereas that batch is being assembled.

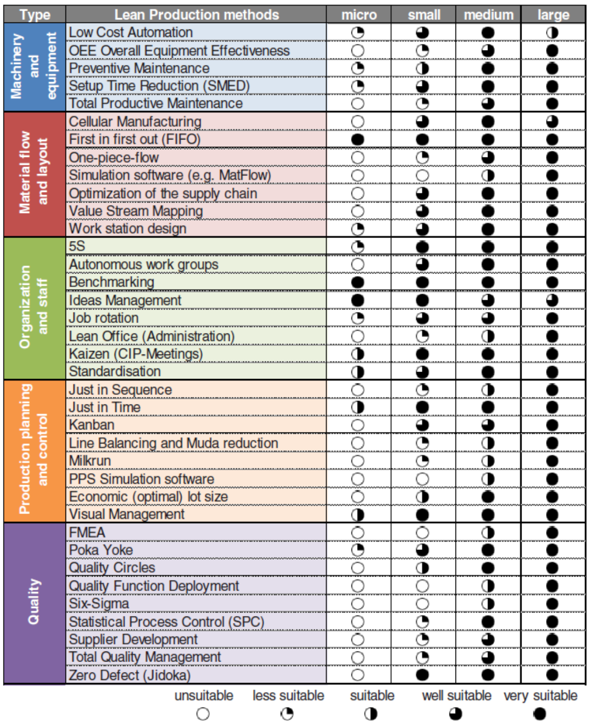

Fig. 5 Lean manufacturing tools related to a company size taken from [18]

The manufacturing process of the welding industry used as a case study fits into the batch type process since the components and torches are assembled in batches to meet the order point of their respective part numbers. This parameter is based on the demand of the item, either for consumption in assembly and/or on sale.

TABLE IV
ANALYSIS OF LAYOUT TYPES CONSIDERING LEAN MANUFACTURING, TAKEN FROM [19]

Layout types/Criteria	By process	By product	Positional	Cellular
Continuous flow	Low	High	Low	High
Inventory	High	Low	High	Low
Visual management	Low	High	High	High
Quality	Low	High	High	High
Mix and volume flexibility	High	Low	High	Low
Multifunctional workforce	Low	Low	Low	High
Programming complexity	High	Low	Low	Low
Motion	High	Low	High	Low

The types of layout related to this type of process are the process or cellular layout [7]. Since the objective of this paper was to elaborate the layout of the assembly line of a welding industry using the principles of lean manufacturing as the main driver and considering Fig. 5 and Table IV, the cellular layout is the most suitable.

It is worth mentioning that the current layout already has pre-assembly and assembly cells. In addition to this factor, the sector of assembly of the headquarter of the welding industry, located in Germany, is considered as benchmarking and also presents a cellular layout.

For the definition of the lean tools to be used in the layout of the assembly line, Fig. 5 must be considered, which relates the type of area to be improved with lean tools and the size of the company. The welding industry is classified as medium size [20], since it has annual gross operating revenue greater than € 714.902,74 and less than or equal to € 44.681.421,00.

Considering that the industry used as a case study is a medium-sized company and the type of improvement is in material flow and layout, the lean tools to be used in the proposed layout were defined according to Fig. 5. Below follows Table V with the considerations about the lean tools to be considered or not in the proposal of layout of the assembly line. Therefore, all lean tools indicated as very suitable will be considered and applied to the new layout of the welding industry assembly line used as a case study for this paper.

TABLE V
LEAN TOOLS CONSIDERED IN THE PROPOSED LAYOUT

Lean tool	Classification	Applicable?	Reason
Cellular manufacturing	Very suitable	Yes	In accordance with the definition of the layout type described above.
First in first out (FIFO)	Very suitable	Yes	Considering the implementation of kanban in the assembly line and since this tool is already applied in the company's warehouse.
Optimization in the supply chain	Very suitable	Yes	Considering the implementation of kanban in the assembly line, optimizing the replacement of components.
Value Stream Mapping	Very suitable	Yes	Included as a step in the methodology of layout planning as a tool for analysis and comparison of results.
Workstation design	Very suitable	Yes	The current workstations consider the ergonomics, work safety and quality of life of users and it will not be changed.
One-piece-flow	Well suitable	No	The batch size of the POs is directly related to the fulfillment of the order point of the components and torches assembled in the welding industry.
Simulation	Suitable	No	The use of simulation software was not prioritized, as the company already uses VSM in its internal projects, being a tool well accepted by other subsidiaries in the welding industry.

V. RESULTS

A. Space Relationship Diagram: Initial Proposed Layout

The main alteration in the proposed layout is the division of the second pavement into pre-assembly and assembly cells instead of maintaining the product line division. Visually and having as reference the access ladder to the second floor, the left side will include the pre-assemblies of components and the right side the assemblies of torches and robot cables. The monocable cell, which is component pre-assembly, will not be changed, since it is strategically located in the middle and in front of the PPC department office and is related to the assembly of MIG/MAG torches and robot cables. In this way, the amount of transport is reduced and becomes visually linear, since production starts on the left side from the pre-assembly of components, there is storage in supermarkets and supports in the middle of the second floor so that there are the assembly torches on the right side. According to the cellular layout, there will be two macrocells, one of which is pre-assembly and assembly, and within each of them, the cells listed according to Table VI.

TABLE VI
MACROCELLS OF PRE-ASSEMBLIES AND ASSEMBLIES

Microcell of components pre-assembly	Microcell of torches and robot assemblies
Power cable cell	MIG/MAG torch cell (gas cooled)
Toch neck cell	MIG/MAG torch cell (water cooled)
Plug cell	TIG torch cell
Liner cell	Robot cable cell
Wire guide tube and cable assembly cell	Packaging bench
Brazing cell	Kanban supermarket
Stamping cell	Liner, monocable and power cable support

There will not be inclusion of new tables and workstations or any other equipment. The only inclusion will be new supports for storing liners of 3, 4 and 5 meters, in which they will be fixed to the wall next to the area of finished products. As there is a need to allocate specific lengths of liners and considering the presence of at least four operators with medium to low height, a lifting device will be contemplated for leveling the height and feasibility of collecting liners for the assembly of torches, in accordance with Brazilian ergonomics regulation [21].

All the shifts done in the proposed layout considered the available space. The 5S tool, already implemented in the current layout, will be considered and maintained in the layout proposal.

B. Modifying Constraints

This step is considered one of the practical points of the application and consists in interviewing the layout operators and users and collecting their needs. In this way, "there is the added advantage of making them feel that they have a personal part in a decision that affects themselves and their jobs" [6]. Therefore, the employees were interviewed, and the layout proposal was presented to them. Only one change consideration was reported in relation to the torch neck cell, which was initially in front of the power cable cell.

According to the operator, in view of the electrical point and the compressed air point, the torch neck cell should be located next to the power cable cell. So, in order to consider this suggestion, the power cable cell was moved about 3.00 meters to the right and, since it was already 2.10 m away from the stairs, it becomes viable the positioning of the torch neck cell next to it.

C. Practical Limitations

Since there was no inclusion of new benches, workstations or any other equipment, the practical limitations considered were the electrical point and compressed air point, so that the positioning of cells and equipment respected the perimeter of coverage of these resources.

D. Evaluation

In this way and according to the feasibility of changes within the schedule of this project, the proposed layout was implemented. The improvement suggested by the layout users was considered in order to align their needs. It was possible to calculate the benefits in time and cost savings, which are described in the next topic.

E. VSM: After Layout Changed

Equally to the third stage, this stage was added to the methodology so that the VSM of the situation after layout changed could present the results according to the new layout and was used as a comparison parameter to visualize the benefits in relation to the current situation. For the development of the VSM, the second was also used as a unit of measurement and Fig. 2 as a legend for the symbols.

For both VSM of MIG/MAG and TIG torches (see Figs. 6 and 7), the conclusion of the kanban and OLE projects was considered, related to the availability of pre-assembled and assembled components in the workstations themselves and visualization of PO, drawings and work instructions via tablets with software integrated with the company's ERP system. Thus, for both situations after layout changed, the NVA of activities are reduced due to the elimination of the need for operators to collect inputs in supermarkets and, also, to the new layout.

For the analysis of results, the same parameters of analysis of the VSM of the current situation were used. Tables VII and VIII show the results of the VSM of the situation after layout changed with the proposed layout for the MIG/MAG and TIG torch lines, respectively.

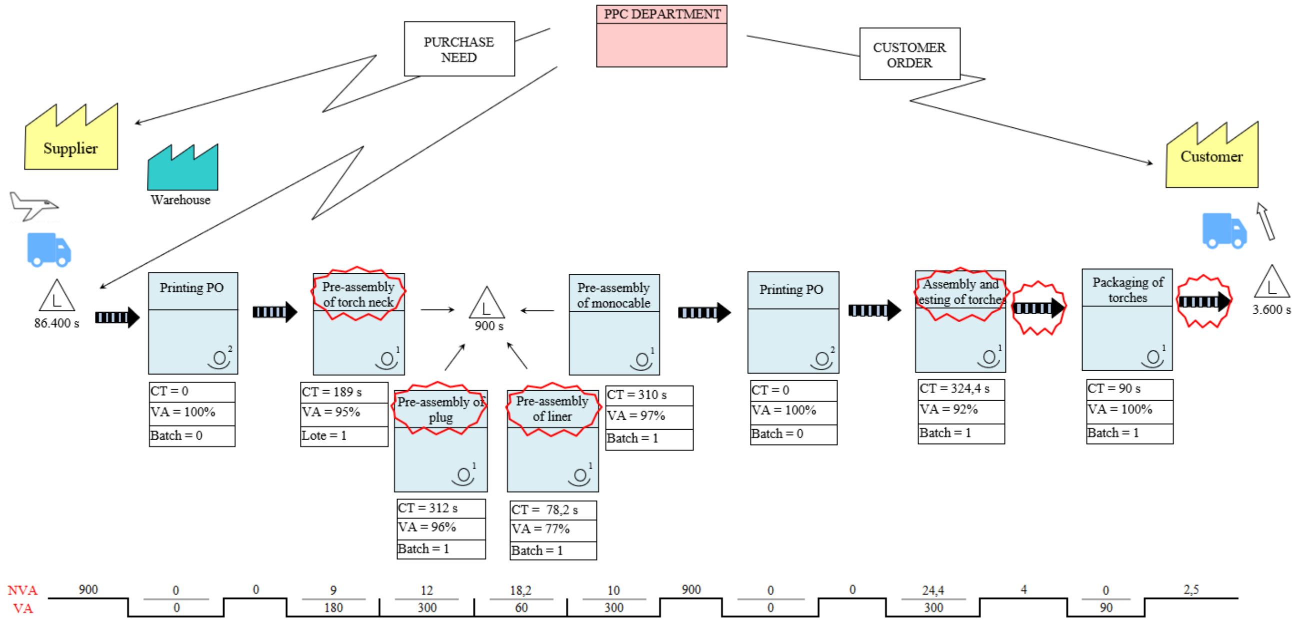

Fig. 6 Value Stream Mapping of MIG/MAG torches – situation after layout changed

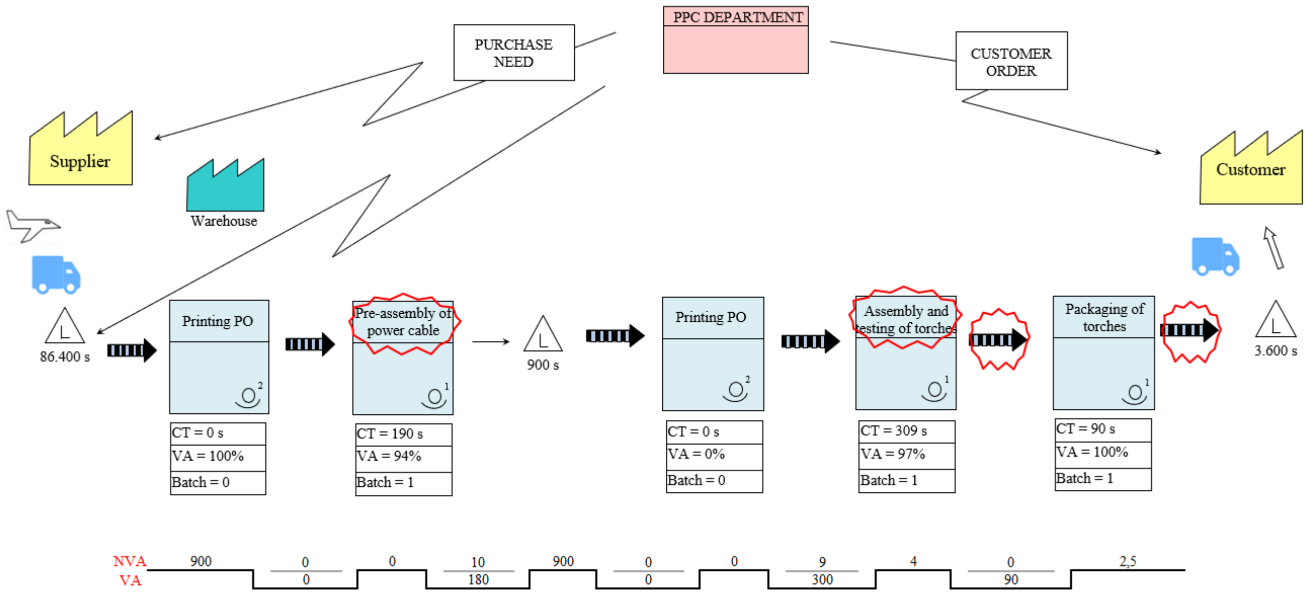

Fig. 7 Value Stream Mapping of TIG torches – situation after layout changed

TABLE VII
VSM RESULTS OF MIG/MAG TORCHES: SITUATION AFTER LAYOUT CHANGED

Parameter	Current	After layout changed	Variation
CT (s)	1.397,9	1.303,6	↓ 7%
VA (s)	1.230,0	1.230,0	↓ 0%
NVA (s)	5.049,8	1.880,1	↓ 63%
Lead time (s)	6.279,8	3.110,1	↓ 50%
Value-adding (%)	24%	65%	↑ 41%

The CT will be reduced as employees will not need to collect components in supermarkets since they will be available at their workstations, in addition to the fact that the layout will provide a shorter travel distance between the cells and the supermarket for disposal of finished components. The VA will not change, as assembly times were not considered as the focus of this paper. The NVA will be reduced due to the implementation of the OLE project, kanban and the reduction of distances with the new layout. In turn, the lead time will also have a reduction, accommodating reductions in CT and NVA and, consequently, the percentage of value-adding will increase for both torch lines.

To identify the reduction in movement time due to the layout proposed, only activities and movements emphasized with the kaizen symbol were considered. For the movements after the assembly, testing and packaging activities of MIG/MAG and TIG torches, the time reductions were considered in their entirety. Time reductions related to PO printing activities were not considered as they were caused exclusively by the OLE project. For the reduced times in the other activities emphasized with kaizen symbol, only half the time decrease was considered, since they are also related to the implementation of the kanban project. Therefore, according to Table IX, there will be a decrease in movement time by 25 seconds for the assembly of a MIG/MAG torch unit and 18 seconds for a TIG torch unit.

TABLE VIII
VSM RESULTS OF TIG TORCHES: SITUATION AFTER LAYOUT CHANGED

Parameter	Current	After layout changed	Variation
CT (s)	638,0	589,0	↓ 8%
VA (s)	570,0	570,0	0%
NVA (s)	4.905,0	1.825,5	↓ 63%
Lead time (s)	5.475,0	2.395,5	↓ 56%
Value-adding (%)	12%	31%	↑ 19%

TABLE IX
TOTAL BENEFIT

Parameter	MIG/MAG	TIG
Reduction in movement (s)	25	18
Annual demand – sample (piece)	358	2.000
Cost saving/year – sample (€)	€ 551,92	€ 2.220,00
Annual demand – gas cooled torches (piece)	4.805	3.728
Cost saving/year – gas cooled torches (€)	€ 7.407,71	€ 4.138,08
Annual demand – gas and water-cooled torches (piece)	5.781	3.745
Cost saving/year – gas and water-cooled torches (€)	€ 8.912,38	€ 4.156,95
Total cost saving in movement (€)	€ 13.069,33	
Labor cost (€)	€ 932,40	
Infrastructure cost (€)	€ 70,00	
Implementation total cost (€)	€ 1.002,40	
Annual benefit (€)	€ 12,066,93	

The cost saving study was carried out in three stages and considered estimated values. In the first stage, it was considered only the annual demand of the selected torches through the P, Q, R, S, T and activities analysis. The second stage considered only gas cooled torches, since the selected torches are into this category. The third considered the annual demand for all torches done in the assembly line, both gas and water cooled. For the calculation of the cost saving, the demand for the reduced time in seconds was multiplied, transforming the unit of measurement into hour and, finally, multiplying by the company's man-hour value. Therefore, there is a total cost saving of € 13,039.33 due to the layout proposed by this paper.

Regarding the cost of implementing the layout, 4 hours are considered in addition to the three liner supports for 3, 4 and 5 meters, which were purchased and fixed on a wall near the MIG/MAG torch cell, totaling € 1,002.40. Consequently, the annual benefit of implementing the proposed layout is € 12,066.93.

VI. CONCLUSION

This paper aimed to redesign the layout of the assembly line of a welding industry using lean manufacturing as the main driver.

According to the method of evaluation and selection of methodologies for the layout planning, the SLP was defined as the model to be used in the redesign of the layout of the welding industry according to its specificities.

VSM was selected as the tool for measuring and comparing results. Based on the VSM of the situation after layout changed, it was identified that the new layout will offer a reduction of 25 seconds for the assembly of a MIG/MAG torch unit and 18 seconds for a TIG torch unit.

It is concluded that the implementation of the layout proposed in its entirety will bring to the company in the first year a reduction of € 12,066.93 in costs invested in movement times. In the following years, this avoided cost will be € 13,039.33, since with the changed layout, there will be no implementation cost. This cost saving refers to current demand database, so it is possible to increase this annual benefit due to the growth in demand.

The implementation of the layout proposed by this paper is relevant, because if the layout remains, the same would continue to decrease the productivity indicators of the factory by 10% and add 28% in production times, both due to the movement times.

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