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Proposal of lean manufacturing in the fertilizers warehouse of a grape agroexport company

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Abstract—**The quality of the inputs used, particularly in the food industry, is a crucial factor in delivering a superior product. Therefore, this study focuses on the input warehouse area, specifically fertilizers and agrochemicals, of a grape agro-export company. This area is considered fundamental in ensuring the delivery of a proper final product. Our approach incorporates the principles of Lean Manufacturing, including the application of the 5S methodology, Total Productive Maintenance (TPM), and Systematic Layout Planning (SLP). The agro-export company being studied faces challenges in the input area, characterized by process delays, errors in input dispatch, and inadequate maintenance of the machinery utilized in this department. Consequently, the efficiency of the storage process is compromised, currently standing at 79%. In order to address these issues, a proposal for improvement is developed, incorporating the tools of Lean Manufacturing to address these challenges.**

Keywords— 5S, Fertilizers warehouse, Lean Manufacturing, SLP, TPM

I. Introduction

Fresh grapes are the Peruvian leading products in the agricultural sector for the key markets including the United States, the Netherlands, China, and others [1]. Furthermore, the remarkable growth of this sector can be attributed to years of diligent efforts. As reported by the Ministry of Agriculture and Irrigation (MIDAGRI), grape production achieved a value of 520 million soles in the first quarter of the year 2021 alone, exhibiting a substantial growth rate of 27.9% [2]. Peru's grape industry focuses on the months of October, November, December, January, and February for production and export. Therefore, it is of utmost importance that grape agro-export companies are prepared for the high peaks of demand to maintain their competitive position in both the Peruvian and international markets [3]. Expectedly, due to the significant boom of grapes in various markets, it is foreseen that grape exports will reach up to 1.4 billion dollars in the year 2022. This amount represents an increase of 11.7% compared to the year 2021 [4].

Considering that the input warehouse, the area of focus in this research, is one of the most critical aspects for the development of agro-industrial companies' productions, as it represents the beginning of the process. Moreover, the fertilizers and agrochemicals contained must be handled properly and maintained under proper conditions for their effective utilization. Therefore, an improvement proposal is put forth by implementing Lean Manufacturing principles and utilizing tools such as Value Stream Mapping (VSM), 5S, Systematic Layout Planning (SLP), and Total Productive Maintenance (TPM).

The objective of this study is provided a proposal - for solve the problem in the storage area – incorporating tools of Lean manufacturing. The 5S tool is taken into account in order to have a more orderly and clean area; TPM is used in order to improve the quality of life of the machinery used. Finally, the SLP tool is used to have a better distribution of the area.

This research presents novel findings as the area under investigation and the agro-industrial sector to which the company belongs have not been fully explored yet. Moreover, there is a scarcity of resources in the literature in terms of this topic. So, this proposal can serve as a valuable resource for future research and projects that may be undertaken.

II. Literature Review

Previous studies also pointed out the problem of low efficiency in the input warehouse area and its potential causes:

Looking for identify the issues faced by the company, an analysis was conducted using the Value Stream Mapping (VSM) tool. Regarding this, [5] bottlenecks are identified using the VSM tool to pinpoint the primary causes of the gap and reduced labor times. Additionally, [6] described a VSM scheme applicable to various market sectors, which minimized the duration of the production process. Lastly, [7] merged VSM with the ECRS principle, eliminating a process from the warehousing area, reducing the number of workers, and shortening the cycle time of warehousing. By employing the VSM tool for the initial analysis of the company's issues, a more precise diagnosis of the current situation can be achieved. This helps identify the problems and reveal the reasons behind the low efficiency in the storage process. Similarly, continuous improvement is essential to address the problems affecting the company. Therefore, the PDCA cycle is considered as a framework for this process, taking into account the benefits that can be obtained once the framework is implemented.

According to [8], a well-established continuous improvement procedure results in increased process performance and reduced production costs. Furthermore, [9] implemented software that follows the phases of the PDCA cycle, which in turn helped to reduce the defects in the production process. Similarly, [10] mentioned that one can decrease the input losses within the processes by implementing the PDCA cycle along with Ishikawa diagrams. Finally, [11] stated that implementing the PDCA cycle alongside Key Performance Indicators (KPIs) allows for a process based on easily accessible, transparent, efficient, and effective data.

The PDCA approach enables the resolution of the area's problem and provide a comprehensive, easy-to-apply framework for short-term improvements. This allows the company and the area under study to continue their continuous improvement journey effectively. Regarding the issue of order and cleanliness within the warehouse, the 5S tool is considered for its solution and treatment. So, [12] mentioned that the implementation of 5S generates a considerable reduction in business problems within the agro-industrial sector. In addition, Also, [13] implied that a company's waste can be managed by integrating Total Productive Maintenance (TPM), 5S, Takt Time, OEE, SMED, and KPI. [14] affirm that the 5S and the TPM tool optimize spaces within the area under study. Finally, [15] claimed that one can eliminate non-value-adding activities and minimize the steps taken to reach out to an output by implementing KPIs, VSM, 5S, and Takt Time. Given this background, one can be concluded that the 5S tool can optimize the storage space, which provides positive benefits to the company and the treated area.

For the maintenance problem faced by the company in research, a solution was studied in this study. For such problems, the literature review provides important insights. For example, [16] integrated TPM, 5S, OEE, Autonomous Maintenance, and 5 Whys, which helped to reduce machine breakdowns and increase their availability. Furthermore, [17] linked TPM with Reliability Centered Maintenance (RCM) to provide support to maintenance specialists in their daily activities. Additionally, [18] mentioned that the TPM tool can lead to a reduction in machine downtime for the company. Another case study mentioned by [19] demonstrated that using TPM, one can experience increased productivity and minimized labor costs.

It is evident that the maintenance problem observed in the warehouse can be mitigated through the implementation of TPM. This tool enables the reduction of abnormalities, waste, and machine downtime through the preventive techniques proposed for implementation. By adopting TPM, the company can effectively address the maintenance issues associated with machinery in the warehouse leading to improved efficiency and productivity. Regarding the distribution of the area and its current conditions, including the flow and layout, improvements are necessary to create an optimal space for both the operators and the materials used in the area. Enhancing the area's design and organization contributes to smoother operations, increased productivity, and a safer working environment. In this regard, [20] highlighted that TPM improved warehouse distribution, resulting in reduced costs and time constraints in the company's processes. Additionally, [21] found that by integrating Warehouse methodology and SLP (Systematic Layout Planning), it was possible to minimize control and management costs in company warehouses. Furthermore, [22] increased the efficiency of the production cycle by designing warehouse layouts and value flow diagrams. Lastly, [23] implemented a distribution design that improved efficiency and quality levels within the company. The investigation of literature provides that implementation of Lean manufacturing tools has potential to reduce time and optimize the flow of activities in companies.

III. METHODOLOGY

First, all areas of the company were analyzed, in order to find the area with the greatest needs, this is how we focused on the warehouse area because there were the biggest problems and those that generated certain problems for the continuous areas, that is That is, to the productive areas. The activities carried out by the operators within that area were observed, identifying delays and problems in the processes they carried out, as well as the lack of knowledge of some regarding the activities to be carried out or the procedure to be carried out. Likewise, meetings were held with the operators and the person in charge of the area, seeking opportunities for improvement to meet the needs of the area.

Next, an analysis of the problem, the reasons and causes is performed, searching for the root cause of the observed problem in order to provide a more efficient solution. Subsequently, similar problems are identified in the literature to compare them with the case presented, in order to find possible solutions to the problems encountered and to deliver an innovative and functional solution, also, in order to validate with previous studies, the usefulness of the proposal and how it can improve the area under study.

Likewise, an innovative proposal arises to solve the problem and its causes, covering the necessary points and closing with the validation of the delivered model.

Finally, in order to develop the proposal and check its effectiveness, a pilot plan is carried out within the area under study, detailing the stages carried out, ranging from the initial study to the implementation of the proposed tools and model.

It should be noted that during the study process, both quantitative and qualitative evidence of the current state of the area was taken, to be evaluated and compared with the results of the proposal, in order to obtain and observe favorable results for the agroexporting company.

IV. PROBLEM ANALYSIS

A case study was conducted in an agro-exporting company of grapes, which has encountered issues in the storage process of inputs (fertilizers and agrochemicals) despite years of experience and presence in the Peruvian market, resulting in an impact equivalent to 4% of the company's annual revenue.

The reasons behind the problem are twofold. Firstly, there is a delay in the storage process (18.6%), which is caused by an incorrect layout of the facility. Secondly, there is an error in the input dispatch process (67.9%), which is associated with inaccuracies in input records and mistakes in the dispatch procedure. Lastly, there is an issue with the improperly calibrated weighing equipment (13.5%), which is linked to unplanned maintenance. Figure 1 shows the problem tree with the reasons and root causes that lead to the problem.

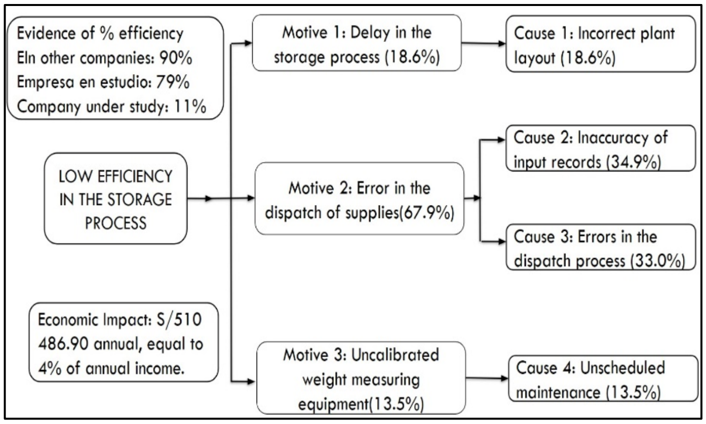

Fig. 1. Problem tree

A total of four main cases were identified, which are:

Cause 1: Incorrect plant layout

Outcome: Errors in warehouse activities were observed due to the incorrect plant layout, resulting in increased activity times. Therefore, a time study was conducted revealing that the approximate time for a dispatch was 50 minutes with several instances exceeding the allotted time (Figure 2).

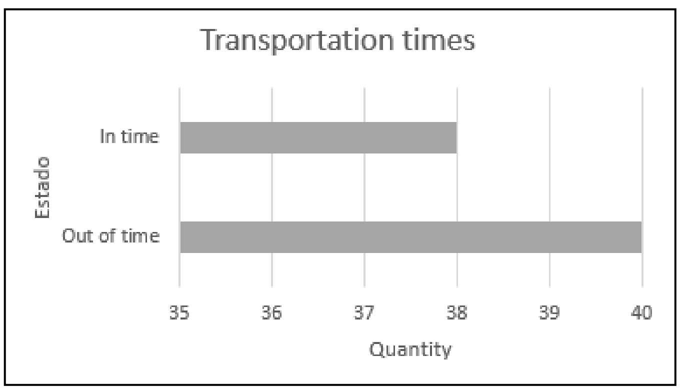

Fig. 2. Transportation times

Cause 2: Inaccuracy of input records.

Outcome: Due to the disorder in the area for reasons such as not having a fixed location, outdated processes and in general having a chaotic warehouse, as well as errors in the recording of inputs and outputs of agrochemicals and fertilizers, there is an inaccuracy between the actual stock and the recorded stock of inputs. Figure 3 shows the stock of products versus their condition.

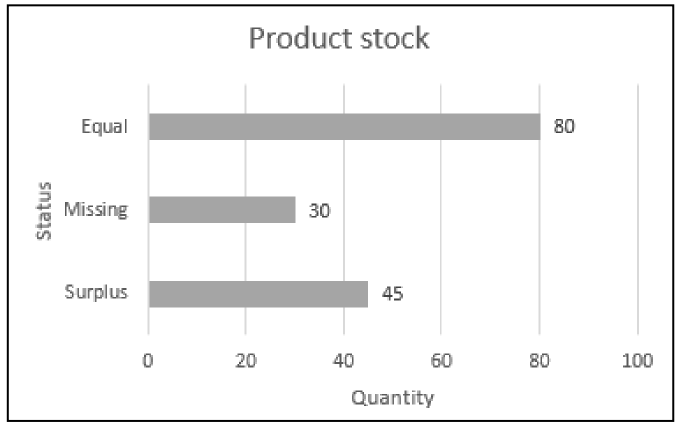

Fig. 3. Product stock

Cause 3: Errors in the dispatch process.

Outcome: Errors were observed in the process of dispatching inputs to the area that initiates the production process in the company, such as the erroneous identification of inputs, attributed to the disorder in the warehouse, the volume of fertilizers, the lack of knowledge of the process and the lack of availability of tools for carrying out activities. These factors have caused delays and inaccuracies in the quantities dispatched (Figure 4).

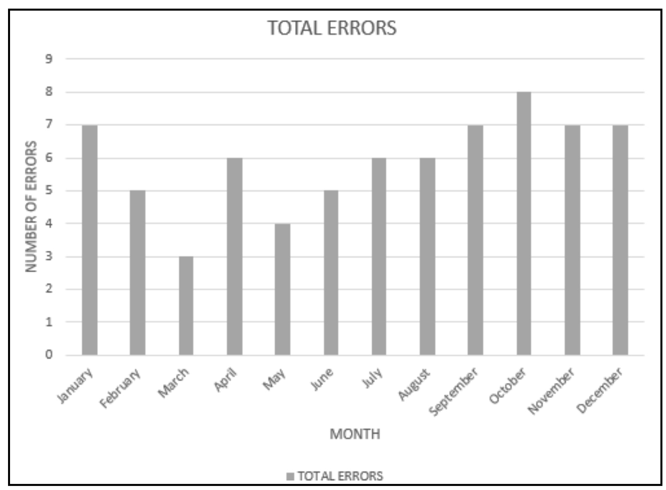

Fig. 4. Total number of error in dispatch

Cause 4: Unscheduled maintenance.

Outcome: The area lacks a scheduled machinery maintenance, resulting in frequent downtime of the weighing scale used. This leads to continuous delays and errors in the dispatch process. The scheduled downtime and maintenance time for the machinery are set at 30 and 20 minutes, respectively.

Once the results of the causes were obtained, a Pareto diagram was developed to observe the level of importance of the root causes, as well as their impact on the efficiency problem in the warehouse process, obtaining the percentages observed as shown in Figure 5.

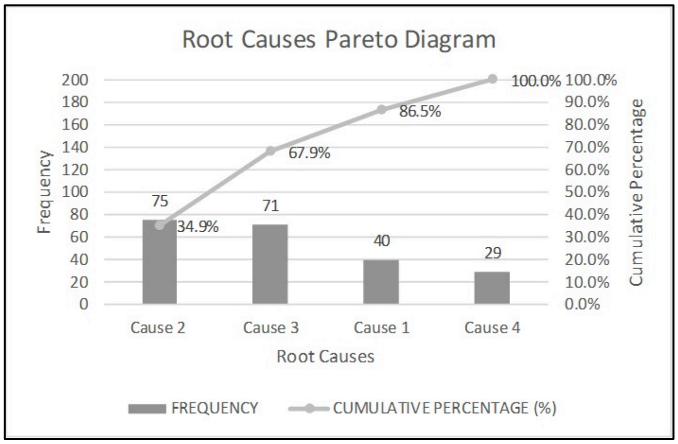

Fig. 5. Percentage of root causes

The following order of importance for the root causes was obtained, with the first being the imprecision of input records at 34.9%, followed by errors in the dispatch process at 33%. This is followed by improper layout distribution and unscheduled maintenance at 18.6% and 13.5% respectively.

V. INNOVATIVE PROPOSAL

The Lean Manufacturing methodology is applied to reduce mercury elimination and process variations in a company. This has a set of tools focused on specific problems observed within the process and areas, covering the productive, operational and labor parts.

A model centered around the methodology of continuous improvement, commonly known as the PDCA cycle, is proposed. This model comprises four stages: Plan, Do, Check, and Act. These stages focus on the implementation of Lean Manufacturing tools and are accompanied by effective change management practices. Furthermore, the change management process includes training programs for the operators to familiarize them with the improvements within the storage area. The proposed model can be seen in Figure 6.

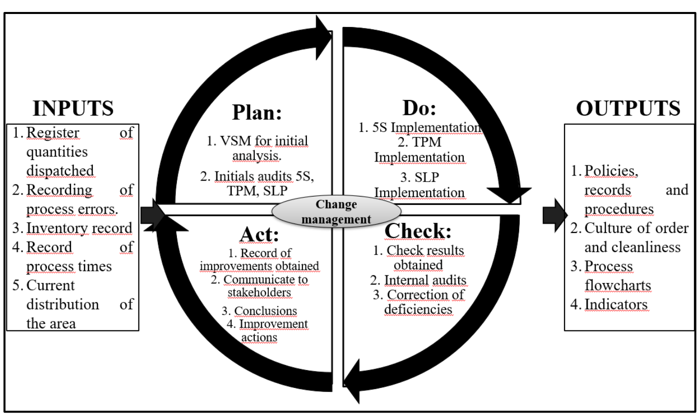

Fig. 6. Proposed model

The reason for the use of specific tools as Lean Manufacturing is in function of similar problems in the literature review and in the look for diagnostic problems solution.

The following four steps are taken to institutionalize the improvement in the system:

A. *Stage 1: Plan*

Within the planning stage, initial studies of the current situation in the area were conducted, as well as audits of the 5S, TPM, and SLP tools.

VSM for initial analysis.

An initial analysis of the current activities in the area was conducted using the diagnostic tool called Value Stream Mapping (VSM). It was observed that the activities causing the most time delays are the dispatching, the location of the inputs, and the weighing process, creating bottlenecks within the process, observing that there is a worthless time of 43.55 minutes making a total time for the development of activities of 121.87 minutes in the area.

TABLE I. Current activities time

Tiempo sin valor	43.55
Tiempo de ciclo	78.32
Total:	121.87

Initial audits:

5S:

The initial 5S audit was conducted, which consisted of 5 parts corresponding to each stage of this tool, starting with sort, set in order, shine, standardize, and sustain. Within each stage, 5 questions were addressed, resulting in an overall compliance rate of 38%. Based on this result, an improvement plan should be established.

TPM:

An initial TPM audit was conducted, which is divided into 6 parts: organization, planning, execution, personnel skills, supply, and maintenance management, accompanied by the radar method. It was observed that only 35.3% of the maintenance requirements are being met. Therefore, improvements need to be implemented that involve both personnel and machinery.

SLP:

Furthermore, a current assessment of the storage area and its layout was conducted, including a relational activity diagram, to identify potential improvement actions that would enhance the flow within the area without disrupting ongoing activities.

B. *Stage 2: Do*

During this stage, improvements were implemented within the warehouse based on the proposed tools for each observed problem, considering the literature review conducted. A pilot plan of approximately 8 weeks was implemented.

5S:

After conducting the initial 5S audit in the planning stage, the improvements to be implemented within the area are identified. This is done through the five stages of the tool:

- Selection (Seiri): There will be a classification of supplies within the area, and they will be categorized based on whether they will be discarded, rearranged, surplus, or classified in another way. The goal is to have a more organized area with only the necessary items.

- Organization (Seiton): In this stage, the use of suitable shelves within the storage area is proposed. The aim is to have the supplies in an optimal area and classified according to their level of activity.
- Clean (Seiso): Cleaning processes and records will be implemented within the warehouse to ensure an optimal working environment and facilitate efficient activities.
- Standardize (Seiketsu): In this stage, the compliance with the first three S's (Sort, Set in Order, and Shine) will be observed. Controls and conditions will be developed to prevent regression and maintain the improvements achieved in the previous stages.
- Sustain (Shitsuke): In this stage, training sessions will be provided to the staff to instill a culture of order and cleanliness. Continuous audits will also be conducted to monitor the progress and adherence to the 5S tool.

TPM:

Regarding the Total Productive Maintenance (TPM) tool, after observing the poor performance of the machinery used in the area, the restoration and evaluation of the machinery in use was proposed. Additionally, a maintenance plan was implemented, which includes a schedule of preventive maintenance activities and ongoing performance evaluations. Finally, training programs within the area were conducted to educate the operators about these maintenance practices and the importance of having them in place.

SLP:

For the SLP tool, an initial study was further conducted focusing on improving the flow of the storage area to optimize the activities performed and achieve better organization of the workspace. Various restructuring efforts were carried out to reconfigure the current layout. Subsequently, relational diagrams of the activities were created along with an analysis of the improvements that would be achieved with the new distribution of the storage area.

It should be noted that for the implementation of each tool, change management was taken into consideration, that is, for each change made or implemented within the area, inductions and training were carried out for the operators, with the purpose of familiarizing and familiarizing them with these, obtaining from them a great initiative to know and learn, as well as a contribution of knowledge, since they present a different knowledge of the area, serving as support for the proposed solution.

C. Stage 3: Check

The Check stage involves collecting and analyzing relevant data to assess the implementation of the design within the company. Internal audits and performance indicators are used to validate the effectiveness of the implemented tools. The goal is to ensure that the changes are aligned with the desired outcomes and are producing the intended results. Table 1 presents the comparison of indicators with respect to different sources.

TABLE II. Comparison of indicators

Indicator	As Is	To Be	Source
Fulfillment of supplies orders	33.0%	69.0%	Ministry of Transport and Communications (2020)
Raw Material Registration Accuracy	34.9%	95.0%	APPROLOG (2016)
Maintenance error level	13.5%	10%	Carrillo et al. [14]

D. Stage 4: Act

In this stage, a summary of the results obtained from the improvement model will be prepared so that they can be observed, evaluated and adopted by the stakeholders of the agroexport company, the main point of interest being those in charge of the storage area. In addition, possible improvement actions that can be implemented in the future within the company will be provided, with the objective of ensuring continued growth both for the agroexporter as a whole and for the specified storage area.

Often, agroexport companies tend to focus on improvements only within the production process, neglecting the storage area, where various problems can arise. Therefore, emphasizing the implementation of Lean tools and integrating practices such as 5S, SLP and TPM will not only improve studies within this area, but will also serve as an example for other companies to adopt this proposed solution model, thus contributing to the input storage literature and future studies.

VI. CONCLUSIONS

The presented proposal, according the objective specified in the introduction, focuses on the integration of various Lean Manufacturing tools to address efficiency issues in the storage area of an agro-exporting company. Likewise, as this is a proposal for continuous improvement, it can be modified and adapted over the years based on the specific needs of the company or the area under study, as well as it can be adjusted to other types of industries.

Moreover, it is worth noting that the tools considered in the proposal have been validated based on various research studies reviewed during this study. Therefore, this proposal can be utilized in future as a supportive contribution to the existing literature on the presented problem.

The results obtained through the implementation of the proposal are planned to be presented in future studies through pilot studies, where will make a comparison before and after the implementation.

Similarly, it is worth highlighting the value of Change Management within the proposal, since the operators are responsible for carrying out the activities within the area, so they will be affected by the changes or modifications that are made within it, so it is necessary to take advantage of the human resources of the company and make them part of the solution, also taking into account their opinions and knowledge.

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