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Layout Optimization using Computer Simulation Tool for Decision Making

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Abstract — *The purpose of this study is to present a case study based on real production data in which the computer simulation was used to analyze the efficiency of the current layout, paying attention to indicators defined by the value stream mapping, which determined the need of layout restructuring. For this purpose, it was used a computer tool for discrete events that permits to explore the features of the system, aiming to provide a more comprehensive view of the assembly line, since the software has several performance analysis tools. The method was developed through "in loco" data collection, in similar cases studied in the literature, and in the computation tool learning, thus creating a virtual environment that allowed simulate various layout restructuring strategies to reach the desired result, verifying a great potential for improvement with this restructuring. Finally, the results obtained with the simulation proved that its use emerges as a powerful tool for evaluating the rationalization of resources and production layout restructuring, making clear the advantages and features of the use of computer simulation as a tool to help making decisions in industrial manufacturing process.*

Keywords — Digital Manufacturing, Process Layout, Production Simulation, Value Stream Mapping.

I. INTRODUCTION

The physical arrangement project is very important for a good performance of a manufacturing process, for implanting and layout changes can result in high costs for the company, since experiments in the physical environment can lead to delays and even paralyze production. Therefore, more and more organizations have acquired computer systems that make it possible to view different distributions of the production cells in search of a better performance, avoiding the interruption of production so changes in their physical arrangement can be made.

The correct project of the physical arrangement has a decisive role for the survival and success of a company, since it is strongly connected to the strategy and to its objectives, and allow the rationalization of space, minimizing the movement of materials and people, leading to reduced costs and increased production system efficiency [20].

This study was developed in a company specialized in automotive manufacturing car radio, having as main objective the use of computer tool in the physical arrangement restructuring, using Tecnomatix Plant Simulation® software, which is a simulation tool for discrete events that allows a greater visualization of manufacturing through simulated experiment, as a tool, it is possible to optimize the flow of materials, production bottleneck and make layout changes in the simulation environment, giving greater security in changes of the production process.

Given the above, based on some decision variables, there was a comparison between the current physical layout and the simulated scenarios, which presented indicators that made it possible to propose a production layout restructuring, using computer simulation as an analysis tool.

Considering the presented facts, the importance of this study is relevant because Digital Manufacturing Implanting is becoming a differentiator within organizations, for digital manufacturing helps with companies' processes changes, in which are involved high investment costs, helping predicting problems and searching for a solution. In short, the use of technological resources help managers make decisions. However, for the desired costs, time and quality results in implementation to be achieved, it is essential to have a careful implanting project.

Thus, in seeking to improve the manufacturing process, it is necessary to create a simulation scenario that allows the control of the production process and evaluate the possibilities of improvements. The simulation environment allows the prediction of resource requirements for the demand increases. Another reason is the search for the best manufacturing environment, aiming to achieve the best results with equipment / existing resources.

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II. USE OF SIMULATION IN MANUFACTURING

For a good understanding of simulation, it is essential to know the definitions of systems and models. In short, the system is a set of different elements, which exert on each other an interaction or interdependence. The systems set limits or boundaries. That is, they are limited. Therefore, one can set the system into other systems, and so forth.

A model is an abstraction of reality, where given a system, contains a simplified representation of the various interactions between its parts. Symbolic, mathematical and simulation models are the three basic categories [5].

- Symbolic Models, also called diagrammatic or ionic. They represent a static way system through the use of graphic symbols, not taking into account the behavior over time. The lack of quantitative data and the difficulty to represent many details of the same system are among the limitations of this type of model. Its greatest use is in the documentation of projects and as a communication tool.
- Mathematical Models, also called analytical models, being interpreted as a set of mathematical formulas. The vast majority of them are models of static nature, and many of these do not have analytical solutions for complex systems, so simplifying assumptions must be used. On the other hand, they are models that possess a fast and accurate solution, when an analytical solution exists.
- Simulation Models, which can capture more faithfully the characteristics of real systems, providing, on the other hand, a greater complexity due to its nature, since they change their states over time and have random variables.

The modeling comprises the use of mathematical techniques to describe the operation of a system or part of a production system [2]. A complement is the use of simulation, which consists in the use of computer techniques to simulate the operation of production systems, based on a set of variables in a given area in order to investigate the causal and quantitative relationship between these variables [3].

In literature, one can find various simulation application studies as an analytical tool of production systems [7], presents a study that seeks to simulate the manufacturing system of a company in order to find optimized solutions, analyzing the demanded production levels, lines balancing, cycle times and order processing times.

The simulation makes it possible to recreate a real system in a controlled environment, which allows a possible understanding of the manufacturing performance, safely and at lower cost than would be necessary in analyzes with changes in the real production system form.

The simulation applied to manufacturing enables the resolution of the following issues: a) how to work with the product mix, required through lower investment and operating costs; b) how to allocate resources so that the fulfillment of production targets is possible and great financial results are obtained; c) how to improve the flow of production in terms of total cost, within the cycle time limits.

According to [12] many factors affect in a decision-making, such as: the time available, the importance of the decision, the environment, the risks, certainty / uncertainty, the decision agents and conflict of interests. The influence of these factors in decision-making can be minimized by preventive analysis that enables managers to previously obtain facts and reliable data that add to their experiences.

According to [8], in a computer simulation model it is possible to test various values for variables that can be controlled and modified by the designer. The control of variables enables desired output results and or comparison between models. The variables usually analyzed are: Processing time, lead time, resource utilization index, average quantity produced, queue time, drive time, among others.

III. ELEMENTS FOR SIMULATIONS

For the system behavior to be reproduced reliably, it is necessary to use the elements in the making of simulation models.

Entity: An entity may represent a person or object moving along the system, changing its state;

Resources: Resources are seen as constraints to the flow of the entities in the simulation. The authorities need to make use of resources to move through the model;

Attributes: Attributes are assigned to each individual entity and represent the features that entity must have along the simulation.

Queue: This is an element by which an entity passes when you need a resource. If there are others being served by the resource, this entity is in a queue.

Understand the objectives of a simulation project is one of the most important aspect. The project goals must be clearly defined at the beginning of the work. Additionally, other items should be defined at the beginning, such as:

- Define the problem and objective;
- Analyze the system;
- To get the actual data of the system;
- Create model;
- Validate the model;
- Experiment and analyze the model;
- Evaluate the results;
- Propose improvements.

Although the simulation is an excellent analysis tool, it is necessary to know a little more deeply about the advantages and disadvantages of their use. All simulation models are called input and output models, thus the entry conditions determine that produce output. They cannot generate an optimal solution by themselves, as is the case of the analytical systems. Simulation models only play the role of system behavior analysis tool under certain conditions.

Some of the benefits of using simulation are listed below, according to:

- New policies, operating procedures, decision rules, organizational structures, information flows, etc., can be operated without causing disturbances in the processes in use;
- New layout projects, transportation systems, machines and equipment, software, can be tested before its implementation, thus evaluating the need of purchase or modification;
- Assumptions about how and why certain phenomena occur can be tested;
- The time factor can be controlled, i.e., it may be expanded or compressed, allowing to increase or decrease the speed in order to study a phenomenon;
- Allows the analysis of variables which are significant to system performance and how these variables interact;
- Bottlenecks can be identified;
- A simulation work can be proven important to the understanding of how the system really works.

Despite the many advantages of using simulation, it is important to point some constraints or difficulties in the implementation of a simulation model. The main ones are:

- The need of training, since the quality of analysis depends on the quality of the model and therefore the ability of the analyst;
- Sometimes the simulation results can be difficult to interpret. This is because the simulation try to capture the randomness of a real system, leading to difficulty in identifying if an event occurred due to randomness or the interactions of system elements;
- Analyses made through the use of simulators can be time consuming and expensive, and may even derail its use.

A factory production capacity is directly linked to the better use of the process completion time, and the layout is among the performance factors of any production operation. Set any physical arrangement is to plan and integrate the ways of the components of a product, in order to achieve an efficient and economical relationship between personnel, equipment and moving material [4]. Structuring steps and improvement of production layouts can be favored by the use of computer simulation, by analyzing the behavior of different layout alternatives before practice deployment. Interrupting a production line so that changes in their physical arrangement can be made, with the intention of performing experiments, would have a high cost to the organization, which is a point in favor of the use of computer simulation. Its application allows you to analyze various process parameters simultaneously where, through the animation dynamism, it is possible to increase the sensitivity on the elaborate proposals.

[13] and [9] present some benefits of using computer simulation in similar conditions to the ones studied here: (i) development of models adaptable to reality, testing different scenarios and operating possibilities of a system, without compromising resources; (ii) simulation capability of complex systems (equipped with stochastic components) which are not adequately described by deterministic mathematical models; (iii) assessment of the distribution of available resources, allocating them appropriately to the process and ensuring high standards of production; (iv) better control over the experimental conditions compared to the practical application in the real system; (v) analysis of long periods time of an operation in a short time simulation; and (vi) determination of bottlenecks in the system and studies related to process optimization.

In scenarios that require rapid and low-cost decision-making responses, the computer simulation is increasingly applied in companies in search of production layout improvement. The computer simulation can avoid unwise decisions that may jeopardize the operation of the company or result in inadequate investment [11].

For, by analyzing the behavior of different layout alternatives before practice implementation, mistakes and unnecessary cost will be avoided.

The use of simulation is justified in the evaluation of the distribution of available resources, allocating them appropriately in the process and ensuring high levels of production and its use in systems characterized by a high number of decision variables [15]. Importantly, the modeling and simulation of manufacturing cells, the features of the cell project in analysis (cell size, layout, types of machines, storage equipment, transportation and material handling and machine loading capacity and workstations) must be considered.

After considering the relevant issues related to the use of computer simulation, follows the approach method of research used.

Tecnomatix Plant Simulation® is a simulation tool for discrete events that allows the creation of different digital scenarios of the production system. With this tool it is possible to do simulation experiments that allow you to exploit the characteristics of systems and optimize their performance, therefore, the results provide information essential for decision-making, since with the creation of hypothetical scenarios it is possible to reach results performance without affecting the existing production system, avoiding stoppage of production to make experiments that could cause injury by production delay or equipment damage.

In addition to providing better visualization to model and simulate production systems and processes, Plant Simulation allows you to optimize the material flow, the resource utilization and the logistics for all factory-planning levels, from production facilities, through local factories to specific lines.

Resources

- Models oriented to the object with a hierarchical structure
- Open architecture with various standard interfaces
- Libraries and Object Management
- Optimization triggered by the genetic algorithm
- Automatic analysis of simulation
- Results report builder based on HTML

Benefits

- Saving of 3% to 6% of the initial investment
- Increase of 15% to 20% of the existing system productivity
- Reduction of 5% to 20% of the costs of new systems
- Optimization of consumption and resource reuse
- Reduction of 20% to 60% of inventories
- Reduction of 20% to 60% of the cycle time

[1] suggest the use of discrete events simulation as a project management tool that allows ongoing management of the project functionality even during implementation.

IV. METHODOLOGY OF RESERACH

According to [6], the great challenge of scientific research is the integration of theory and practice, being in the form of intervention in the study object and the researcher's ability to recognize the relevance of the scenario and draw conclusions.

In order to achieve the goal proposed in this paper, it was done a mapping of the entire manufacturing process in the finished production area of the company in question.

The method was adapted based on the development and implementation stages of simulation models proposed by [13] and [9]. The steps of the proposed method of work are: (i) Problem formulation and study plan; (ii) Data collection; (iii) Construction of the conceptual model; (iii) Validation of the conceptual model; (iv) Construction of the computer model; (v) Verification and validation of the computer model; (vi) Definition of the experiment (s); (vii) Simulation (s) Experiment (s); and (viii) Analysis of the results. The flowchart with the defined method steps is shown in Fig 1.

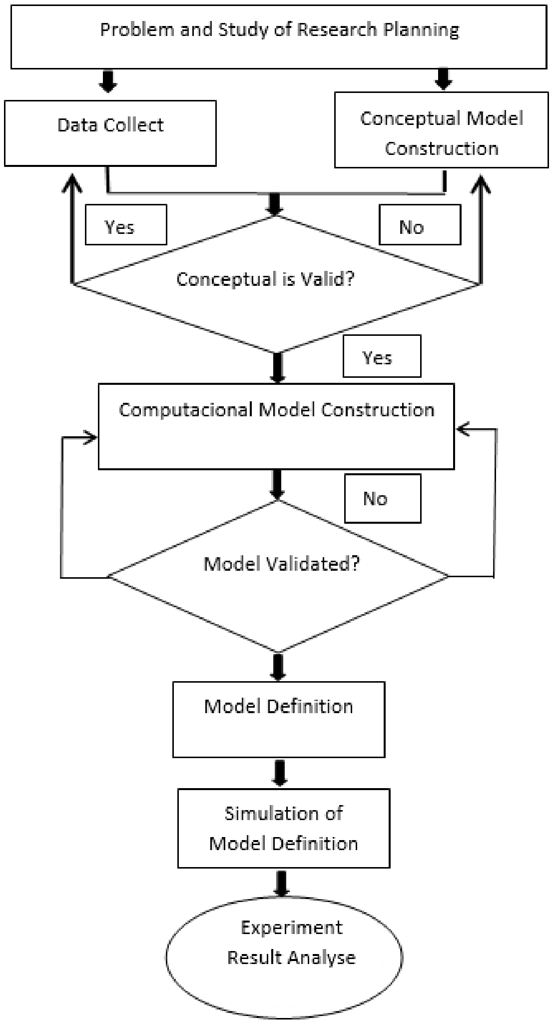

Fig.1: Proposed method for modeling and simulation

In the first step the manufacturing problem to be simulated is identified, for this, a mapping of the value stream was carried out so that it the problems to be solved could be identified, and. this way, the new scenario will be planned over the desired purpose. Importantly, in this beginning it is necessary a clear definition of the simulation work objects, so the implications of the problem are evident. It can also be updated if necessary.

In the second stage are collected "in loco" the necessary data to compose the computer model, conducted through interviews with managers and other process professionals, as well as literature and case study, therefore, it has an exploratory character. It must be considered that the quality of the input data is essential for the reality to be analyzed is portrayed in the best possible way in the computer development.

The next step is the Construction of the Conceptual Model, which is based on real scenario to build a simulation model that makes it possible to measure the current performance that will be evaluated in the computer modeling. After collecting data and formulating the conceptual model, it must be validated, defining the real characteristics of the system to be modeled and verifying if the model is in accordance with the actual system and the purposes of computer simulation [18].

After validating the conceptual model, the computer model will be developed with the help of the Tecnomatix Plant Simulation® software that allows the creation of environment and a better assessment of production capacity through simulated experiments, as well as enabling analysis of production resources in the system.

Ascertainment and validation of the simulation model. At this stage, it will be verified if the model represents in fact the actual system. The process simulation tests will be performed for the purpose of checking and then validate the computer model, for this is made a comparison of results of the actual process with the proposed ones, in which case it is the layout restructuring. It is at this stage that the information generated are verified, if the settings and the input data were assimilated correctly by the computer model [14].

The definition of the experiment came from the need for change in the production process, identified in the first step of the method, which identified shortcomings in the physical arrangement which caused movement of waste and need for performance improvement.

After defining the experiment, the desired changes will be modeled so the computer model can simulate the improvement changes allowing a comparative analysis of the results, to evaluate the viability of implementation of the proposed changes.

According to [16], the case study it is a methodological approach research especially proper when looking for understand, explore or describe events and complex contexts in which several factors are simultaneously involved.

The planning of case study should be designed carefully considering, in addition to the following operational aspects, the different types of validity that threaten the characterization of the work of a scientific nature research. In addition to predict which types of validity the case study is subjected to, the case description must contain a critical analysis resulting from the research quality in terms of these different types. Unfortunately, this is one of the biggest oversights in the conduction of a case study [16].

V. MANUFACTURING MAPPING

An assembly line consists of work stations, where a certain number of operations are performed in a certain sequence and at a constant speed. Manipulating with the operational composition of the work stations, more or less workers can be allocated on the assembly line in search of a better balance. It is said that an assembly line is perfectly balanced when all work stations are 100% occupied [17].

The Value Stream Mapping (VSM) or value flow mapping is a communication and planning tool that provides an overview of the entire process chain, allowing you to know in detail its manufacturing processes. It is a simple tool which uses pencil and paper and helps to see and understand the flow of materials and information as the product follows the flow value.

To start mapping it is necessary to draw the current state, using as a basis the collection of information: cycle times, number of people involved in each process, operations, material flow, material supply etc.

Once the process is clearer, actions to eliminate or contain waste become easier, because these same actions may be simulated by digital modeling, which, in turn, might indicate the best results.

According to [19], an important factor in creating an effective VSM is collecting information on the operating environment, and the perspective of those involved routinely in the processes, in order to capture the process "as it is" and not "as we think it is. " That is why for the realization of the VSM project it is recommended that the mapping is done on the shop floor in the simplest and most objective way.

It was done the mapping of the current state of the organization in order to identify opportunities to improve the process. During the observation period all the information that could indicate improvement or that could be the possible cause of the delay of the process, was collected. The mapping was initiated by the representation of all the steps involved in the production process, making it possible to understand the waste and their generating sources, and from this problem the experiments that will be performed by simulation can begin, using the acquired information by mapping as the basis of an implementation plan, aiming the future scenario projected.

Fig 2 illustrates the current state of the organization by the VSM tool where the information flow is; in it is observed the path of materials and cycles of each process stage, from the arrival of the raw material until the delivery to the final customer.

According to the current state map, reducing the waiting time in front of each workstation is an opportunity to

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reduce the lead-time and, consequently, to increase the service level. This is of interest because the focus of the present study is to explore a lean production system design for fishing net manufacturing using lean principles and simulation optimization. However, reducing WIP and its associated non-value-adding time, while maintaining the required system performance, is not straightforward. In fact, it is quite challenging and is the main concern for any scheduling decision and shop floor control system [22].

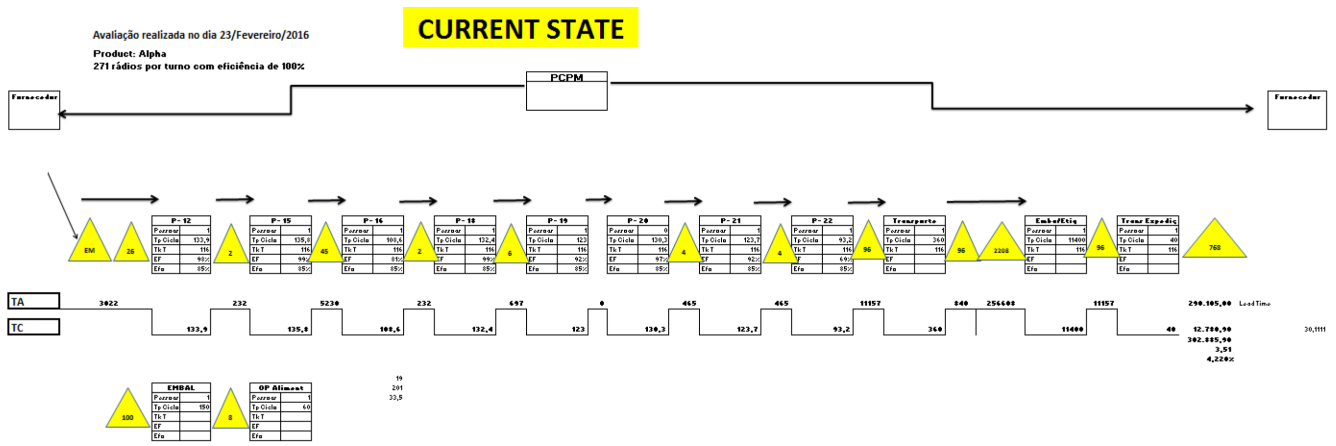

Fig.2: Current State Map

Fig 3 shows the future state proposed by the multifunctional team, in which the potential waste and action plans for activity to reduce the time of crossing of the product were analyzed. It became evident during the analysis that the layout change would increase the opportunity with reduce of movement and over processing waste. This way the point observed and researched in this study was in the layout change project, aiming to reduce waste between the process steps.

Future state map demonstrates the output of the proposed changes based on the gaps identified in the snapshot of the "as-is" state of the current state. It was asked to involve the supplier earlier in the process to have a high degree of correct information and coordination. It should be achieved by improving communication up front to foster proper information regarding product and process. This will bring the necessary knowledge to execute the steps in correct manner eliminating the need of rework through iterations at back end of the process. It will also help the involved departments to understand and share same vision for future products [21].

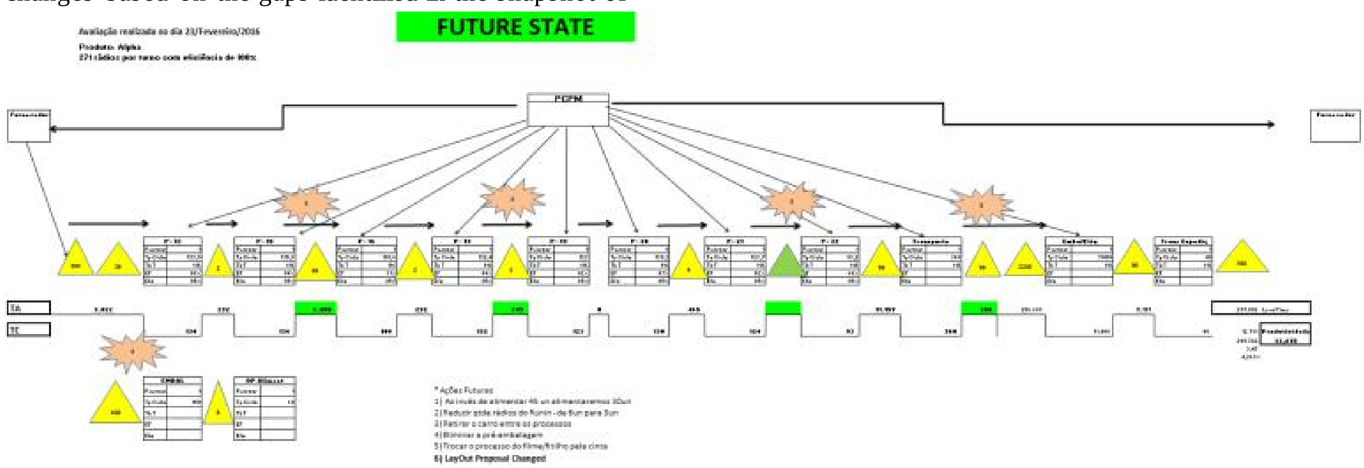

Fig.3: Future State Map

In Fig 4 you can see the real way process, with the two sequences in an illustration that represents the current layout. The choice of layout type depends largely on the process structure - the position of the processes in the array of customer contact for service providers and product-process matrix for the manufacturing process. The four basic types of layout include: (1) by process or functional or job shop; (2) product; (3) hybrid; and (4) fixed position [10].

The layout for process involves three basic steps, either to a new layout, either for a review of an existing layout: (1) collect information; (2) develop a general plan; and (3) design a detailed layout [10].

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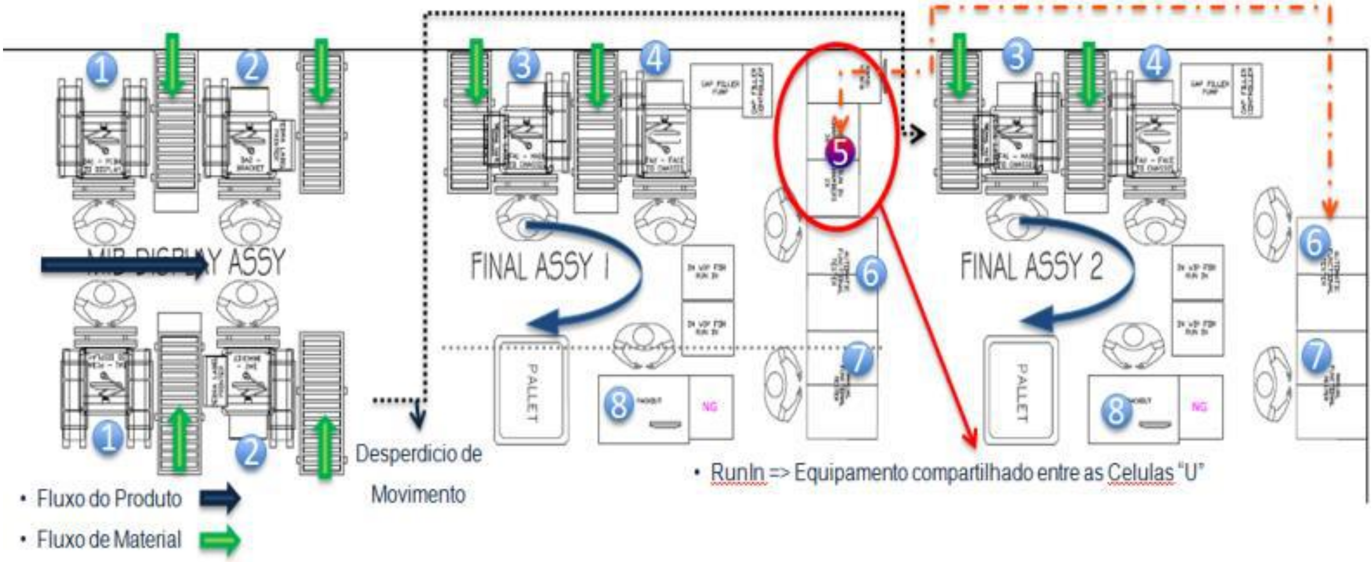

Fig.4: Stage of Manufacturing Process

Computer simulation of the proposed physical arrangement

Based on the model of the current layout, experiments using Tecnomatix Plant Simulation® software were initiated, which made it possible to design a physical arrangement more suitable for the production sequence, in order to increase productivity, making a distribution of work stations and equipment in order to eliminate the waste of movement from work stations 2 and 5, tracing a sequence that would enable the increase in production capacity. According to Fig 5.

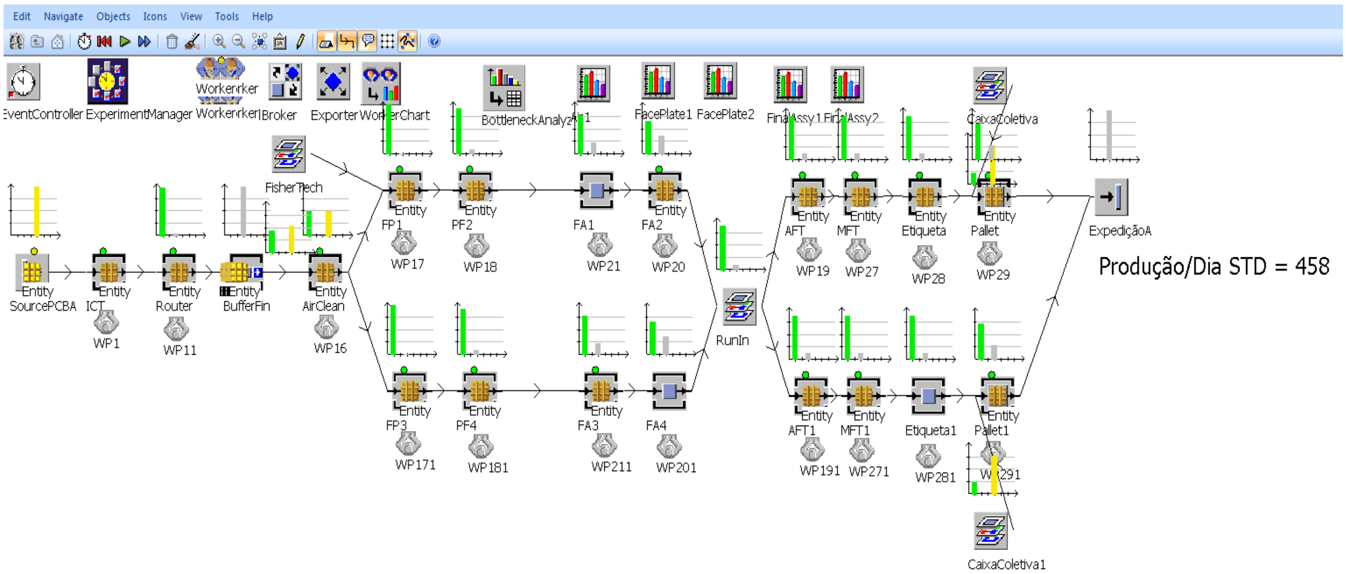

Fig.5: Virtual Simulation with New Arrangement

Process Mapping - New Physical Arrangement

Considering that the computer simulation of the redesigned process showed satisfactory results, it was proposed a new arrangement to share resources in order to mitigate costs and increase productivity, eliminating the handling of waste, as shown in Fig 6.

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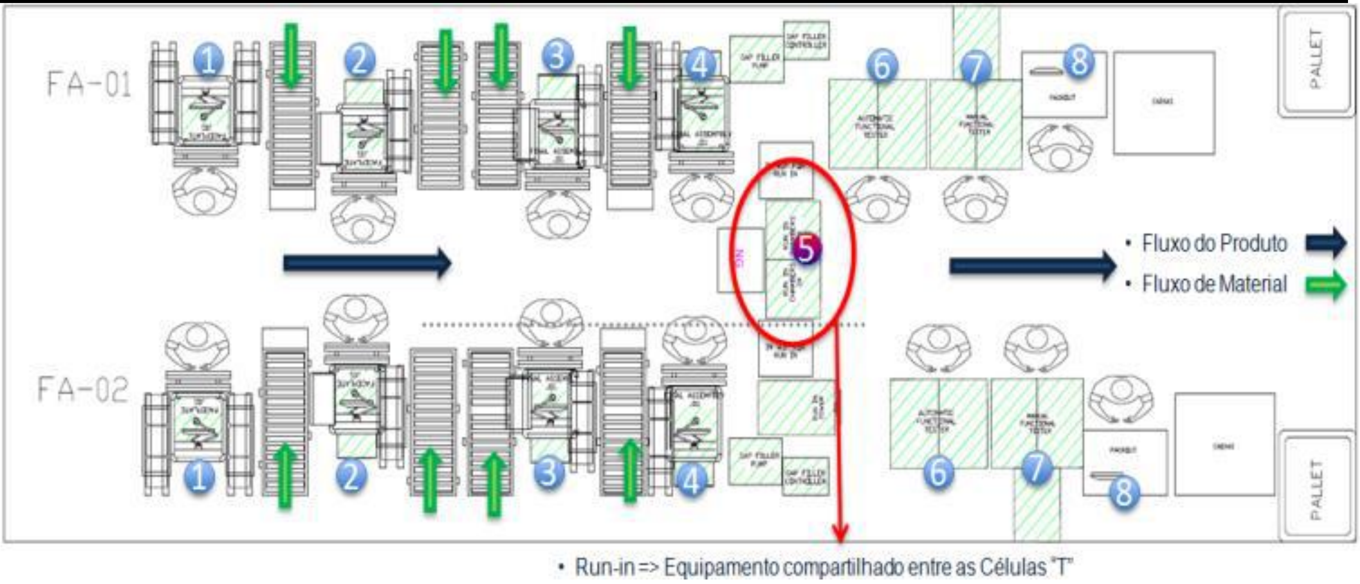


Fig.6: New Physical Arrangement – "T" Cells

VI. RESULTS ANALYSIS

Based on the information that the monthly demand of radios is 20,000, and from the simulation of the proposed model used, such improvement will be exemplified by results of comparative charts of production results obtained before and after the improvement proposal shown in Fig 7, that shows the Production Evolution per hour.

In the chart, which represents the production of radio per operator. Shown in Fig 7, it is noted that in the 29th week of 2018 before commencing the restructuring changes, the production rate was 208 radios per person per month, reaching a total of 96 people to reach the desired volume of production by the client was 20,000 radios.

After the changes proposed layout, the results showed that there was a decrease of persons, from 96 to 77, and an increase in monthly production per person 208 to 259, since there was a reduction in wasted motion, thus increasing the production capacity and reducing cost labor, since there was a decrease of 19 people.

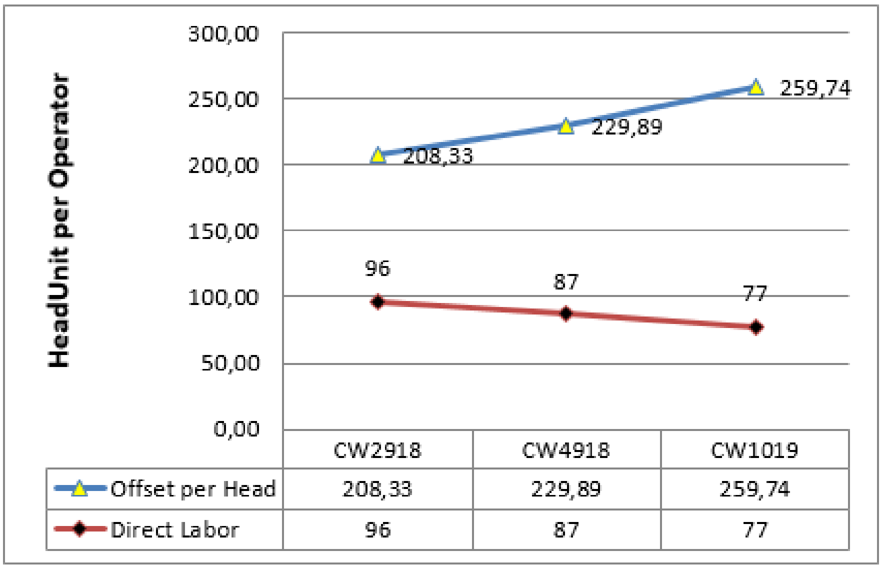
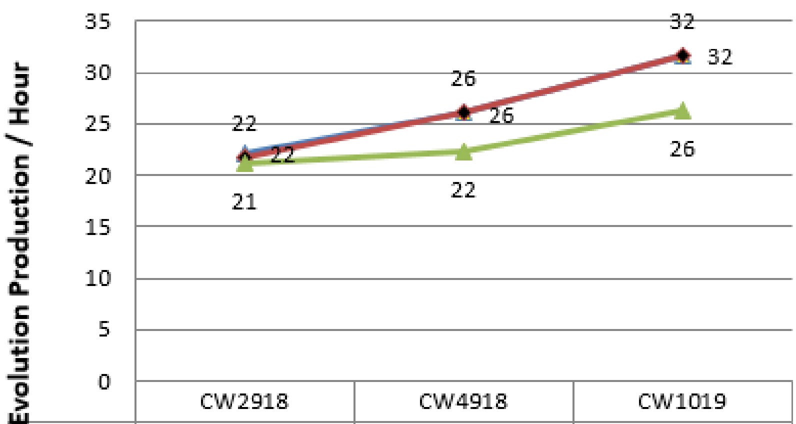


Fig.7: Comparison chart of increase productivity per operator

According to Fig 8, that represents the Evolution of production per hour, it shows that after the improvement with the restructuring of the layout there was an increase in production, which went from 22 units per hour to 32, with improvements in the production of three models produced between weeks 29/2018 and 10/2019, layout change period.



	CW2918	CW4918	CW1019
Entry	22	26	32
Std	22	26	32
Plus	21	22	26

Fig.8: Comparative chart of output per hour evolution

VII. CONCLUSION

This research, developed a model that aims to construct manufacturing simulation using existing computer tool due to it being easily understood, a simulation model is often simpler to be justified than some analytical models. Furthermore, a simulation model usually has more reliability since it can be compared with the real system or because they require little simplification, capturing the actual characteristics of the system and shows results of snapshots manufacture daily.

Therefore, it was seen in this research that there is much room for gains and improve production of car radios, because the software includes features that allow deeper analysis in a simple way. Remember that with the mapping was clear the evidence of work stations with higher capacity than required. Especially with the excessive use of buffers among various work stations, making the cost of in-process inventory is very high. Thus, we suggest the continuity of the work, therefore, there is already a virtual structure built and new scenarios can be created in order to seek new proposals for improvement.

It is good to remember that this subject was addressed during the construction of the Value Stream Mapping, where it has been suggested to reduce buffers in order to reduce the crossing time, however to meet the customer demand because the deployed logistics characteristics, it is need a week of inventory of finished product and two weeks of production on the road, not to run the risk of the client stop. Because of this feature is not possible to improve this external logistics process, but the other intermediate phases must be addressed with a more forceful approach by the multifunctional team.

It is recommended a new balance after the change of the physical arrangement, particularly where work stations are over the capacity, therefore, must be added some functions and achieve the same result, so that the organization can reduce costs and keep more competitive in the current market, so the standardization of this work format needs to be implanted so the engineering group can always work in the pursuit of operational excellence.

It is also recommended the analysis of other projects discussed during the VSM in order to seek constant improvements to the process and use the simulation environment created for quick decision-making and when necessary make the changes and simulations to support the decision of the organization's managers.

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