Optimized plant distribution and 5S model that allows SMEs to increase productivity in textiles

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Abstract*–In Peru, the Textile sector generates between 350 and 400 thousand direct jobs, representing 1.9% of Gross domestic product (GDP) and just over 10% of manufacturing. SMEs are characterized by being formed by family businesses, low levels of investment in new technologies and limited financial resources. This context has made SMEs are delayed compared to large companies in implementing Lean Manufacturing. Manufacturing textile companies that have problems with low productivity, excessive use of physical space, unnecessary movement and transport, use the tools of Lean Manufacturing and distribution plant for solving these problems. Many of the problems found in companies are related to the disorganization of processes, material flow and layout. Therefore, companies have seen the need to apply different strategic tools to help them increase the efficiency of their processes and become more competitive in their market. Among the strategic tools is the Lean Manufacturing. Several authors conclude that the plant distributions that SMEs have are not correct for increased productivity, however, the improvement models presenting lack information on how to create step by step a new layout of the company. Because of this, this article details the steps that SMEs can follow in search for a plant distribution model under the SLP tool.

Keywords-- Lean manufacturing, 5S, distribution plant, SMEs, SLP

I. Introduction

In a situational analysis of textile SMEs, it reveals that 35% of SMEs in Lima have a capacity of more than 11 machines, providing "service" to large companies; 2.24% of SMEs in Lima have an idle capacity of more than 60%, 59% for lack of workload and 41% for lack of qualified personnel. On the other hand, 61% doesn’t have a cutting area and 5.59% doesn’t have a finishing area [1]. Therefore, the textile industry is important to Peru, not only for its great contribution in jobs, but because it represents a significant percentage of the total manufacturing GDP. SMEs are characterized by being formed by family businesses, with flexible management structures, low levels of investment in new technologies and processes, lack of skilled manpower and limited financial resources. This situation has made SMEs are delayed compared to large-scale enterprises in the implementation of Lean Manufacturing [2]. Based on the interviews, the benefits of implementing "Lean Manufacturing" included: reduction of inventory (by 50% in a company), creation of smaller lot sizes, reduction in product complexity, changeover times reduced (1.5 days to 45 minutes in one example), increased production (after implementing 5S, a company experienced an increase of 16% in 1 month), cleared space for increased production and new business, reduced inventory of finished products, increased quality first pass (53% to 80% in one case); and reduced production time [3].

Many of the problems found in companies are related to the disorganization of processes, the flow of materials, layout and workstations, they cause unnecessary use of physical space, excessive movement and transportation, low productivity and delayed orders [4]. For a manufacturing SME the activity that consumes most of the time without value added was minimized by implementing 5S [5] [6], through the use of SLP with Lean tools, creates efficiency in the flow of material. Several researches show improvements for these problems, one of them to solve the problem of high cycle time in the sewing process of a textile company used lean techniques Flexsim simulator to validate the results, movement, transportation, occupied area stock fell in the process, among others were reduced, activities that add value had an increase of 7% [4], other one aims to reduce waste (mudas) in the workshop of a manufacturing small-scale enterprise (SME) with the implementation of 5S, as a result, it obtained that the nonproductive manipulation time of the elements in the work areas was reduced by 50% [2]. Finally, other author aims to reduce the duration of the activities (cycle time) in the production process, through the use of Lean techniques: Kaizen and 5S in a Brazilian SME, as a result, reported a considerable decrease in lost times due to unnecessary tasks, promoting, in the first month after the implementation, an increase of 10% on the production of upholstery [7].

The motivation for this research arises from the several investigations concerning industrial plant distribution applied to SMEs that don’t detail the correct way how to apply SPL at a production plant. Therefore, an optimized model of plant distribution is proposed in which the process to be followed for development and further detailed implementation. This study is complemented with the use of Lean philosophy in order to reduce and eliminate waste.

II. Literature Review

A. *Plant distribution*

The distribution of plant consists of the physical order of industrial and commercial elements, this order includes both the spaces required for material movement, storage, indirect workers and all operating activities or service, that is,

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considered optimal distribution design of a workplace [8]. In research by Asad (2016), details the creation of four plant distributions for a medium-scale manufacturing company. For the development of plant distribution, the author performs the following steps:

- Step 1: PQRST Analysis: This analysis is performed for all production activities. This includes P (product), Q (quantity), R (routing), S (support) and T (time).
- Step 2: Activity relation analysis: At this stage, the process diagram is constructed by observing the production line for weeks in random changes.
- Step 3: Material analysis flow: a table is made where the intensity (trips) of the flow of materials and the interaction between different departments are represented.
- Step 4: Relations diagram: It establishes the decision of relative positioning between functional areas.
- Step 5: Space requirements / analysis available: in this step the amount of space assigned to each department is decided.
- Step 6: Design alternatives: This step converts the relation diagram in block design.
- Step 7: Evaluation: a table is made where each design proposal is evaluated, where the number of adjacent departments, the flow of materials in meters, and the observations and problems are placed. Then the accepted design is chosen.

All these steps led to find results of decrease in total distance traveled and decrease in costs per year.

B. Lean Manufacturing

Lean manufacturing is a collection of practices that work together synergistically to create a streamlined, high quality system that produces finished products at the pace of the customer demand [9]. Use of Lean Manufacturing has succeeded in manufacturing SMEs, some researches who investigated the problem of a textile SME located in Brazil, they discovered that production cycle times they managed were prolonged. Also, the use of physical space was excessive and had unnecessary movements, this caused delays in meeting demand and low productivity [4]. To solve this problem, they used tools from Lean Manufacturing and Flexsim simulator to validate the results, which showed that unnecessary movements, transportation, stock in process were reduced and activities that generate value increased by 7% reduction.

C. 5S philosophy

The 5s belongs to the Lean Manufacturing tool set and is the first tool that should be implemented in the SME if you want to cover a total implementation of the management system [10]. In a research, it is desired to reduce waste (mudas) in the workshop of a small-scale manufacturing enterprise (SME) located in India, through the implementation of the 5S tool [2]. The authors claim that the 5S is the zero step in the implementation of Lean techniques. The saving of time was achieved through better work practices, reduced location of tools, good cleaning and healthier working conditions. Implement 5S according to these authors consist of the following steps:

- Sort (Seiri): The inventories are labeled with three colors, red for total elimination, orange for items for sale and green for suitable for use.
- Set in order (Seiton): machines out of service move to a safe place.
- Shine (Seiso): duties are assigned to operators for daily and periodic cleaning of machines and equipment.
- Standardize (Seiketsu): responsibilities are assigned, awards are given, a toolkit is prepared for the workers and verification remained for 3 weeks, verification is maintained for 3 weeks, then the "before" and "after" are displayed in photographs.
- Sustain (Shitsuke): Periodic audits (every two weeks) and corrective and preventive actions are identified for continuous improvement.

D. ARENA Simulation

The ARENA modeling system is a flexible and powerful tool that analysts use to create animated simulation models which accurately represents any system virtually [11]. In a research, the authors use ARENA as a virtual simulation to verify and validate the existing situation as well as to propose the results and the effectiveness of lean principles in a systematic manner.

III. The Proposed Methodology

To make the proposed improvements, it was necessary to investigate the contributions of various authors, who used the SLP and Lean Manufacturing tools in their research projects to eliminate the waste of the productive system, increase productivity, satisfy demand, reduce costs and cycle times. These authors take as a case study SME manufacturing companies.

The contribution of this research is based on developing the step by step of the implementation of a correct redistribution of the plant and the philosophy of the 5S for the textile company, specifically to increase the productivity of the manufacturing process of backpacks. Figure 1 shows the proposed methodology. It contains 2 main phases.

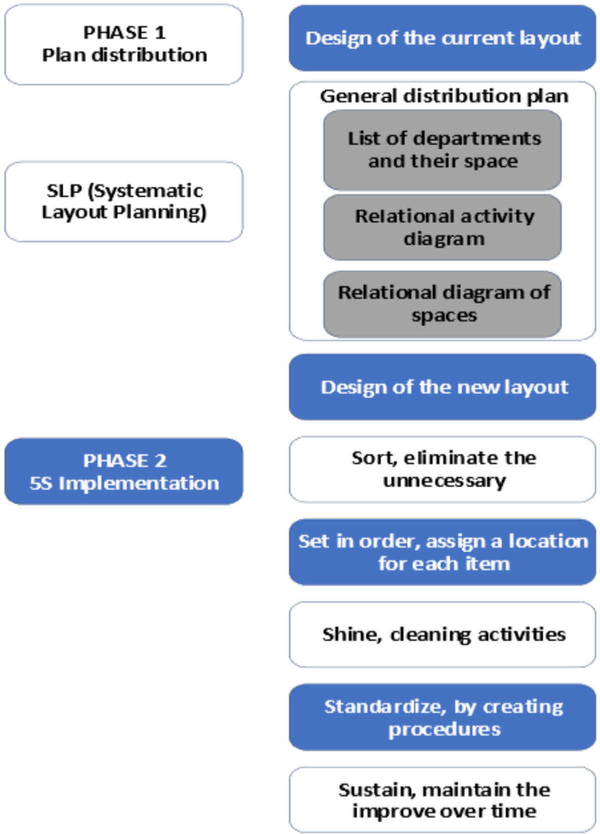

Fig. 1 Phases of the methodology

A. Distribution plant

SLP is used as a tool to design a new plant distribution.

1. *Design of the current layout of the plant*

Design the productive flow of the first and second floor of the company through a layout.

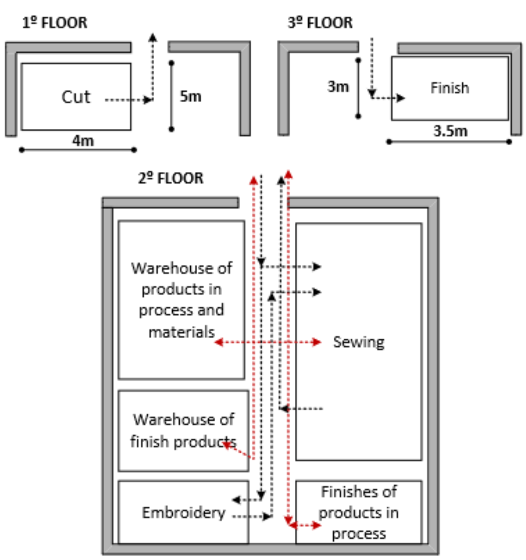

Fig. 2 Current layout

It is important to consider that in the case of a redistribution the objective will be to determine if the plant will remain in the current location or if it will be moved. The plant for this case study will be maintained at the current location.

2. *General distribution plan*

In this phase, the flow pattern is indicated for the total areas that are involved in the activity to be developed, indicating also the required area and the relationship between the different areas.

i) List of departments and their space: As a next step, the measurements of the required area are listed, for this case is the second level.

Nº	Departaments	Measurements (m)
1	Cut	4 x 5
2	Warehouse of products in process	9.5 x 6
3	Sewing	4.5 x 14
4	Embroidery	6 x 4
5	Finishes of products in process	4.5 x 4
6	Warehouse of finished products	6 x 4.5
7	Finish	3.5 x 3

Fig. 3 Areas and measures

The required space of an area doesn't only depend on factors inherent to it, can be conditioned to the characteristics of the productive process

ii) Relational activity diagram: This diagram is performed to determine the relation of proximity between different areas using an importance code.

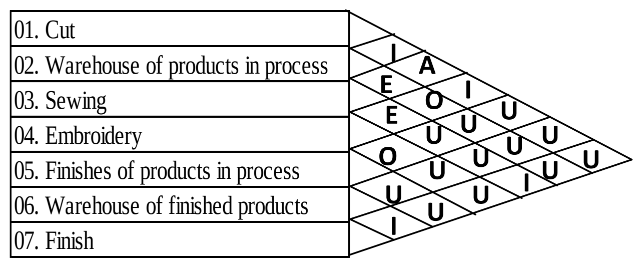

Fig. 4 Relational activity diagram

It is usual to express these relationships through a code of letters, following a scale that decreases with the order of the five vowels: A (absolutely necessary), E (especially important), I (important), O (ordinary importance) and U (not important); the undesirability is usually represented by the letter X.

iii) Relational diagram of spaces: The new distribution is sketched using a line code resulting from the relational activity diagram.

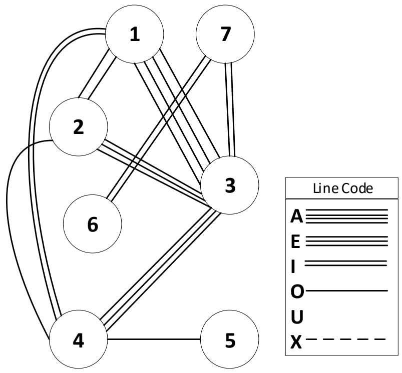

Fig. 5 Relational diagram of spaces

This diagram is adjusted, which must be done in a way that minimizes the number of crosses between the lines that represent the relationships between the activities, or at least those that represent a greater relational intensity.

3. Design of the new layout

A new layout is designed with the new distribution, and with a flow chart is evidenced the decrease of crossings and transfers in the flow.

Considerations: take into account the facilities, machinery and work equipment for each workstation, in order to determine the feasibility of transferring it to another location.

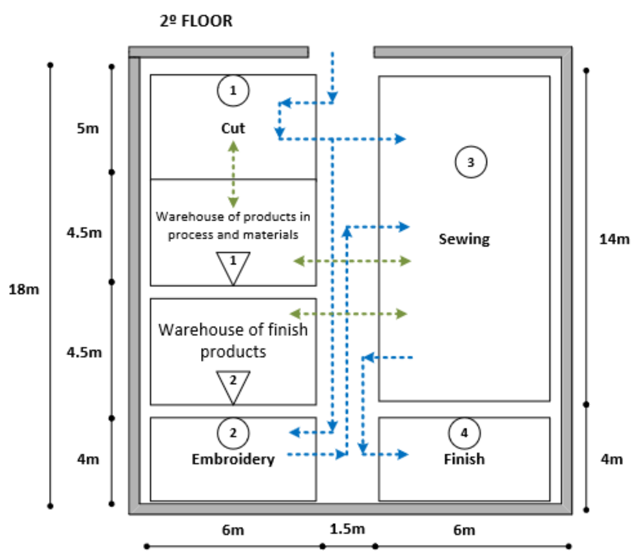

Fig. 6 Design of the new layout

B. 5S Philosophy

As part of the improvement methodology, the application of the 5S was proposed, through a 5S implementation manual.

1. Sort: List unnecessary items, apply red cards with their respective motive on each selected item and finally take an action plan: remove, relocate, order or stay.
2. Set in order:

- The use frequency criterion is applied to allocate a location for each item.
- Sort objects according to patterns and place signage to facilitate the search.

BEFORE	AFTER
Threads cones of tonalities	
	
Materials warehouse	
	

Fig. 7 Order of shelves and warehouses

3. Shine: cleaning checklist of activities assigned to one operator per week and completed by the supervisor.
4. Standardize: control the compliance of the first three S, by creating procedures.
5. Sustain: maintain 5S over time, through audits. Continuous improvement should be part of the routine activities of the workday.

This methodology is used to improve the work stations. Also, it helps to improve the working culture. So, each step in the 5S is equally important.

C. Indicators

$$\%P = \frac{Production\ output}{Resources\ input} x100$$

$$\%MI = \frac{Unnecessary\ moving\ time}{total\ cycle\ time} x100$$

$$\%T = \frac{Unnecessary\ meters\ travel}{Total\ meters\ traveled} x100$$

$$Relaionship\ Benefit/Cost = \frac{Benefit}{Cost}$$

$$\%I = \frac{Expected\ Revenue - Real\ income}{Real\ Income} x100$$

IV. VALIDATION

For the development, two scenarios are validated, the first consists in the simulation of the current situation of the company, whose data used were those of the first half of 2018, the second stage is after making the improvement with the proposal.

Table 1 shows the data of the company corresponding to the first semester of the year 2018.

TABLE I
CURRENT DATA OF THE COMPANY

Average monthly demand 2018 (units of backpacks)	3,374
Minutes available per month	13,080
Production minutes (cycle time)	33.64

ARENA Simulation results: The proposed layout and resource allocation was successfully authenticated using Arena software. For both scenarios, the input data used were production times of each subprocess, these data were placed in the Input Analyzer Program, in order to find the distribution of each subprocess, in both cases the result was the uniform distribution for each one. in this way we proceed to simulate the model in the software Arena Simulation in order to have visibility and verified the results.

Table 2 shows the times for each subprocess in the production of backpacks.

TABLE II
CYCLE TIMES BEFORE IMPROVEMENT

Subprocesses	Total (min)
Preparation of fabric	2.94
Cut	5.47
Embroidery	4.51
Sewing of minor pieces	6.49
Assembling parts	10.48
Finish	2.82
Packaging	0.93
Total (min)	33.64

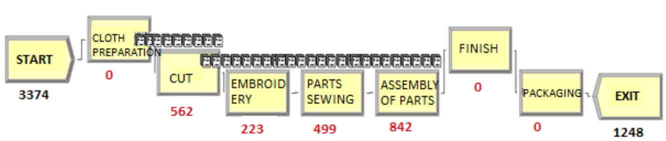

Fig. 8 System before improvement in Arena Simulation

It is observed that there are queues in the processes of cutting, embroidery, sewing of pieces and assembling parts, these queues refer to the products in process, which are generators of the high total cycle time. The output shows that before the implementation of the improvements, the company produces 1248 units of backpacks per month.

The times obtained after improvement are shown in Table 3.

TABLE III
CYCLE TIMES AFTER IMPROVEMENT

Subprocesses	Total (min)
Preparation of fabric	1.69
Cut	4.84
Embroidery	4.51
Sewing of minor pieces	4.18
Assembling parts	4.45
Finish	2.82
Packaging	2.83
Total (min)	25.32

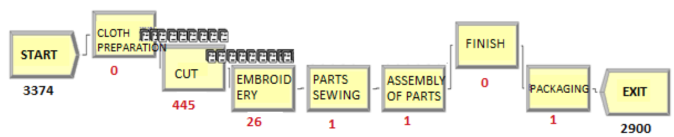

Fig 9 Enhanced system in Arena Simulation

After the improvement, it shows that the queues in the sub-processes sewing of pieces and assemblies were eliminated, this means that the product in process was reduced to what exists in the sub-processes of cutting and embroidery. At the output of the system they are displayed at 2900 units, that is, after the improvement that number of units is produced.

V. DISCUSSION

The results found before and after the improvement proposal are analyzed.

A) Productivity: For the calculation of the percentage the following formula was used:

$$\%P = \frac{Production\ output}{Resources\ input} x100$$

The data shown in table 4 is taken for the calculation of productivity

TABLE IV
DATA TO CALCULATE PRODUCTIVITY

Units produced per month	Before the improvement	After the improvement
	1,248	2,900
Number of operators	15	
	Monday-Friday	Saturday
Man-hours per day	9	5
Days a month	22	4

Table 5 shows in summary the results of productivity, before the improvement is 0.38 units per man hour, while later, this increases to 0.89, which is positive for the company, since productivity increases by more than double.

TABLE V
PRODUCTIVITY COMPARISON

	Before	After
Productivity (units/M-H)	0.38	0.89

B) Percentage of compliance: The percentage of fulfillment of the demand before and after the improvement is analyzed, under the current model (before the improvement) there is 37% of the fulfillment of the demand for backpacks, while in the model after the improvement it increases to 86%, this means that compliance more than doubled and that the improvement proposal helps the demand is 14% fulfilled.

C) Percentage of waste in unnecessary movements: The application of the 5s aims to reduce waste, which in this case are unnecessary movements. This type of waste is the activities that the workers carry out in the production of backpacks and that don't generate value for the customer, but, it generates a high cycle time. The following formula was used to calculate the percentage:

$$\%MI = \frac{Unnecessary\ moving\ time}{total\ cycle\ time} x100$$

The percentage of unnecessary movements in the backpacks production process before making the improvement is 84%, while after applying the 5s this percentage is reduced to 16%.

D) Percentage of transportation waste: This type of waste refers to the unnecessary distances that operators travel during the production process of backpacks, for the solution of this problem, the distribution of the plant was made. For the calculation of the percentage the following formula was used:

$$\%T = \frac{Unnecessary\ meters\ travel}{Total\ meters\ traveled} x100$$

In a first scenario, the unnecessary distances covered account for 56% of the total, while after redistributing the plant, this distance is reduced to 44%.

E) Costs/Benefits: If the result of the benefit between costs is greater than 1, it is verified that the project is profitable for the company, it is necessary to consider all the costs and benefits incurred in the implementation of the proposal. Table 6 shows the implementation costs for each tool.

TABLE VI
IMPLEMENTATION COSTS

TOOLS	COST
PLAN DISTRIBUTION	S/ 170.00
5s	S/ 2,212.00
TOTAL	S/ 2,382.00

Table 7 shows the benefits, this refers to the extra turns costs that were before the improvement, because in the second scenario the production time decreases, and it is no longer necessary to have extra turns to meet the demand. This old cost becomes a new income for the company.

TABLE VII
MONTHLY INCOME FOR EXTRA SHIFTS

CONCEPTS	INCOME
EXTRA TURNS	S/ 5,040.00
TOTAL	S/ 5,040.00

$$Relationship\ Benefit/Cost = \frac{Benefit}{Cost}$$

$$Relationship\ \frac{Benefit}{Cost} = \frac{5{,}400.00}{2{,}382.00} = 2.1$$

The result is 2.1 greater than 1, therefore, the benefits of the project outweigh the costs and the investment is profitable.

F) Actual / expected income: The following formula was used to calculate the percentage:

$$\%I = \frac{(Expected\ Revenue - Real\ income)}{Real\ income} x100$$

TABLE VII
COMPARISON OF INCOME

	Before	After
Entry	S/ 512,348.11	S/ 547,628.11
Cost extra shift	S/ 35,280.00	S/ 0.00
	S/ 35,280.00	
Increased income	7%	

Table 8 shows that the company saves S/ 35,280.00 for extra turns after the improvements, since it reduces the average cycle time, which means that it is no longer necessary to perform extra shifts to satisfy the demand, this amount represents an increase of 7% of the income.

VI. CONCLUSIONS

In the case of the evaluated study, the main problem was the lack in meeting the demand for backpacks, currently produces 1248 units, while the demand is 3374 units per month. The implementation of the tools for plant distribution (SLP) and

5s were proposed in order to reduce waste in the production process, since this generated a high total cycle time. The SLP allowed the resolution of the plant distribution problem based on qualitative criteria. In the scenario before the improvement, the company had a cycle time of 33.64 minutes per backpack, while after the improvement it decreased to 25.32 minutes, with which, the percentage of fulfillment of demand increased from 37% to a 86%. It was also observed that the waste caused by unnecessary movements were reduced after implementing 5S, in a first stage this percentage was 84% and then became 16%, demonstrating a considerable reduction in time caused by activities that don't generate value. For the case of transport, this is considered a waste because there are unnecessary routes that delay the production cycle, for the case of the company, it was found that 56% of the total journey, were made unnecessarily, after applying redistribution plant, this route decreased to 44%. Finally, the research proves to be profitable for the company, since the income increases by 7% once the proposal is implemented.

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