Optimization Of the Manufacturing Process for School Portfolios Through the Implementation of The Cellular Layout

Gilmara C. dos Reis[1] and Edinaldo José de S. Cunha[2]
[1] Coordination of Accounting Sciences, School of Social Sciences, State University of Amazonas.
[2] Department of Postgraduate Program in Process Engineering, Federal University of Pará.

Abstract

One of the most common problems encountered in the manufacturing process is improper layout. About 30% of production time is wasted on transporting materials and products. The causes of this waste are problems in the disposition of stock and machines in production, that is, in the factory layout production of school desks became more efficient with the use of the cell layout. The result found was that with the implementation of the cell layout, there was an increase in the number of wallets produced and a reduction in the waste of materials. It is concluded that the. In this context, the production line based on the cellular layout has been an excellent ally, since the cells of this layout can improve the use of available space, without increasing costs due to major renovations or constructions. To prove such improvements, through the implementation of the cell layout, the PSL method (Systematic Layout Planning) was used, which follows steps such as data collection, analysis of necessary and available space, and factory limitations. With these stages of knowledge and analysis of the factory, it becomes possible to discard layouts that do not fit the characteristics of the company, whether related to financial resources, available space, and factory culture. Using the Chi-Square test for statistical analysis, it was possible to verify that the cell layout is an efficient optimization tool in the school desks production process, as it brought numerous benefits to the factory under studies, such as increased productivity, greater organization, and flexibility in the processes.

Keywords: layout; manufacturing process; process mapping.

1. Introduction

The layout has an indispensable mission in an enterprise, deciding where to place all the facilities, machines, equipment, and operators. Within an available space, the layout seeks an optimized combination of industrial facilities, to allow maximum production yield, through the best distance and in the shortest possible time.

The interest in studying layouts arose during the period of academic training, in which there were several technical visits to the factories at the Industrial Pole of Manaus. During these visits, it was found that the physical spaces of these medium and large factories were well structured and the manufacturing process was easy to understand, as the stages of the process were well distributed and organized. Therefore, the curiosity to analyze the situation of small factories concerning the layout applied in their manufacturing process arose. After a few searches, a positive response was obtained, authorizing the visit to verify the questions that guide the physical space. In the first visit, it was possible to verify the disorder and lack of standardization in the processes. A very different reality from the factories of the Industrial Pole that were seen during the graduation period. Thus, the general objective of this article was to suggest a layout more suited to the needs of the factory that would improve production, making the process more agile and practical. To assist you, the following specific objectives were elaborated: to measure all the factory space to start to elaborate the floor plan, to make the simulation of each layout using the PSL method (Systematic Layout Planning), and to evaluate the result of the simulation, if it was negative, positive or null.

The main contribution of this study was to show that one of the improvement tools that a company can use to reduce the waste of material and time is the correct use of the industrial layout in the manufacturing process.

This article is divided into five parts, namely: the first registers the introduction, with the theme, motivation, and objectives; the second examines the theoretical framework; the third describes the methodology; the fourth point is the analysis of the results and finally; the fifth part, the final considerations, and suggestions for future research.

2. Bibliographic Review

2.1 Manufacturing Process

Several studies on the manufacturing process have addressed issues related to inputs, processes/operations, and mainly the results from the manufacturing process implemented. Among them, it is possible to mention the work developed by BATISTA AND OLIVEIRA (2014), who reports the manufacturing process as a structured set of sequential activities that they have a logical relationship with each other and aim to meet, supplement the needs and expectations of customer's internal and external of the organizations.

The manufacturing processes are composed of inputs, such as operators, equipment, installations, materials, services, land machines, and energy. The set of these inputs results in final consumers goods and services RITZMAN AND KRAJEWSKI (2004).

2.1.1 Types of processes

As seen, the production of goods or services takes place through successive processes which are evidenced in the research by BALDI (2019) that deals with process mappings. Through the work of this author, we have the following concepts: primary are those that touch the client and any failure the client immediately identifies; support processes are those that collaborate with the primary processes in achieving success with customers; and managerial processes are those that exist to coordinate support activities and primary processes.

2.2 Process Mapping

The study by ARAÚJO (2017), regarding process mapping, had the following contributions: the emergence of process-oriented organizations may be a milestone in business administration, especially in the manufacturing phase, a paradigm shift. Before that, the focus was on functional structuring, which led to a great specialization of employees and a compartmentalized view of the functioning of the entire organization, generating several conflicts and inefficiencies.

Mapping is crucial to understand how the organization's processes are being conducted and to enable an analysis of possible improvements.

The research carried out by SOUZA (2014), enriches the subject stating that the mapping is also considered as the phase of analysis or understanding of the current process, comprising the investigation of the entire scope of the process, including its metrics, benefits for the organization, identification of actors, customers and suppliers, necessary artifacts, expected results, operational limitations, current problems and so on.

In DUTRA's (2015) studies on process mapping, he reports that such activity is carried out through various techniques, including modeling, interviews, workshops, simulations, among others. It often includes a study of the business environment, the organizational context of the process, factors that contribute to the operating environment, characteristics of the business segment, government regulations, and the business segment, market, and competitive pressures.

2.3 layout

According to studies by WANG et al. (2018), the layout involves decisions about the layout of the economic activity centers of a unit. A center of economic activity can be anything that uses space, such as a person or a group of four people, a cashier's counter, a machine, a workbench or workstation, a department, a staircase or a corridor, a time cardholder, a cafeteria or a storage depot, and so on.

PASQUALINI et al. (2010) define that layout as a productive operation that is concerned with the physical location of transformation resources. SILVA & RENTES (2012), through their studies on the subject, add that in addition to a physical location, the layout deals with the spatial distribution of productive resources, such as machines, equipment, people, installations, on the factory floor.

The work developed by FERNANDES (2013) says that if the layout is not well planned, it will hinder the smooth functioning of production, due to setbacks, such as those that can be highlighted: machinery out of place or distant, loss of time in location and displacement of parts of stock and final product, loss of parts during the process, among others that lead the organization to not be efficient and reducing the possibilities of generating more profits, given this is what took place in this case study, which aimed to demonstrate small changes in the studied layout and expanded the possibilities of using industry spaces by implementing a logical production sequence, which eliminates long times of locating and moving parts, allowing greater control over the progress of production as well as being able to obtain more efficiency by employees.

The research carried out by HONORATO et al. (2015), determines that the layout is the form and appearance of a productive operation and that is why it is one of the most evident characteristics, generally the layout is the first thing to be noticed when entering by a location.

In his article entitled: The importance of layout in companies, SANTOS & FILHO (2019) clarifies that the layout can be considered the first element evidenced by everyone who enters the factory, it is of substantial importance that it is allocated in an organized and easy way understanding of production processes.

In a study by ISTVÁN (2013), it turned out that the layout is related to all decisions regarding the physical space of the enterprise, that is, the layout of machines, equipment, people, sectors, processes, among others. The main goal of implementing a good layout is to allow employees and equipment to operate more effectively.

According to KRAJEWSKI (2009), the layout affects not only the workflow of the processes but also the processes in other places of a value chain taking into account the effects on the whole process.

MONTEIRO's (2017) work has intensified in showing that the proper choice of layout can positively affect costs and the overall efficiency of production.

In short, the proper choice of factory layout is essential to enable and increase a company's competitiveness in today's globalized economy.

Therefore, it is necessary to understand the importance of the proper layout.

2.3.1 The importance of the proper layout for each company

In the research carried out by LUCENA (2015), the importance of the layout is emphasized, saying that the proper choice is essential for the harmonious productive progress of any factory or company, regardless of the branch, size, or segment.

The study intensified by SANTOS (2019), affirms that to develop a new layout in an organization is to research and solve problems of positioning machines, sectors and decide on the most appropriate position that each one should stay. In the whole development of the new organizational layout, a basic concern must always be pursued. Make workflow more efficient, whether employees or materials.

In their article, GERLACH et al. (2017) mention that in many cases, the layout used by companies becomes the big bottleneck, as it is not well-designed and, therefore, presents an inefficient yield, whether in terms of production or movement. Although a new layout involves time and costs, if well-structured, it can bring many benefits to the company.

The research carried out by GHIRALDE et al. (2018), states that the layout of an industry is fundamental for industrial health because if the machinery and processes are not in harmony, production will be more vulnerable to control errors, inaccuracies in time, poor logistics of internal delivery, risks of loss or damage of parts/products and generation of bottlenecks in addition to offering safety risks to employees.

Therefore, to define which layout is suitable for the company, it is necessary to know mainly which types of layouts exist.

2.4 Types of Layout

Each type of layout must be chosen considering the management models practiced by organizations and their respective alternatives to arrange work processes more efficiently.

Organizations must present their layout in such a way that they can adapt to the specific movements of materials and people with their area of activity and business needs, that is, for each type of organization, a layout or physical arrangement suitable for their functions is planned.

There are five types, which can be evidenced by the authors NEUMANN & SCALICE (2015) who list as layout by product, cell positional, by process, and mixed, which will be described below. The difference and application of each depend on the diversification of products, quantities, and processes. You can have the same plant with two or three types implanted. Adequacy to the best type to be used is a key point to achieve a reduction in production costs and an increase in productivity, with maximum efficiency.

2.4.1 Cell Layout

In his article related to cell layout, PINHEIRO (2019), calls such a layout the one in which the necessary materials are previously chosen for a certain stage, which is called a cell, it contains all the tools and equipment that are indispensable in that specific manufacturing process.

In his article, CALAIS (2012), explains this organization and separation of materials as a group, that is, each step is a new group, where there will be all the components necessary for the manufacture of the product.

In line with the authors referred to above, PEREIRA (2013), in his work on the theme, adds that in this type of layout, the transformation resources necessary to carry out a certain task, activity, and or production are allocated together, to form a production cell.

GERLACH (2013), on the other hand, intensified his studies stating that the pre-selected materials move during the manufacture of the product and they are close, ready for use so that there are no delays, to meet the immediate needs of the process.

In his work, MATTOS et al. (2017) state that in addition to the high degree of quality and productivity, the use of cell layout leads to a drop in transport and inventory levels, as each cell now has its autonomy to produce its products, that is, the level of responsibility on the manufactured product increases, giving greater satisfaction at work, seeing the finished product ready.

Figure 1. Cell layout showing the "U" shape.
Source: Adapted from DOBLAS, 2010.

In figure 1 it is clear that the structure of the cell layout has the shape of the letter "U". It thus becomes a very peculiar feature and easy to recognize.

The article by FIGUEREIDO (2016), focuses on a very visible feature of the cell layout: the fact that it is formatted in a "U" shape, such a peculiarity makes it easy to identify on the shop floor, this "U" format provides greater fluidity and optimization of the flow of products and workers, and since each cell is a complete productive flow, each cell has products or parts with varied manufacturing routes, contributing to greater agility, autonomy, and productivity to the process.

2.5 Systematic Layout Planning – PSL

In the study by PEREIRA (2013), the author emphasizes that the proper planning of the macro space of a factory is of great relevance to the functioning of the production process. This planning contributes in a decisive way to the growth or decline of the activities performed in the manufacturing area. On the factory floor with vast manufacturing processes and departments, they are the ones that most need well-improved planning due to the high complexity of manufacturing steps and the variety of their product mix. Given the precision of creating an efficient layout, the PSL appears.

The research applied by SANTOS et al. (2018), highlights the PSL as an ordering step, procedure model, techniques for verifying, analyzing, and evaluating elements and areas that incorporate planning. With the PSL, decision making on which scenario to choose becomes more practical, because through it will be found the layout that best meets the needs and characteristics of the factory.

3. Method

The survey of data in the sector of manufacture of school desks of the company Hadar-Commerce of Recreational Products and Assembly Services LDTA., Took place from October 2019 to July 2020.

It started with the study of space, flow, the layout of machines and workers, necessary space, and available space. After collecting this information, we started to research. Where the possibilities of reorganizing the space and its limitations after these researches were understood.

The following aspects were observed: allocation of workstations, the access of operators on the shop floor, the movement of people and materials, the location of raw materials. Given these characteristics, the current layout of the company was designed to portray its inadequacies.

The PSL method was chosen to define which layout is most suitable to meet the needs of the factory. For the preparation of the correct layout, the 3 steps of the PSL method were taken into account. The flowchart below will describe how the simulation and layout choices were made.

Data and information about the measurements of the manufacturing space were collected, analyzing the available space together with the space needed for its reorganization.

In the research, tests were carried out in which there was the elimination of layouts that did not fit the reality of the factory.

As a result, the cell layout that fit the factory's needs as it does not require a large investment, is aimed at repetitive processes that require standardization, is easy to control and understand, and is independent and flexible. Therefore, the most suitable for the factory's needs, according to the PSL guidelines, is the cell layout. A flowchart was prepared based on the PSL steps, showing the simulation steps to propose the most appropriate layout for the factory's issues. Figure 2 represents the flowchart used.

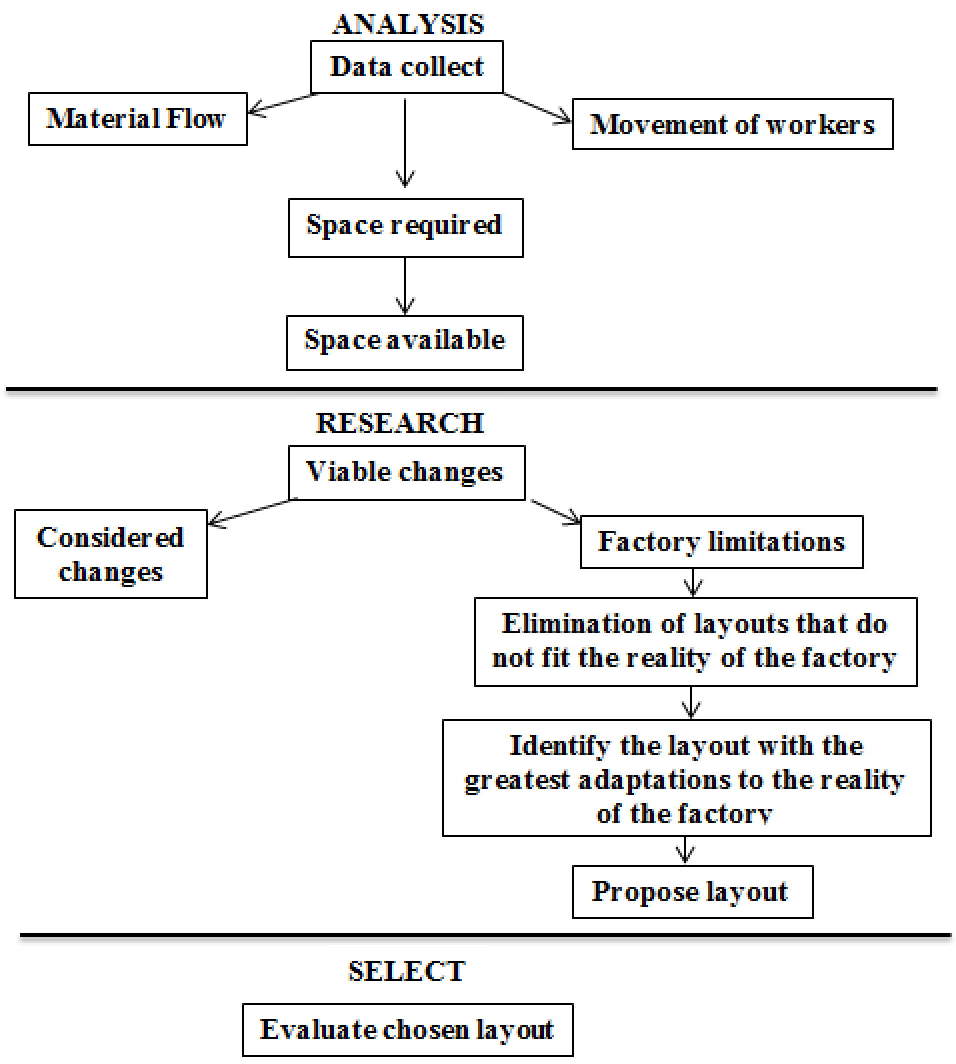

Figure 2. Flowchart showing the layout simulation steps.

Source: The author.

3.1 Data Processing

Pearson's Chi-Square test is used when one wants to compare two independent categorical variables with each other. The $\chi 2$ or chi-square distribution is one of the most used distributions in inferential statistics, mainly to perform $\chi 2$ tests. This test serves to quantitatively assess the relationship between the result of an experiment and the expected distribution for the phenomenon.

To better understand the process of making school desks, it was divided into 5 parts, namely:

Cuts sector, place where all the pieces that will compose the metallic part of the chair are cut.

Fold sector, the place where folds are made in those pieces that they need, such as arm, legs, and shoulder.

Welding sector or welding template sector, This is where a template is available so that parts such as the arm, legs, clipboard support, shoulder, and notebook holder when being welded do not come out differently from each other. Painting and drying sector, place where the jet painting is done and drying is expected without absorbing dust. Final assembly, place where the plastic parts of the wallet are assembled with seat, backrest, and drawing board.

Elaboration of the problem: determine at a significance level of 10%, if the portfolio manufacturing process remains the same with the implementation of the new layout.

Establishment of the hypothesis:

Ho = O = E (Process remains the same)

H1 = O ≠ E (Process changed)

For this, it was necessary to apply the Chi-square test to assess the hypothesis (Ho) in each of the sectors above.

The degree of freedom (ϑ) was determined, where ϑ = n-1 → ϑ = 5-1 = 4.

Critical Chi-square: was calculated:

For α '= 0,10 / 2 = 0,05 and ϑ = 4 =≫ = 9,488

For α '= 1-0,05 = 0,95 and ϑ = 4 =≫ = 0,711

According to figure 3, there is a rejection area for the Ho hypothesis. Which will serve to analyze whether the five sectors of the portfolio manufacturing process in the implementation of the new layout brought results?

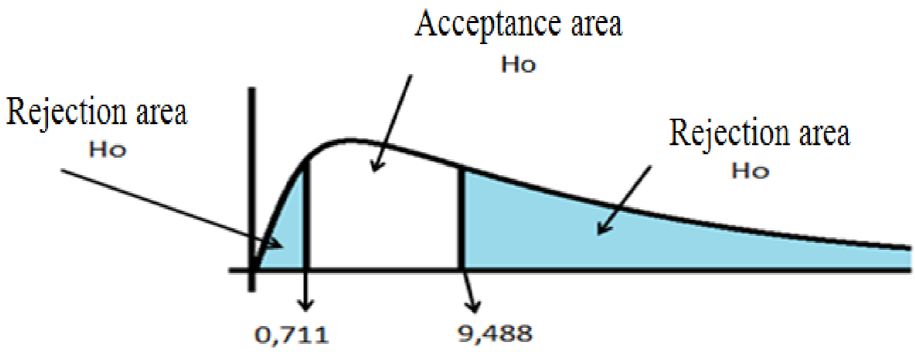

Figure 3. Graphical representation of the rejection area for Ho.

Source: Own authorship.

To assess each of the sectors, the following theory will be used:

$$X^2_{\text{found}} = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$$

Critical Chi-square

$X^2_c = 9{,}488$, for α= 0,05 and grade 4 and $X^2_c = 0{,}711$, for α= 0,95 and grade 4

Se $X^2_{\text{found}} < 0{,}711$ or $X^2_{\text{found}} > 9{,}488$, it will reject Ho.

Se $0{,}711 \leq X^2_{\text{found}} \leq 9{,}488$, it will accept H**.**

4. Analysis and discussion of results

Twenty days before the implementation of the new layout, the following information was available according to the graph shown in figure 4.4. This result was a reflection of the lack of organization that can be shown in figure 4.4. The production started with the cut of the pieces in the number of wallets that it was hoped to manufacture in the day. As noted below, on Monday, the equivalent of 45 portfolios was cut. But it only doubled the equivalent of 34 portfolios, leaving 11 for Tuesday. In the welding sector, out of 34, it only sold 25, in turn, the painting and drying sector, only managed to do the job in 20, leaving the assembly for another day. The total sum presented in the cutting sector was 201 units of portfolios to be produced, however, the total sum in the assembly sector presented only 153 portfolios produced in the week. That is a production delay of 37.35% in the week.

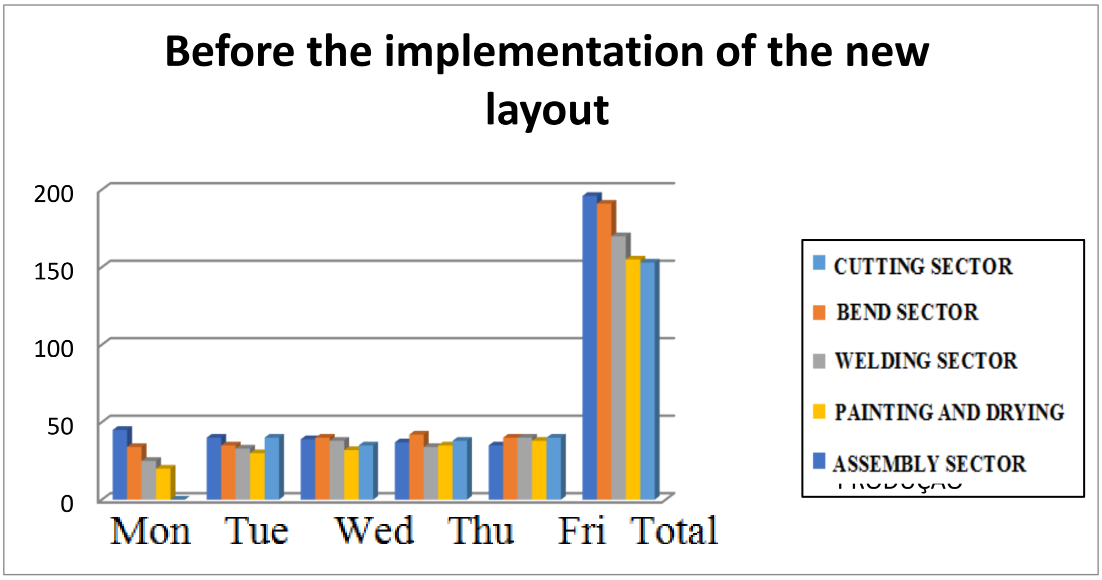

Figure 4. Graphical representation of the production before the new layout.
Source: Own authorship.

Fourteen days after the implementation of the new layout, the following information was found, as shown in figure 5. The cutting sector increased the number of wallets that it hoped to manufacture, during the week, by 21.89% compared to the data period to the production of cut pieces collected before implantation.

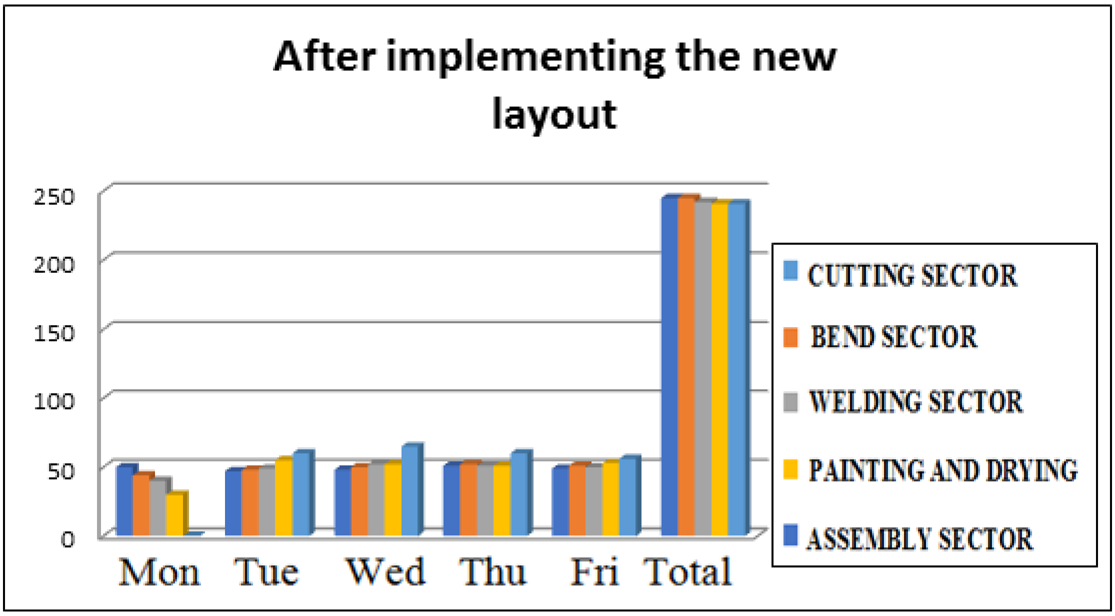

Figure 5 - Graphical representation of the production after the new layout.
Source: Own authorship.

It is also possible to observe that the amount of leftovers in the weekly accumulation, in the sectors from one day to the next, has reduced. That is, in the cutting sector, the surplus left by the bending sector, the reduction, was 70%, in the bending sector the surplus left by the welding sector, the reduction, was 81%, in the welding sector, the surplus left by the painting and drying sector, the reduction, was 45%. Although in the painting and drying sector there was an increase in the number of leftovers in the weekly accumulation, by 71%, left by the final assembly sector, at the end of the working day, this accumulation was zeroed. One of the positive points presented by the new layout was the total of the final assembly sector compared to the cutting sector, since the difference between the two was 4 units of portfolios aimed at manufacturing. Therefore, the delay in production went from 37.35% to 1.6% in the week.

5. Conclusion

Considering that the general objective of this research was to suggest a layout more adequate to the needs of the factory and for that, the three specific objectives developed to serve you, are listed below with their respective results achieved.

Firstly, the aim was to measure the entire manufacturing space: When measuring the entire manufacturing area, it was found that there is a good space for manufacturing. Except that it was not being used well, it mixed machinery with finished products and defective material. Given this analysis of the space, it was possible to notice a lack of standardization in the execution of activities, and this made it difficult to understand the manufacturing steps. In addition, it was found that these steps were spread across the area and did not follow any permanent flow or organized sequence. Consequently, this mess in the infrastructure hampered the process of making school desks.

For the second objective, which was to simulate each layout using the PSL method, it was possible to discard layouts that did not fit the reality of the factory. Through this evaluation, it was verified which layout had the most adaptable characteristics to the reality of the company, thus leaving the cell layout.

In the last objective, which was to evaluate the result of the simulation with the Chi-Square test and to propose changes in the production line, the following result was obtained: With the implantation of the cell layout, there were improvements in the production of the sectors of cutting, bending, welding, painting and drying and assembly of the plastic parts in the company of manufacture of school desks. With a significance level of 10%.

It was concluded that the cellular layout was the most adequate to the needs of the factory.

It is suggested for future research to address the importance of the Kaizen tool as a factor of continuous improvement in terms of reducing and improving productivity.

6. References

ARAÚJO, Adolfo. Vicent. Modeling and simulation of the yoghurt production process. Federal University of Viçosa, March, 2017.

BALDI, Brayan. Aquino. Mapping of the contract management process and external interference in a railway company using the BPM methodology – A case study. Completion of course work. Faculty of Engineering of the Federal University of Juiz de Fora, 2019.

BATISTA, João. Henrique, OLIVEIRA. Francisco. De. Paula. Analysis of production processes and use of FEMEA in the Datacom line at Phelps Doage Brasil LTDA. ISSN 1808-6594. Management and Knowledge. Management Course Magazine. PUC Minas, 2014.

CALAIS, João. Filipe. Lourenço. Gomes. Layout as a determining factor in the efficiency of the industry's production process. Dissertation to obtain the title of Master in engineering and industrial management; University of Beira Interior; Covilhã; 2012.

CARLO, F. D.; ARLEO, M. A.; BORGIA, O.; TUCCI, M. Layout design for a low capacity manufacturing line: a case study. International Journal of Engineering Business Management Special Issue on Innovations in Fashion Industry, v.5, n. 35, p. 1-10, 2013.

DOBLAS, D. Physical arrangement and strategic planning. April. 2010, Rio de Janeiro. Electronic Annals. Rio de Janeiro: Gama Filho University. Technological Center for Exact Sciences, 2010. Available at: http://www.ebah.com.br/content/ABAAAA820AC/arranjofisicoplanejamentoestrategio Accessed on: February 2nd, 2020.

DUTRA, Danilo. Lima. A framework for process mapping. Recife: The Author, 2015.

FERNANDES, Giovani., STRAPAZZON, Rafael., CARVALHO, Andriele. Layout of Companies and their Benefits. XXXIII National Meeting of Production Engineering. ENEGEP, Salvador, October 8th to 11th, 2013.

FIGUEREIDO, Luís Henrique Wanderley de. Application of layout types: An analysis of scientific production. Graduation project. Technology College. Department of Production Engineering. University of Brasilia, 2016.

GERLACH, Gustavo, SILVA, Vilmar. Bueno. Da., SANTOS, Lucas. Almeida. Dos., ADAMY, Ana. Paula. Of. Amaral, GARLET, Eliane. Layout improvement proposal as a factor for optimizing the organizational production process. Rev. Adm. UFSM, Santa Maria, v. 10, Special Edition, p. 41-55, AUG. 2017

GHIRALDE, Rafael., JOIA, Augusto. Breda., GOBBO, Elivelton. Henrique, CHITOLINA, Jean. Rodrigo., FERRARI, Vitor. Improved layout of an auto parts industry through the use of Flow Diagram. VIII Brazilian Congress of Production Engineering, Ponta Grossa, PR, Brazil, December 5th to 7th, 2018.

HONOR, Antonio. Edson. Oliveira., FERREIRA, Lairena. Almizia. Miranda., CORREIA, Ana. Maria. Magellan. Study on the physical arrangement in a materials sector for the optimization of industrial production in a cement factory in Mossoró/RN. XXXV ENEGEP Production Engineering Meeting, Fortaleza, October 13th to 16th, 2015.

ISTVÁN, Albert., HASSAN, Charaf., LÁSZLÓ, Lengyel., Layout definition considerations for a content-based model-based layout system, Eurocon. Zagreb, 2013, pp. 543-549, DOI: 10.1109/ EUROCON.2013.6625034, 2013.

KRAJEWSKI, Lee., RITZMAN, Larry., MALHOTRA, Manoj. Production management and operations. São Paulo: Pearson Prentice Hall, 2009.

LUCENA, Josineide. Pereira., LIMA, Larissa. Escobar., COSTA, Maria. Isabel., JESUS, Antonio. Carlos. Grandson. The use of physical layout as a strategic tool in a steel distributor. Proceedings of the VII ENIAC Multidisciplinary Seminar, 2015.

MATTOS, James. Lisbon., ROSA, Larissa dos Santos., BASTOS, Alexandre. Paranhos. Productivity analysis based on layout optimization: a case study in the fabrication of trapdoors. XXXVII National Meeting of Production Engineering ENEGEP, Joinville, October 10-13, 2017.

MENSES, Renan. Neris., RODRIGUES, Saulo Guilherme., SANTANA, Wilber Davila., MOSTESCO, Richard. Andres. Stumbling. Proposal to improve the physical arrangement in a company that produces animal feed located in the state of Sergipe. XXXVII National Meeting of Production Engineering ENEGEP, Joinville, October 10-13, 2017.

MONTEIRO, Daniel. Andrew. Pereira. The industrial layout problem: analysis of the current situation and development of improvement proposals. CDU 658.5(043). Engineering and industrial management. Bibliographic catalog: Libraries of the University of Aveiro, 2017.

NEUMANN, Clóvis., SCALICE, Régis. Kovacs. Factory Design and Layout. 1. ed. ISBN 978-85-352-5407-5. Rio de Janeiro: Campus, 2015.

PASQUALINI, Fernanda., LOPES, Alceu. Oliveira., SIEDENBERG, Dieter. Production Management. Ijuí: Unijuí, 2010.

PEREIRA, Alexandre. Kluge. Typology and sustainability management and family swine farming in the Federal District and proposal of the physical arrangement of facilities via Systematic Layout Planning (SLP) method. Dr.; Federal University of Viçosa; Minas Gerais; 2013.

PINHEIRO, Lucas. Augusto., RISSO, Lucas. Antonio., RABBIT, William. Douglas. Breads. Cell layout design for automotive component assembly process. XXXIX National Meeting of ENEGEP Production Engineering: São Paulo, 2019.

RITZMAN, L.P., KRAJEWSKI, L.J. Production and operations management. São Paulo: Pearson Prentice Hall, 2004.

SANTOS, A.L.V.; REIS, R. R. The importance of layout for companies. Technological Interface Magazine, [S. l.], v. 16, no. 2, p. 157-168, 2019. DOI: 10.31510/infa.v16i2.677. Available at: https://revista.fatectq.edu.br/index.php/interfacetecnologica/article/view/677. Accessed on: 8 sep. 2020.

SAINTS, Andrew. Luiz. Vieira., SON, Ramilio. Bouquet. Kings. The importance of layout in companies. DOI: 10.31510/infa.v16i2.677. Technological Interface - v. 16 n. 2 Faculty of Technology of Taquaritinga. São Paulo, 2018.

SAINTS, James. Silva., SILVA, Estela. Victory. Da. Silva., MONTEIRO, Amanda. Sousa., ROCHA, Nathalia. De. Souza, ALVES, Lucas. Son. Layout improvement proposal for a truck workshop through the application of the PSL methodology. Cover > v. 6, no. 9. Digital Journal Library. UFPR 2018.

SILVA, Alessandro. Lucas., RENTES, Antonio. Freitas. A layout design template for job shop environments with a high variety of parts based on lean production concepts. v.19 n.3, São Carlos, 2012.

SOUZA, Daniele Gonçalves. Mapping methodology for process management. Dissertation (Masters in Engineering). Federal University of Rio de Sul, 2014.

GREEN, Larissa. Queiroz. Lime. ARAÚJO, Maiara. Musy., LIMA, Marcelo. Elijah. Okay., MEDEIROS, Rayanna. Reeds. de., FRANCE, Lucas Damasceno de Almeida. Physical arrangement analysis in a coffee producing company from Ceará. XXXVII National Meeting of Production Engineering ENEGEP, Joinville, SC, pp. 3, Oct., 2017.

WANG, Ruiqi., ZHAO. Huan., WU, Yan., YUFEI, Wang., FENG, Xiao., LIU, Mengxi. An industrial facility layout design method considering energy saving based on surplus rectangle fill algorithm. DOI:10.1016/J.ENERGY.2018.06.105Corpus ID: 115195267. China Petroleum University, 2018.