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Layout analysis and restructuring in the pre-assembly sector of the serial line in a furniture industry

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ABSTRACT
The constant search to reduce operating costs, as well as to increase productivity and reduce internal problems, has been the target of companies to remain inserted within a highly competitive market. To this end, internal changes are part of the strategies to achieve these goals. The present work aims to implement a new layout with optimization of the productive space in the pre-assembly sector of the serial line, in a furniture industry. The method used for the elaboration of this work was action research, which enabled a detailed analysis and allowed the implementation of a new physical arrangement, compatible with the company's manufacturing process. As a result of the work, it was obtained clarity of the process, optimization of the physical space, reduction of material movements and transports, reduction of inventory in process, ease in internal logistics flows due to the well-dimensioned corridors, better visibility of the sector, organization and cleaning, more efficient production control and reduction of waste.

Keywords: Layout, Optimization, Waste, Improvements, Productivity.

1 INTRODUCTION

With the increase in competitiveness in the market, organizations seek to make improvements within the production process that provide increased productivity. One of the alternatives is to carry out a restructuring of *layout* that adapts to the company. There are four types of *Layouts* such as positional, functional, mobile, and by product, and each of them suits the type of process or product of the organization. For this reason, a well-harmonized structuring between equipment and machines within the production environment provides process clarity, reduction of inventories in process, cleaning and organization, improvement of logistics flow, improvement in production control, reduction of waste, increase in productivity, reduction of handling and transport times.

The present work was carried out in a furniture industry, in which it presented an arrangement of machinery and equipment that generated great waste and losses during the manufacturing process of the products.

Thus, this work obtained the following research problem: What are the benefits offered from an optimization and restructuring of *layout* of the production process?

The general objective is the implementation of a new *layout* structure in the pre-assembly sector of a furniture industry with improvement in the production flow. As specific objectives, we can

mention: mapping the production process, elaborating a process flowchart, identifying the products of the serial line, analyzing existing waste, analyzing possible alternatives and defining a new layout proposal, presenting its benefits.

This research is justified, as it can be used in the future as a study tool for engineering students, as well as contribute to the company improving its operational performance. In addition, together with the analysis of the physical arrangement itself, it can provide a detailed understanding of the entire *layout implementation process,* going through all the steps to do so, as well as denoting the advantages of a physical arrangement to the flow.

2 DEVELOPMENT

For Lakatos and Marconi (2003), the selection of methodological instruments is, therefore, directly related to the problem to be studied; The choice will depend on the various factors related to the research, i.e. the nature of the phenomena, the object of the research, the financial resources, the human team and other elements that may arise in the field of investigation.

Scientific methodology, in its essence, aims to study the methods that identify the paths taken to achieve the objectives proposed by the research plan (Güllich, Lovato & Evangelista, 2007).

This work is characterized as an action research, which is named as a social research with an empirical basis configured and executed in fusion with an action or solution of a given problem, where the researcher and the participants representing the problem are involved in a cooperative or participatory way (Thiollent, 2007).

2.1 MATERIALS AND METHODS

The company in which this study was carried out is Schuster Móveis and *Design*, located in the municipality of Santo Cristo, in the Northwest region of Rio Grande do Sul. The study was carried out specifically in the pre-assembly sector of the serial line, where there was the biggest bottleneck in the company.

A laser tape measure was used for a more precise and correct measurement of the area to confirm the existing measurements on the floor plan and, through the *software SolidWorks*, the drafting of the new proposal for *layout*. Several proposals were simulated until the ideal one was found.

2.2 PROCEDURES AND TECHNIQUES

In carrying out this work, the action research approach was followed, where both researcher and team cooperate and participate in solving the problem, through information collection, documentary research, observation activities, meetings and, thus, formulate concepts between researcher and team.

Firstly, the data collection technique was used to identify the existing waste in the sector under study and to analyze possible improvements that may help in the new proposal of *layout*, as well as drawings referring to the company's floor plan. Photographic records of the manufacturing environment were also used to make a comparison between the current and after the implementation of the new proposal.

The technique of direct observation in the manufacturing environment was also used to monitor the activities and verify the manufacturing process of the products, and informal interviews were conducted with some employees to obtain more detailed and accurate information.

By identifying the *layout* Ideally, the proposal was presented along with its benefits to the organization and also the possibility of future improvement works that could be addressed after the completion of the restructuring of the physical arrangement.

2.3 LITERATURE REVIEW

2.3.1 Process mapping

The purpose of mapping production processes is to identify and describe the stages through which materials pass during their manufacturing process. Encompassing the description of processes mentioning how the activities connect within the process. For this, there are techniques that can be used for process mapping. Through these techniques, the types of activities carried out in the process are identified, exposing the flow of materials, people and information (Slack, Chambers & Johnston, 2009).

According to Peinado and Graeml (2007), process mapping is a very useful tool and can have the following applications: improving the understanding of the work process, showing how the work should be done, creating a work standard or a procedural standard.

Table 1 – Process mapping symbology

	Indica o inicio ou fim do processo
	Indica cada atividade que precisa ser executada
	Indica um ponto de tomada de decisão
	Indica a direção do fluxo
	Indica os documentos utilizados no processo
	Indica uma espera
	Indica que o fluxograma continua a partir desse ponto em outro círculo, com a mesma letra ou número, que aparece em seu interior

Source: Peinado and Graeml (2007).

According to Chart 1, the symbology shows the activity that the process is performing at each stage of the production process.

2.3.2 Process Flow Chart

According to Ceolin (2011), the term flowchart designates a graphic representation of a particular process or workflow. Through this representation, it is possible to quickly and easily understand the transition of **information or documents between the elements participating in the process in question.**

The flowchart technique has several advantages for the organization, as its use allows the possibility of analyzing how the components of a system are connected and related, allowing the verification of its effectiveness; It provides greater ease in locating deficiencies, through the visualization of steps, transports, operations, forms, etc.; and, because it is an easy-to-visualize technique, it provides a clear understanding of the changes that are proposed to existing systems (Abreu & Trindade, 2015; Villar, 2008).

2.3.3 Waste

The idea of waste as a factory problem has been around the ages, since Henry Ford, without changing its definition. Any unnecessary *input* or any undesirable output in a system and, specifically, in the manufacturing process is waste (Reis; Figueiredo, 1995).

The Toyota Production System considers that waste can be defined as any activity that does not add value to the final product (Slack et al. 2009). For Pinto (2009), the concept includes not only human activities, but also any other type of activities and resources misused that contribute to the increase in time, cost, and non-satisfaction of stakeholders in the project, good, service or business.

According to Ohno (2006), there are seven types of waste that can be found within the production process, such as:

- Overproduction: Producing more than is immediately needed for the next process in production is the biggest source of waste.
- Lead time: Machine efficiency and labor efficiency are two common measures, which are widely used to evaluate the lead times of machines and labor, respectively. Less obvious is the required waiting time for materials, disguised by employees, busy producing excess inventory, which is not needed at the moment.
- Process: In the process itself, there may be some sources of waste. Some operations exist only because of poor component design or poor maintenance, and can then be eliminated.
- Transportation: The movement of materials within the factory, as well as the unnecessary movement of inventory in process, does not add value.

- Stockpile: All stockpile should become a target for disposal. However, stocks can only be reduced by eliminating their causes.
- Movement: An operator may seem busy, but sometimes no value is being added for their work. Simplifying work is a rich source of reducing handling waste.
- Defective products: Quality waste is usually quite significant in operations. The total costs of quality are much higher than have traditionally been considered, and it is therefore more important to tackle the causes of such costs.

Such waste has a significant impact on production costs, which ends up influencing the final product.

2.3.4 Layout Types

The *layout* consists of the way in which machines and equipment are distributed within a factory environment, in order to optimize space and increase productivity.

The study of the physical arrangement of machinery and equipment in any workplace is of indisputable importance, as the well-being and, consequently, the best performance of people depend on it. A good arrangement of machinery and equipment provides greater efficiency of workflows and an improvement in the appearance of the site itself (Piccoli; Carneiro & Brasil, 2003).

According to Yang and Hsu (2000), a factory *layout* project has a significant impact on the company's performance and directly affects its results, being decisive for its survival in the global competitive market. According to Drira, Pierreval and Hajri-Gabouj (2007), the arrangement of production resources in a facility directly affects production costs and productivity. A rational allocation of resources contributes significantly to increased efficiency of operations and reductions in handling costs.

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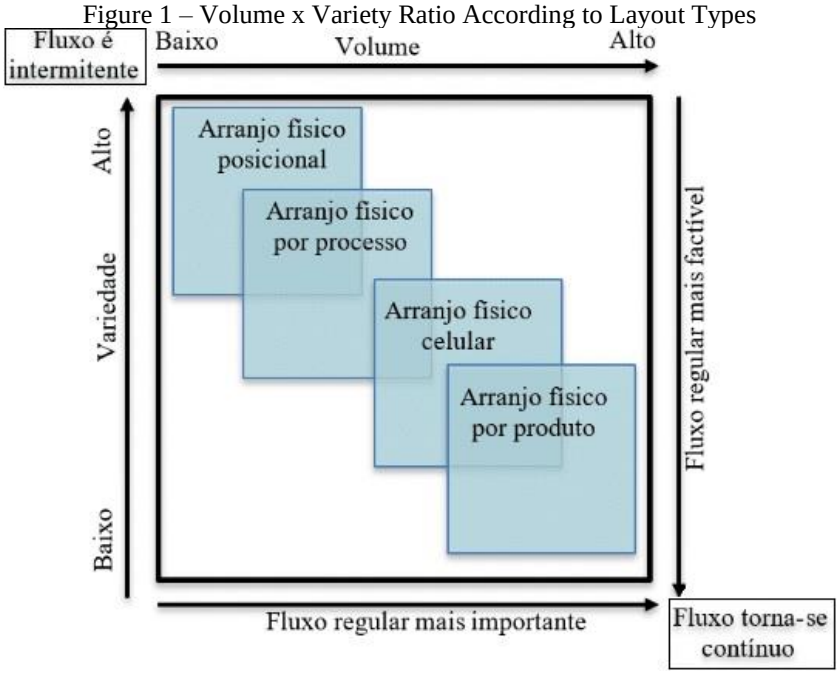
Figure 1 – Volume x Variety Ratio According to Layout Types



Font: Slack, Chambers & Johnston (2009).

There are several types of physical arrangements that are used according to the characteristics of the site, adapting to them according to the need for productivity, quantities, movements of people or materials within the production area. For Slack (2009), *layouts* can be classified into four types: positional, functional, mobile, and by product.

- Positional (or fixed-position): Transformed features don't move between transformer features. Instead of materials, information, or customers flowing through an operation, the processing is stationary, while equipment, machinery, facilities, and people move as needed. The reason for this is that either the product or the service subject is too large to be moved conveniently, or it may be too delicate to be moved.
- Functional (or process): it is so called because it conforms to the needs and conveniences of the functions performed by the transforming resources that make up the processes. In this *layout*, similar resources or processes are located next to each other. The reason for this is that it may be convenient for the operation to keep them together, or that in this way the use of the transformer resources is benefited.
- Cellular: is the one in which the transformed resources, entering the operation, are pre-selected to move to a specific part of the operation (called the cell) in which all the necessary transforming resources are located. Each cell can be arranged according to a functional layout or per product. After being processed in the cell, the transformed resources go to another cell. The *cellular layout* is an attempt to bring some order to the complexity of flow that characterizes the functional physical arrangement.

- By product: it involves localizing transformative productive resources entirely according to the best convenience of the resource being transformed. Each product, information element or customer follows a predefined script in which the sequence of activities required coincides with the sequence in which the processes were physically arranged. Transforming resources follow a flow along the process line. For this reason, this layout is also known as a flow or inline layout. The flow of the products is very clear and predictable, making this *layout* relatively easy to control. Generally, it is the uniformity of product or service requirements that leads the operation to choose a physical arrangement per product.

Due to the fact that there are several types of physical arrangements, a study must be carried out on the processes and products existing in the company to be able to identify the one that suits the activities developed in the manufacturing environment. This verification is essential, as a well-structured physical arrangement is essential for the smooth running of manufacturing activities and, consequently, affecting productivity.

2.4 RESULTS

2.4.1 Current situation

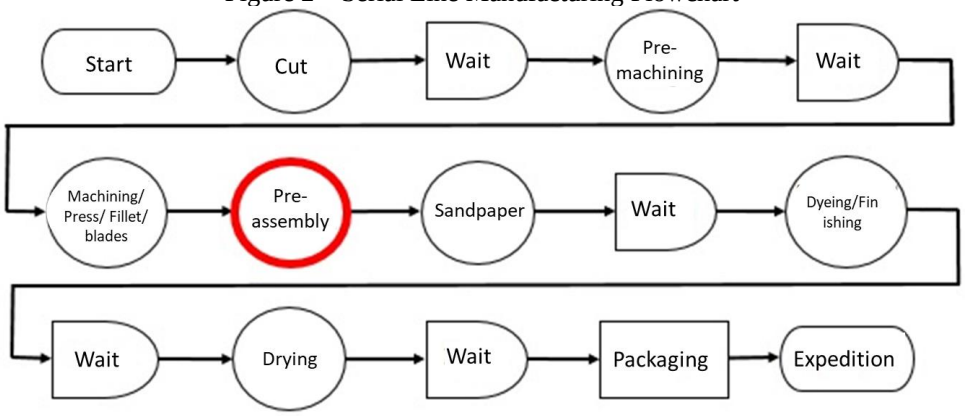
The company has a wide range of products manufactured in the serial line, consisting of more than six hundred products, where each one has specific characteristics and differs from each other according to types of raw material, dimensions, finishes. The products are divided into categories such as: side, coffee and dining tables, buffets, benches, sofas, sideboards, lamps.

Currently, the company does not have a clear and demarcated sectoral separation, and several sectors are interconnected in a disorganized way. There are no corridors that allow a flow of people or transport of materials from one place or another, not even a standardization of the employees' benches, nor does it have a clarity of the production process, lack of cleanliness in the work environment and little space to carry out activities, transport and movement.

2.4.2 Manufacturing Flow Chart

In Figure 2, it is possible to see the basic sequence of the manufacturing process, which are the transformation steps of most of the products. In addition, it can be seen that the pre-assembly sector is located in the intermediate part of the process, that is, it is a place that needs to receive the raw material, transform it and quickly pass it on to the subsequent process to continue the manufacturing process.

Figure 2 – Serial Line Manufacturing Flowchart



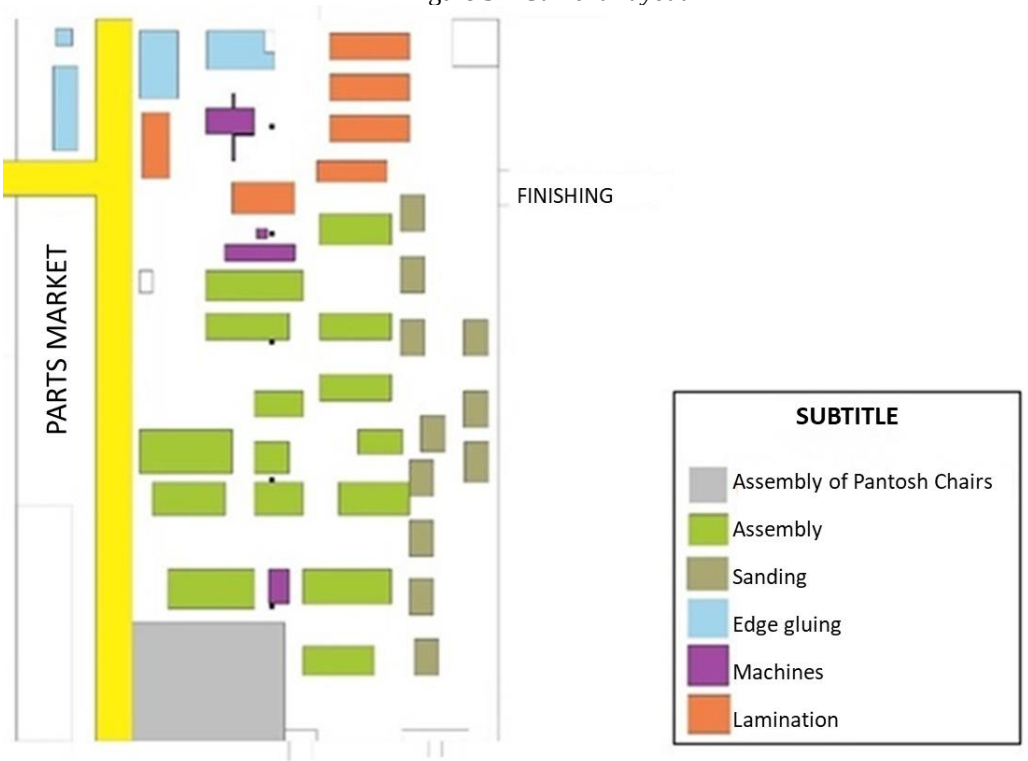
Source: Prepared by the author (2016).

The pre-assembly sector of the serial line is the only step in the process in which all products go through to be manufactured. The other steps are also of paramount importance for the manufacture of the products, however, for the manufacture of some products, some steps are not necessary.

2.4.3 *Current Layout*

For the employee to be able to perform his/her activity correctly and safely, the work environment must have conditions that allow the performance of such activities. In the pre-assembly sector, the distribution of machines, equipment, workbenches, and people is misaligned and non-standardized, as shown in Figure 3.

Figure 3 – *Current Layout*



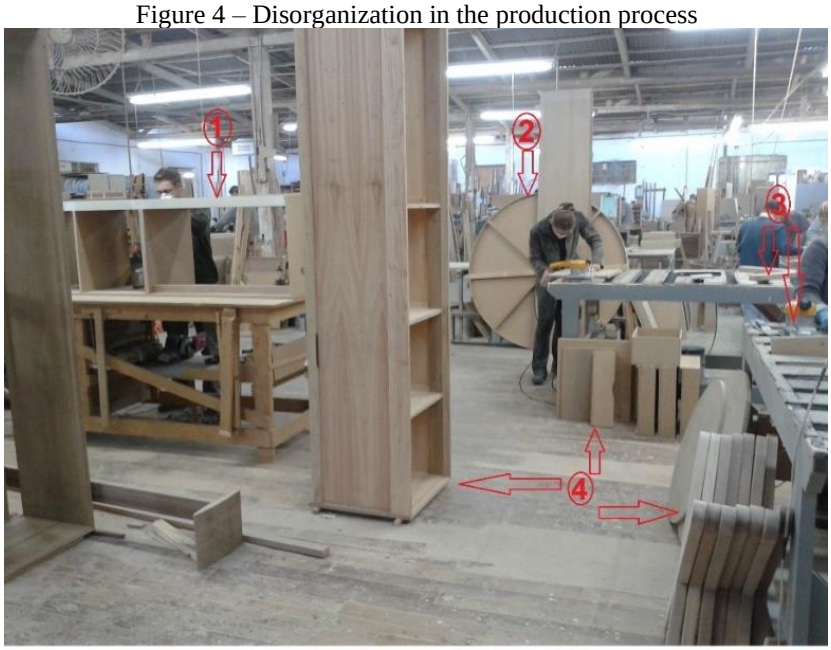
Source: Prepared by the author (2016).

There is no well-defined production line, because all the benches, of the assemblers and also of the sanders, are arranged without a well-elaborated organization and this ends up hindering the flow of people and the transport of materials from one process to another.

Figures 4 and 5 below demonstrate the work environment and allow us to clearly identify several opportunities for improvement that can be found.

Figure 4 demonstrates more clearly the disorganization of the workbenches, as well as the lack of alignment in the assembly of products. In addition, the mixture of materials in the same work sector is noticeable. In the same place, it is noted that there is an assembly bench, jigs propped up on other benches and with a risk of falling, damage or loss, and sanding benches with various materials in process propped up.

Figure 4 – Disorganization in the production process



1- Bancada de Montagem 2- Gabarito 3- Bancadas de Lixa 4- Estoques em processo

Source: Company surveyed (2016).

Figure 5 – Difficulty in visibility of the sector

Source: Company surveyed (2016).

Figure 5, on the other hand, highlights the lack of space between the benches, as well as the lack of organization and, mainly, the difficulty of visualizing the sector, which provides a lack of control of production. This is due to the high structures of the benches that make it impossible to clearly verify the employee performing the activities. In addition, there is no separation of the process steps and the products are propped up on benches or allocated between the benches, which results in obstruction of prime spaces, in addition to the risk of damage causing rework and losses.

In the pre-assembly sector, several wastes were found that occur due to an inadequate poor physical arrangement, lack of clarity of the process, absence of a lean manufacturing system and implementation of 5S. Based on the Toyota Production System, the following wastes can be mentioned:

- Process: There is no SOP (Standard Operating Procedure) that instructs employees on how to assemble or sand a piece of furniture. In this way, the products do not have an assembly standard, in addition to providing rework during the process due to errors or even loss of entire products. In addition, in the sanding process, there is no quality criterion that can be analyzed to know if a material is correctly sanded. For this reason, many products end up being reworked or discarded due to errors in the production process.
- Transportation: due to the fact that there are no aisles that allow the transportation of materials correctly and safely, employees end up moving the products manually between the countertops and the other operators. This task, in addition to wasting precious process

time and being ergonomically incorrect, often ends up damaging the material by bumping into tools, workbenches and utensils and, thus, requiring rework.

- Inventory: There is a lot of stock in process in the pre-assembly sector. This fact occurs because there are errors in the designs or machining of the materials, materials that arrive at the assembly sector incomplete. Thus, the worker needs to stop assembling a piece of furniture and starts a second piece of furniture, as he is waiting for the materials to be able to complete the stopped furniture. In addition, during the assembly process, some products need a drying time due to the use of glues and end up being allocated between the countertops until this step is completed.
- Handling: this waste is one of the most evident in the sector, as employees make many movements when assembling products. Such movements occur to look for tools that are not on the benches or due to their breakage, request new materials, perform rework, travel to the engineering sector to solve doubts about certain projects, remachine some materials due to errors during their assembly.
- Defective products: this waste occurs regularly in this sector due to the poor distribution of countertops and people, excess of materials, tools, equipment and stock in process, and the lack of quality criteria, SOPs and employee training.

Another factor that should be highlighted is the lack of standardization of the benches and the risk of accidents that can be caused by excessive inadequate electrical wiring, as can be seen in Figure 6.

Figure 6 – Workbench

Source: Company surveyed (2016).

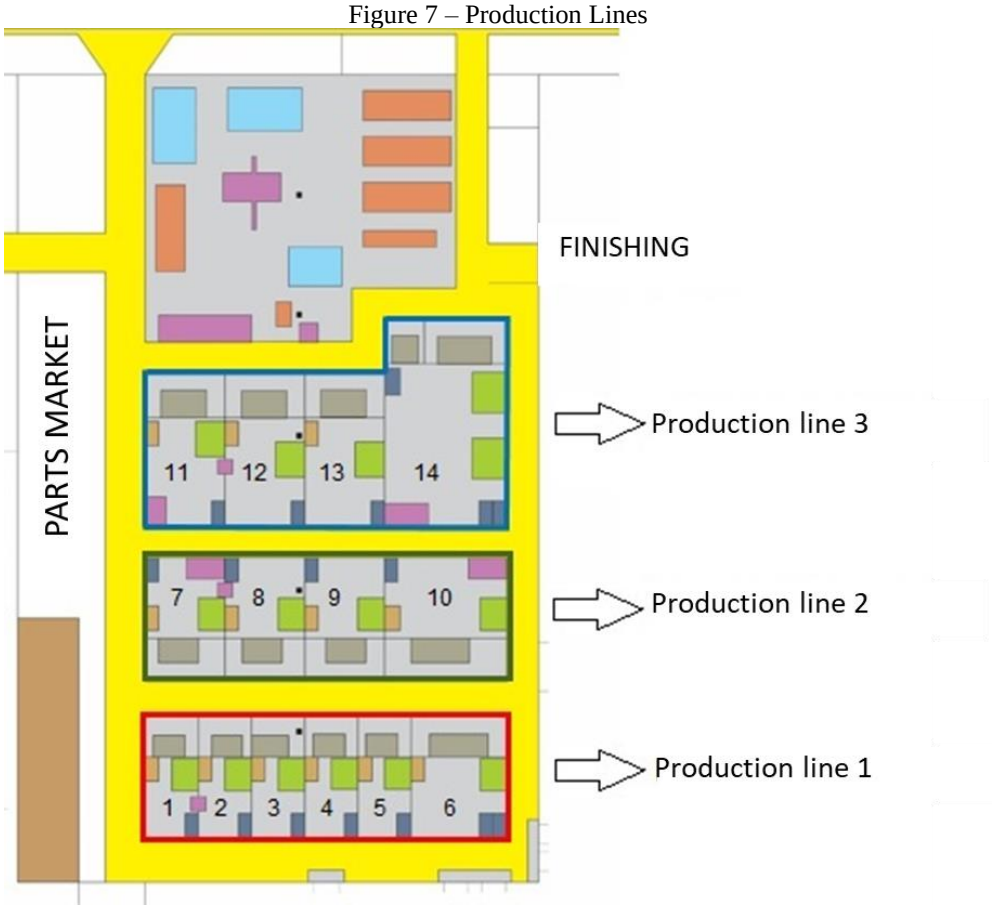
The countertops are made up of reinforced wooden structures to remain stable when some heavy furniture is assembled. It should be noted that they do not have adequate places for the allocation of tools and manual machines, in addition to containing products in process, templates, electrical extensions and disposable items. This disorganization results in wasted time for the employee to find the necessary materials and tools, in addition to loss and damage to the products in process.

2.4.4 Proposed implementation of the new *layout*

Based on the variety of wastes existing in the process, possible ideas for *Layouts* according to processes and products to improve the performance of work activities in the sector, as well as optimize space and eliminate or reduce existing waste.

The physical arrangement with 14 production cells was elaborated, according to the amount of current labor existing in the sector, as shown in Figure 7. It is possible to clearly identify the three production lines established in the pre-assembly sector. Production line No. 1 is highlighted in red, while production line 2 is in green and production line 3 is flagged in blue.

Figure 7 – Production Lines



Source: Prepared by the author (2016).

First, an alignment of the assembly and sanding benches was carried out, establishing three standardized production lines in the sector, in which each line consisted of some work cells. The production lines were elaborated and separated according to the criterion of product size.

In production line 1, cells 1 to 5 carry out the activities of assembling and sanding products with maximum dimensions of 1.5 meters. Cell number 6, on the other hand, produces a line of special chairs, known as Pantosh and for this reason, this special cell is larger than the others in this first row. The main products in this line are: side tables, benches, lamps and Pantosh chairs.

Production line number 2 consists of 4 work cells and these work with products with dimensions from 1.5 to 2.5 meters. This line is used for the production of side, coffee and dining tables, buffets, sideboards.

Production line number 3, on the other hand, is also composed of 4 work cells, where cells 11 to 13 operate with products with dimensions between 2.5 and 3.5 meters, while cell number 14 works with products with dimensions above 3.5 meters or special. The products manufactured in this line are coffee and dining tables, buffets, benches, sofas and sideboards, as well as some special ones with larger dimensions than the standard.

For the restructuring of the *layout*, there was a need for changes in the work methodology and implementation of new ways of operating. One of these changes was the assembly bench of production lines 1 and 2. The cells that were previously composed of reinforced wooden tables have been replaced by mobile trestles that allow flexibility to allocate raw materials during manufacturing and facilitate the movement of the employee within the cell.

Another necessary change that deserves to be highlighted was the implementation of tool trolleys for each assembly cell. Thus, each trolley is made up of a shadow frame of tools, as well as machinery and equipment needed by each assembler. Such a car can be seen in Figure 8.

The tool trolleys have a standard shape and allow them to be moved within the work cell, which facilitates and speeds up the assembly of the products.

Figure 8 – Tool Cart

Source: Company surveyed (2016).

Inadequate electrical wiring in the manufacturing environment can cause risks to employees, in addition to hindering the progress of activities with the excess of electrical extensions and high voltage wires in the work cells. To minimise this risk, an individualised overhead wiring system has been developed at each workstation.

Figure 9 – Implementation of the compressed air ducting system and electrical wiring

Source: Company surveyed (2016).

At the end of the conduit there is a box with sockets for each fitter and sander to turn on their machines when necessary, as highlighted in Figure 9. Even so, some power strips continue to be used

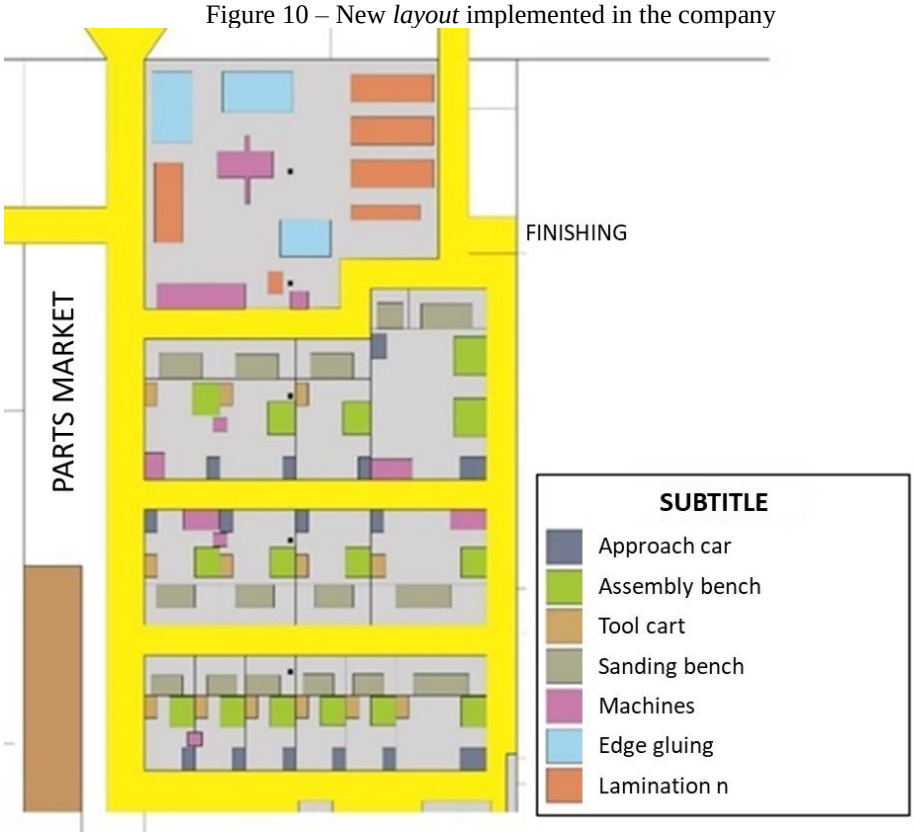
when needed.

Along with this plumbing, the compressed air system was coupled to each workbench, facilitating the cleaning of the furniture during its production and also to clean the work cells at the end of the working day.

Figure 9 also allows you to visualize the demarcation of the cells in the assembly and sanding lines, as well as the new bench structures. It is noted that it is possible to have good visibility of the entire sector, as there are no benches with high structures that make it difficult to see.

Through the analysis of the collected data, together with studies in search of an optimization of the physical space, the physical arrangement considered ideal was elaborated and it was implemented in the company, as can be seen in Figure 10.

Figure 10 – New *layout* implemented in the company



Source: Prepared by the author (2016).

The production flow remained the same, that is, the materials arrive until pre-assembly and go to sanding and, after that, they go to finishing.

Each assembly cell consists of an assembly bench, a tool trolley and an approach carriage, which is used to transport the materials. With this, the assembler receives the materials through the approach carriage, which must contain all the parts of the furniture to be assembled. The fitter then arranges the sawhorses in the best way to fit the furniture inside the cell and then directs the tool carriage around the furniture to begin the assembly process.

The approach carriage is still used to transport the products to the finishing sector, after they have gone through the sanding process. This is to avoid damage to the health of the workers due to the fact that they are working with some heavy furniture.

Right in front of the assembly line there is a sanding line, because the moment the assembler finishes his activity, immediately the sander receives the product and starts his work. This process makes it possible to eliminate the waiting stage for some products and avoids the displacement of employees to transport the products to the sanding benches, in addition to providing greater agility in the process. Thus, it is estimated a reduction in travel time of about 45%.

Some machines, such as circular saws and vertical drills, were strategically redistributed in the sector to avoid waste with the movement of employees, providing a longer operating time and reducing walking and moving.

After the products are sanded, they are moved to the finishing or dyeing sector that continues to carry out the sequence of the process.

The aisles have been designed with dimensions that allow sufficient space for the flow of materials in the cars and also a flow of people. However, they must always be unobstructed to avoid inconvenience and delay in the transportation of materials and in some movements.

With the new *layout* Implemented in the company, several improvements and benefits were noted, such as process clarity, optimization of physical space, reduction of material handling and transportation, reduction of inventory in process, ease in internal logistics flows due to well-dimensioned corridors, better visibility of the sector, organization and cleaning, more efficient production control and reduction of waste.

3 CONCLUSION

A *layout restructuring* contributes in several ways within an organizational environment, such as optimizing space, assisting in the control and management of inventories, providing clarity of the process by finding and reducing waste, bringing machines and equipment closer together to reduce travel and movement times, in addition to improving the production flow.

This work achieved all its objectives, as a mapping of the production process was carried out; a flowchart of the process was elaborated; the products manufactured in the serial line were identified; the existing waste in the sector was analyzed; Some alternatives of *layout* until you find the ideal one for the company; The new proposal for the physical arrangement was defined and its benefits for the company were identified.

The overall objective was achieved, as a total restructuring of the *layout* in the pre-assembly sector of the serial line and it was possible to highlight the changes and benefits provided by the implementation of the new physical arrangement.

The work carried out in the company was of great importance to it, especially due to the fact that a study of the physical arrangement and restructuring of any sector had never been carried out, with changes of high impact in the 48 years of the company's existence. With this, the company begins to have another view of the importance of strategic planning within an organization.

In addition, after carrying out this work, several improvements were raised that could be made in the future to further reduce the waste that still exists and increase the company's productivity.

The present work can serve as a reference for future work in the company, such as the study of the need for restructuring of other sectors, using the thinking of lean manufacturing, space optimization and waste reduction, and implementation of the 5S program, *Kaizen*, *Kanban* and SOPs.

In addition, it can also be used as a basis for other studies of *Layouts* in companies in the furniture industry and other segments, which mainly aim at optimizing physical space and reducing waste.

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