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INCREASED PRODUCTIVITY THROUGH A PRODUCTION MODEL BASED ON LEAN MANUFACTURING AND SLP TOOLS IN SMALL FURNITURE MANUFACTURING WORKSHOPS

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Increased Productivity through a Production Model Based on Lean Manufacturing and SLP Tools in Small Furniture Manufacturing Workshops

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ABSTRACT

The furniture industry has developed globally with exponential growth in recent years. In Peru, it is one of the key sectors in the productive transformation chain that is growing the most. However, these companies are mostly microenterprises and present various challenges such as the lack of quality standards, the high need for labor, the lack of qualified workers, limitations in technology, among others, which leads to low productivity and performance. That said, the main objective of this research is to increase the productivity of a Peruvian SME workshop dedicated to the manufacture of melamine furniture on a small scale. For this purpose, a model composed of the tools Systematic Layout Planning (SLP), 5'S and Standard Work (SW) was proposed and executed through a pilot plan and simulation. As a result, there was an increase in productivity by 11.82%, an increase in production by 50% and a reduction in production time from 398 min to 330.67 min.

CCS CONCEPTS

• **Applied computing**; • **Operations research**; • **Industry andmanufacturing**; • **Supply chain management**;

KEYWORDS

5S, Productivity, Standard Work, Lean Manufacturing, small melamine furniture, systematic layout planning

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1 INTRODUCTION

The furniture manufacturing industry is among one of the most important contributors of the global economy [1]. China and the United States represent 53% of the world's distribution of furniture production, making them the main countries in the sector [2].

In Peru, the furniture manufacturing industry is one of the most important in the productive chain of second transformation of the sector [3]. In the first quarter of 2021, GDP increased by 3.8% and furniture industry grew by 59.6% in that period due to furniture manufacturing with 62.9% [4]. About 97% of the furniture industry is traditionally familiar, uses traditional craft methods and is characterized by limited technological progress and a low diffusion of production techniques [5]. Likewise, 96.4% of the companies are microenterprises, which produce on a small scale, use half of their installed capacity and do not have quality standards in the products they offer to the market [6]. Based on the literature reviewed, it was possible to determine that the main problem is the stagnation of productivity due to high unproductive times, lack of control processes, inadequate workplaces, lack of procedures, among others [2].

Therefore, it is essential to research innovative solutions to this problem, and it is necessary to be more efficient in the way they are manufacturing their products and in the use of their resources. In this sense, a case study was chosen in a SME that presented low productivity compared to the standard of the furniture manufacturing industry. The main causes were the lack of training of the operators, lack of standard procedures, inadequate distribution of the workshop and disorder. Based on this, an improvement model was developed combining 5'S tools, Standard Work (SW) and SLP based on success stories that seek to improve productivity. To publicize the proposal, this academic article has been divided into the following sections: Literature Review, Contribution, Validation and Conclusions.

2 LITERATURE REVIEW

For the literature review, 40 scientific articles with a maximum of 5 years old were used, obtained from indexed databases such as

Scopus and Web of Science. The most important findings are shown below.

2.1 Productivity in the furniture industry

The current context of the furniture industry is represented by a competitive and demanding consumer market [7]. Furniture is a strategic product since it is high value-added, globally competitive, export-oriented, labor-intensive, and supported by the availability of sufficient raw material sources [8]. However, the problem associated with the labor-intensive nature of the furniture industry remains a major challenge to productivity [9]. The main reasons for low labor productivity are limitations in the management of technology, the high need for labor, the lack of supply of skilled workers, high turnover, among others, so they are in danger of not being able to sustain themselves over time [10]. There are seven main wastes: overproduction, waiting time, overprocessing, excess transportation, excess inventory, unnecessary movement, and defects, which must be eliminated to reduce production costs and delivery time of products to achieve greater productivity by increasing resource utilization [8]. The main objective to increase productivity should be to concentrate on reducing costs, eliminating activities that do not add value and reducing the amount of production time [1].

2.2 Systematic Layout Planning in the processes of the furniture industry and / or similar

Systematic disposition planning is a methodology proposed by Muther that seeks to optimize a plant and minimize costs [11]. A poor plant layout can lead to huge production costs, inefficiencies, low yields, unnecessary delays, and low revenue generated [12]. With this tool, an adequate analysis of the design of the facilities is achieved and the performance of the production lines can be improved. This is because it contributes to reducing the rate of bottlenecks, minimizing the cost of material handling, reducing downtime, and increasing the utilization of labor, equipment, and space [13]. In an investigation of the furniture sector that applies SLP in conjunction with other tools, it was possible to eliminate 66% of unnecessary movements of the operators and it was possible to increase production by 63.2%, achieving better efficiency [14].

2.3 5'S in the processes of the furniture industry and / or similar

It is a management model tool that is usually used to work more efficiently, have a better work environment, and achieve continuous production; that is related to minimize losses, in such a way that the value in the final delivery of the product or service is maximized [15]. It is one of the most used tools within Lean Manufacturing. Its name comes from 5 keywords of the Japanese language, which are: Seiri, Seiton, Seiso, Seiketsu and Shitsuke. It can be used in various environments, does not require a large investment, and can be implemented in a brief period due to its simple nature [16]. When this tool was applied in a study of the furniture sector, an increase in productivity was achieved by 27% in the drilling sector and one of the improvements was the implementation of an organizing box to separate the drill bits [17]. In another research that was based on a model that included 5'S, it was possible to reduce production time by 2% and furniture production was increased by 40% [18].

2.4 Standard Work in the processes of the furniture industry and / or similar

Standardization is a specific methodology focused on the operator working in the same way to obtain the best results, to reduce cycle time and increase efficiency [19]. The objective is to maintain the pace of production in line with the market demand, using the concept of takt time as the basis of standardized work [20]. Within the framework of the Lean Furniture Framework (LFF), it sets the guidelines for developing a standardized operating procedure in the furniture segment and establishes a standard of a process in case it is not available [2, 17]. In a case study of the sector, worthless activities were eliminated using Standardized Work procedures and there was an increase in production by reducing cycle time and achieving an increase in productivity of 6.5% [2, 14].

3 PROPOSED MODEL

Figure 1 shows the proposed model that involves 5'S tools and Standard Work in the framework of Lean Manufacturing and Systematic Layout Planning (SLP). In the first stage, the model takes as a guide the different investigations related to the furniture manufacturing industry that are based on these tools [2, 6, 18]. Unlike these, the proposed model is applied in a furniture workshop that is a SME (it has less than 10 workers), the production is based on the orders of the customers, the raw material is mainly melamine and does not use complex machinery. Therefore, the novelty lies in the fact that the proposed tools will be implemented in a workshop that differs from a conventional company in the furniture sector that are characterized by making wood products in large volume. In that sense, it would be contributing to the scientific community and particularly to the furniture industry since it would be marking the first milestone by not finding previous research whose axis of study has been a company of a similar nature.

3.1 Model Components

This section details the phases of the proposed model. Figure 2 shows the implementation process of the proposed model specifying each component that must be followed to increase productivity.

3.1.1 Analysis of the current situation. This component focuses on the diagnosis of the current situation of the study workshop. To do this, first, the workshop was visited, and data, photos and videos were collected. We conducted a time study to determine the delays in the manufacturing process and, from this, the Value Stream Mapping (VSM) was elaborated, in such a way that cycle time and non-value-added time could be established. Also, the efficiency indicators of the operators were calculated and analyzed. The causes of low productivity were captured using the Ishikawa diagram and the main causes were identified with the Pareto diagram. It was applied the Systematic Interrogation Technique to analyze the root causes through an interview with the workshop supervisor.

3.1.2 SLP – Lean Intervention. The second component consists of the development of the selected tools found in the study literature. For this research, the Lean Manufacturing and Systematic Layout Planning (SLP) methodology are used. The tools of the proposed model are developed; for the Lean 5'S tool a pilot plan was executed in a brief period, for the SLP tool a proposal for an improved

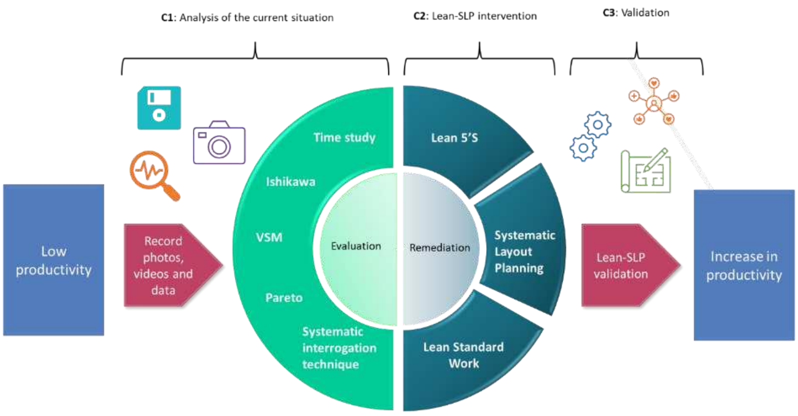

Figure 1: Proposed Model

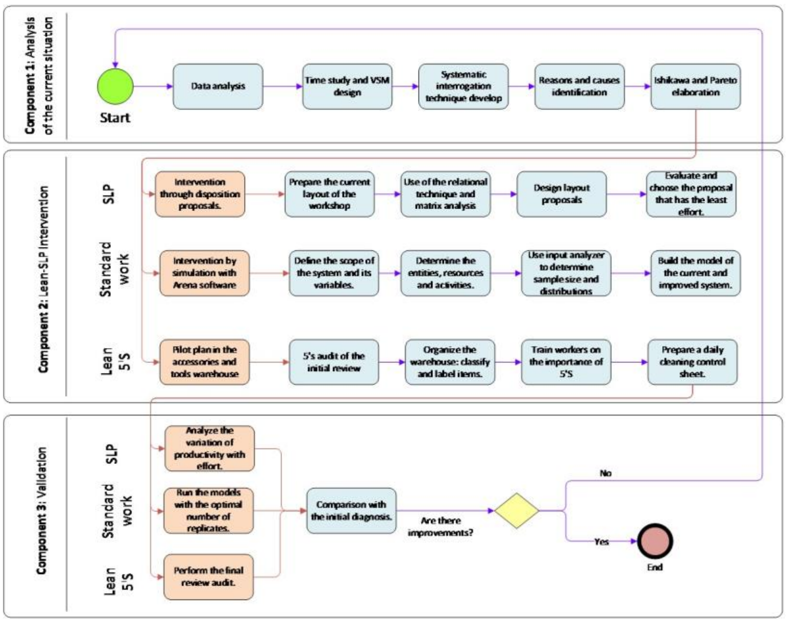

Figure 2: Process of the proposed model

workshop layout was designed and finally, the Standard Work was implemented through a simulation in the Arena software. In SLP, an improved plant design is applied, so that the current workshop effort and distance traveled can be improved. In the same way, for the 5'S, an audit is applied for the disorder and dirt existing in the tool warehouse, to reduce the time of searching for tools. Then, Standard Work (SW) is applied to improve production processes, reducing, or eliminating activities that do not add value, through a training program.

3.1.3 Validation. In the last component, each of the tools is validated. The SLP tool is validated with the variation of productivity in terms of effort and it is verified in this way that the chosen proposal is the best. For the simulation of the standard work, the optimal number of replicates for the system is determined and both models are run in such a way that the confidence intervals of the indicators are obtained. Finally, the 5'S audit of the final review is carried out to assess whether there was any improvement. Thus, the indicators were measured again and compared with the current situation of the diagnosis; in this way it can be determined if the proposed model contributes to the increase in productivity of the company under study.

3.2 Indicators of the proposed model

To evaluate improvements after implementing the proposed model, it is considered pertinent to use the following indicators.

Indicator of productivity. It measures the relationship between the total units of raw material planks and the total costs, based on one month, this because the company does not manage daily production but monthly.

$$Productivity = \frac{Total\ raw\ material\ planks}{Total\ Cost} \tag{1}$$

Indicator of efficiency. It calculates the efficiency of the production process based on the time it should take (optimal time) and the time it takes (executed time).

$$Efficiency = \frac{Optimal\ time}{Executed\ time} \times 100 \tag{2}$$

Cycle time. It is the time that elapses throughout the production process from the beginning to the end.

$$Cycle\ time = \sum Time\ of\ each\ production\ stage \tag{3}$$

Effort in kg-m. It is the effort that relates the quantities to be transported and the distances to be traveled of a plant distribution.

$$Effort\ (kg-m) = distance \times quantity \tag{4}$$

3.3 Validation

According to the main objective of the research to increase productivity in a wooden furniture workshop, a pilot plan for the implementation of the 5'S tool was conducted, a simulation of the current scenario and the improved scenario was conducted in the Arena software and an improved workshop layout proposal was designed. Initially, the study company presents a low productivity with a variation of 24.09% compared to the productivity of the furniture sector in Colombia.

3.3.1 Initial diagnostic. In the current situation there is a significant technical gap, that is, an opportunity for improvement, due to the low productivity of the workshop under study, which is 1.56 x 10-3 in contrast to the furniture companies of Colombia, which present a productivity of 2.05 x 10-3 [18]. Next, the economic impact was quantified, and it turned out that there were losses of 75,810.00 soles in a period of 6 months, and that represents 48,013.00 dollars per month for the company and, in equivalence, 27.06% of the total costs. This means that the loss is significant as it is greater than 6,000 dollars per month and when it exceeds the key indicator for MSEs that is 5%. The main causes that were found were: (a) Lack of training of the operators, (b) non-standardized procedures, (c) Poor workshop layout, (d) Disorder and disorganization.

3.3.2 Validation design. For the validation of the design, the Lean (5S' and Standard Work) and Systematic Layout Planning (SLP) tools were developed, obtaining favorable results as shown in Table 1.

Lean 5'S. First, a pilot plan was conducted for the implementation of the 5S' in the accessories and tools warehouse, which lasted two weeks. The project consisted of training the operators on the 5S' philosophy and the cleaning rules to be conducted to keep the warehouse tidy and clean. Also, to evaluate the continuous improvement of the tool, a team was appointed to validate the implementation of the tool through a continuous cleaning program.

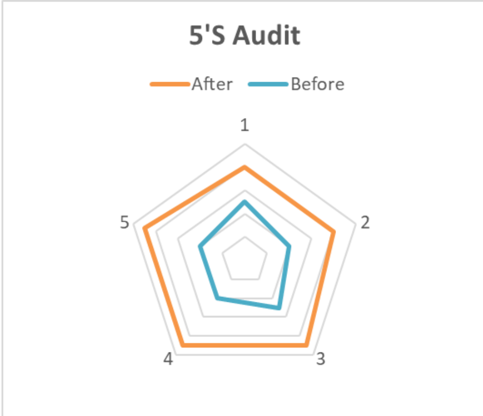

Figure 3: 5'S audit results

Standard Work (SW). Secondly, a simulation was conducted with the help of the software Arena version 16 for the validation of the Standard Work (SW) tool.

The simulation is performed for the closet production line and focuses on reducing the times of activities that do not add value. To do this, the scope of the system was determined in the first instance from the arrival of the melamine pieces to obtaining a finished closet. Next, the input variables (controllable and non-controllable variables) were defined and then the optimal sample rate was determined with a confidence rate of 95% and an error of 10%. Likewise, the entities (box of melamine pieces and closet), attributes (time between arrivals) and resources (operators and corresponding accessory kit) of the system were established. Finally, with all the data needed to model a first scenario, it was found that 80 replicates are necessary for the results to be like reality and ensure their relevance.

Systematic Layout Planning. Third, the relational technique and matrix analysis were used for the development of the SLP tool to analyze the distribution of the workshop by calculating the distance and the initial effort. Subsequently, an improved plant layout design was proposed, and the effort was recalculated to contrast it with the initial effort of the workshop, and thus obtain the variation in productivity.

With the improved scenario, a significant variation in cycle time was obtained, being reduced from 398 min to 330.67 min, which is proportional to 5.5 hours and equivalent to the production of 12 closets in a month. Similarly, an increase in the efficiency of the production process from 52.80% to 63.52% could be evidenced. Consequently, workshop productivity improved by 11.82% and the technical gap with Colombia narrowed to 13.92%. This is because, by applying standardization of work, workers have clearly established the procedures to be conducted, eliminating times that do not add value such as delays in the search for tools and materials.

4 DISCUSSION

After simulating both the current model and the improved model with 80 replicates, the confidence intervals of the process efficiency and cycle time were obtained.

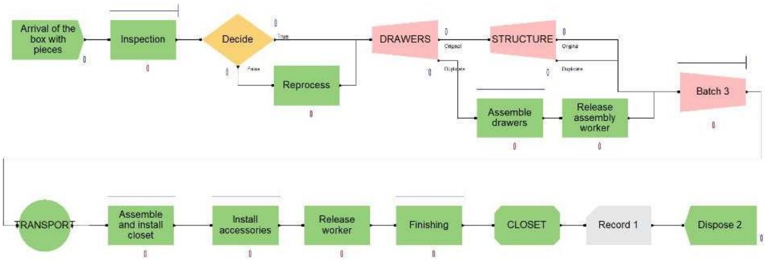

Figure 4: Simulation of the proposal

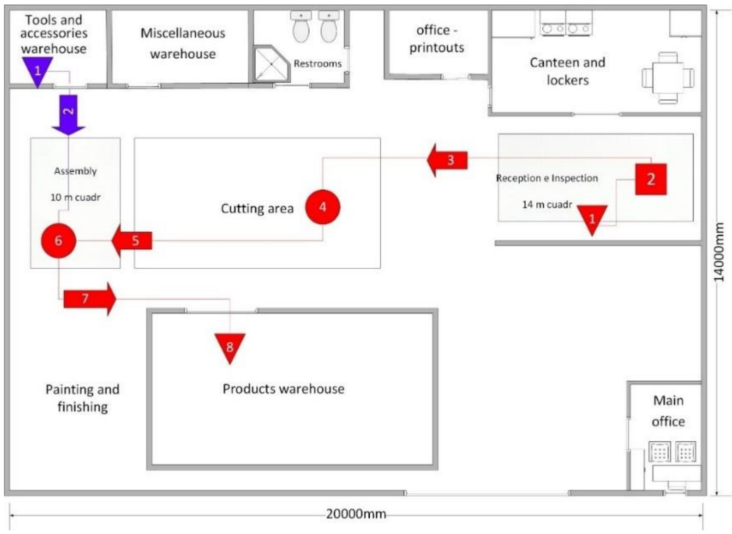

Figure 5: Improved workshop layout

Table 1: Result of indicators

	Indicators	Before	After
General	Productivity	1.56 x 10^{-3}	1.76 x 10^{-3}
Standard work	Efficiency (%)	52.80 %	63,52%
	Cycle time (min)	398	330,27
SLP	Effort (kg-m)	9,013.81	5.858,82
	Distance (m)	51.10	29,39
5's	Tool search time (min)	9,00	2,00
	5's Audit	4,4	8,6

Table 2: Confidence interval of the simulation indicators

	% Efficiency	Cycle time (min)
Current situation	[51,6% ; 54,2%]	[387 ; 407]
Improved situation	[62,1% ; 65;4%]	[321 ; 338]

Table 3: Scenario comparison

Indicators	Current situation	Improved situation	Scenario 1	Scenario 2	Average (scenario)
Efficiency (%)	52,80%	63,52%	64,02%	64,51%	64,27%
Cycle time (min)	398	330,27	328,11	325.54	326.83

Two new scenarios are proposed using the Arena version 16 software to make a comparison between the simulation of the current month (first month) and the simulation of the following two months, using 80 replicates.

To do this, the results of the first simulation (improved situation) are used for the first scenario (second month), and for the second scenario (third month), the data obtained from having implemented Standard Work for the second time is used. In this way, it will be possible to observe the improvement from the current situation until the third month of simulation. The table 3 shows the results of this comparison.

For the first scenario, a second month is simulated, and the efficiency and cycle time indicators have improved by 64.02% and 328.11 min, respectively compared to the improved situation. This shows that there is continuous improvement by having applied Standard Work.

For the second scenario, a third month is simulated, and the efficiency increased to 64.51% and the cycle time decreased by 326 min compared to the scenario 1. Therefore, it continues to represent positive results for the company.

When comparing the two scenarios, in both cases, the efficiency increases and the cycle time decreases, so the indicators show a positive progress after the implementation of the improvement. So, it could be said that as the months go by, better results are obtained.

5 CONCLUSIONS

The application of the proposed model, constituted by the 5'S tools, Standardized Work and SLP, in an MYPE in the furniture sector, contribute positively to productivity since an increase of 11.82% was achieved.

Using the Value Stream Map (VSM) tool, it was possible to determine the activities that did not add value to the closet manufacturing process. Based on this, the causes were identified with the Ishikawa diagram, they were prioritized with the Pareto diagram and, finally, with the Systematic Interrogation Technique (TIS), the main root causes were established. Thanks to the use of these diagnostic tools, a clear picture of the problems, the causes, and the model to be proposed was obtained.

The production time of a closet was reduced by 67.33 min, the efficiency of the production process was increased by 11.34 %, therefore, it would be possible to increase the current production (8 closets) by 50%, it means, 4 more closets per month.

With the SLP tool, the distribution in the workshop was improved, reducing the effort of the workers by 35% and the distance traveled by 42.48%.

Likewise, with the implementation of the 5'S, the time to search for the tools could be reduced by 22.22%, by reducing the time used for searching tools from 9 min to 2 min and improving the audit indicator by 48.84%. Therefore, this research can serve as a guide for other SME in the same area in the achievement of their corporate objectives through the model proposed in this study.

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