Production Model Based on Lean and TPM to Improve Total Productivity in an Agro-industrial Company

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***Abstract*—This article aims to investigate the main reasons for the low productivity of agricultural companies, as well as to propose proposals for improvement based on lean tools, which are not yet well known in the field in question. Additionally, 40 scientific articles were analyzed to analyze the current situation, and proposals made satisfactorily in this and other sectors with lean tools, highlighting the 5S, TPM (Total Productive Maintenance), standardization of work, and VSM (Value Stream Mapping) as a fundamental tool for diagnosis and planning. Finally, to evaluate whether the tools are viable and beneficial, a pilot test was carried out in a small company named Santa Ana S.A.C in the agro-industrial sector in the north of Lima, Peru.**

***Keywords*—lean manufacturing, VSM (Value Stream Mapping), lean agriculture, work standardization, lean tools**

I. Introduction

The main objective of the current research is to identify, highlight and provide value solution proposals to the main factors or root causes that affect the productivity of small agricultural enterprises, since this may give way to the industrial development of a country (Dorado *et al.*, 1999), all of this by the study and analysis of different lean tools used before in this or similar sectors. In this way, the entire agricultural sector will be able to increase its profitability, through the optimal use of its resources. It should be noted that the agricultural sector is very important, especially in the country of the company of the case study, since it employs more than 4 million Peruvians y and contributes 6% of the national GDP. Despite this, this is still far from the productivity of the region (ComexPerú, 2020), which allows a high margin of opportunity for improvement.

There is more than one factor that influences the final productivity per hectare of any agricultural company. Among them you can find the type of climate, quality of seeds and trees, among others, but the main costs incurred are machinery, inputs, and labor. This last cost, in agriculture, represents no less than 60% of total production costs (Espíndola *et al.*, 2012). Although lean agriculture is not yet as popular as lean applied to other sectors (such as automotive), there are some articles that show case studies and diagnostic tools such as VSM applied to them. On the other hand, research was also carried out on other lean tools such as standardization and TPM, but applied to other sectors such as textiles, since it was not possible to collect information on these in the sector of the company under study in this article.

It is crucial for the competitiveness of Peruvian agricultural companies to increase their productivity, and reduce their production costs, which they must do by seeking to match or surpass their competitors in the market (such as the neighboring country of Chile). To this end, this project seeks to diagnose, evaluate and present improvement plans related to the industry in question, in a small Peruvian company in the agro-industrial sector. In it, and in accordance with the provisions above, the main production costs that are developed around the labor are detailed, being the largest number of operators used at harvest time (counting only harvesters). The objective in this company will be to implement lean tools that are not frequently used in the sector, to optimize productivity, reducing labor costs, downtime and increasing the performance of operators, which currently incurs the highest cost of the company.

So the question that arises is, can lean tools be used with satisfactory results in the small Peruvian agricultural companies? To seek to solve this, this article proposes to use various lean manufacturing tools to optimize the harvesting process in a company in the agricultural sector in Peru. First, the main steps to follow will be proposed, defining the objectives, root causes and tools to be used, and then each of the aforementioned ones will be designed and carried out in the company in question. Finally, the results will be evaluated to corroborate whether there is indeed a significant improvement.

II. State of the Art

A. Lean Manufacturing

Currently, lean manufacturing is used to eliminate all operations that do not give value to the service, processes

Manuscript received March 13, 2023; revised May 29, 2023; accepted August 2, 2023.

doi: 10.18178/joams.11.4.151-156

and products carried out by a company, thus increasing the value of each activity performed. Worthless operations fall into nine categories: overproduction, over-processing, waiting, unnecessary transportation, unnecessary movement, excess inventory, uninvited employees, and imperfections (Poma and Maria, 2022). Unfortunately, small and medium-sized enterprises reject the idea of adopting lean manufacturing despite the benefits evidenced during its implementation (Abu *et al.*, 2019). However, lean manufacturing is increasingly used in the agricultural sector due to global competition, this has manifested as a move towards large-scale production, use of standardized technology and the application of innovation in the organization (Martin & Henrik, 2018).

On the other hand, the implementation of lean manufacturing requires time, money, energy, and the total commitment of the company to obtain the expected results (Saumyaranjan and Sudhir, 2018). In general, the reasons for adopting lean manufacturing are to increase efficiency, space utilization and to clean and organize the workplace, mostly using the 5s tool (Abu *et al.*, 2019). The tools used in the agricultural sector are specialization, formalization and standardization which are related to having fewer, but larger farms (Martin & Henrik, 2018).

B. Total Productive Maintenance (TPM)

The lean TPM tool focuses on the optimization of the machinery so that it works at its maximum productivity and avoiding stops in it (Seminario, 2022). For its implementation, it has been determined that all the personnel of the company must be involved, starting with the commitment by the management and the heads of each area (Zamora, 2022). Without this step, carrying out this tool is practically unfeasible. On the other hand, by implementing it, the TPM seeks to reduce the most common losses of the machinery, which are the corrective maintenance time, as well as reduce the number of defective products generated by the machinery and increase its annual availability (Pacheco, 2022).

Similarly, the TPM promotes the autonomous maintenance of the machinery, this means that the operators who use them are also responsible for the maintenance and cleaning that must be carried out on the machinery, in this way, they must be technically prepared to solve and prevent problems (Munive, 2022). Finally, it is emphasized that the TPM is not a tool that will be developed in the short term but is a whole program that must be carried out and be adhered to the culture and day to day of companies; Its most reliable results are usually long-term (Carrasco, 2022).

C. Lean Agriculture

Although the lean methodology applied in agriculture or in the agro-industrial sector, it is still a subject not very studied as it is in other sectors. Despite this, based on most studies it concludes that the organizational part, both in this and in other industries, is crucial for the correct implementation of this and achieve an increase in effectiveness and quality of production (Gonzales-Gutierrez, 2020). Different tools such as the 5S, Kaizen, VSM, as well as lean principles, waste identification, among others are directly beneficial for agricultural companies, to the point of being able to considerably reduce their costs and even increase the quality of their products to an export level (Manrique *et al.*, 2020).

On the other hand, due to the high and growing concern of companies from various sectors in relation to their efficiency, innovation, and technological level to remain competitive in the market, more and more agricultural companies are seeking to improve their productive strategies, many of them opting for the aforementioned methodology (Manrique *et al.*, 2020). With this same purpose and under this methodology, in the same way agricultural companies are orienting themselves to what is known as “Green lean”, seeks to reduce waste, orienting themselves more to make companies more friendly to the environment. This in turn, due to the current era of industrialization and concern for the environment, makes companies more attractive to both potential investors and customers (Manrique, 2020).

D. Work Standarization

The standardization of work, known by its acronym in English SW, is a lean tool that focuses on each activity of the process independently, considering the work system itself, and placing each operator as a subject of study. This tool is used to develop a single way of executing each activity within the process, so that all operators perform it in the same way, being able to better evaluate their performance, calculate the speed of work, and guarantee in some way an adequate or expected quality of each process and the product it generates (Alvarado, 2022).

Within the agricultural sector, this tool can be used in various operations in each area, the most compromising being the harvest, to achieve the above, but also avoiding accidents that may be generated by improvisations of the operator in the process (Alvarado, 2022). The purpose of applying this tool in the activity in question, is to teach the operators the most efficient way to perform the work assigned to them, taking into consideration that, to achieve this, the observations and contributions of the same employees must be considered, since they are the ones who have been doing this activity the longest.

III. CONTRIBUTION

A. Model

With the technological advances that evolve day by day and the need to meet the demands of customers, companies are forced to modernize, renew, innovate, and streamline their processes more and more, maintaining good productivity so that the company can survive and be profitable. On the context presented and the review of available literature, the Lean and TPM tool has been identified as one of the solutions to be applied in the problems of our case study. The solution will be made using the tools belonging to the methodology such as the Total Productive Maintenance (TPM) tool, the standardization of work and the 5’S tool.

Articles versus objectives are presented in Table I.

TABLE I. COMPARATIVE MATRIX OF OBJECTIVES VERSUS STATE OF THE ART

Article/Objective	Material Cost Management	Labor Cost Management	Machinery Cost Management
Poma, J. *et al.*, (2022)	5s	Work Standarization / 5s	
Melin, M., *et al.*, (2018)	5s	Work Standarization / 5s	
Zamora, F., *et al.*, (2022)	5s		TPM
Proposal	5s	Work Standarization / 5s	TPM

B. *Proposed Model*

The proposed model is based on tools such as the Value Flow Map (VSM), work standardization, TPM and application of the 5´S, tools belonging to Lean Manufacturing. Using this methodology, what is sought is to eliminate or reduce processes and activities that do not generate value through the application of these three tools. First, the VSM will identify activities that do not generate value in the company's processes. The standardization of work will allow the company to follow the same methodology for each worker. In this way, we reduce the workload, excess workers, and training. Finally, the application of the 5's will lead the processes to have a continuous improvement, increasing the productivity, quality, and competitiveness of the company. On the other hand, by applying the Total Productive Maintenance (TPM) tool, breakdowns, downtime, defects, and accidents that could be caused using harvesting machines will be reduced.

The components of the model are presented in Fig. 1.

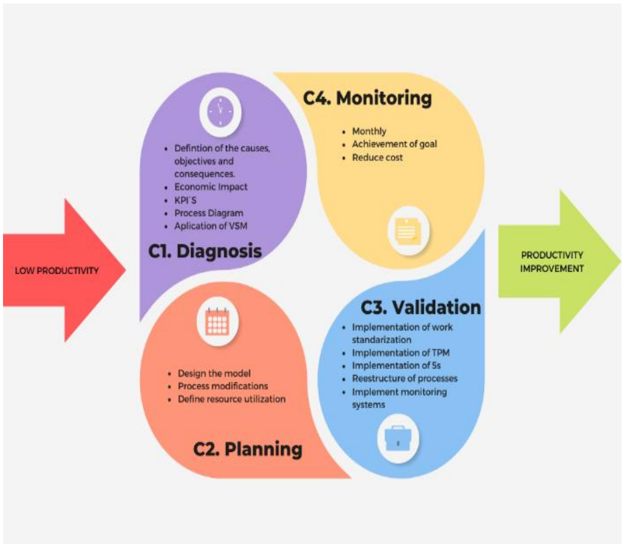

Figure 1. Proposed model.

C. *Model Components*

1) *Diagnosis (C1)*

This stage of the model will focus its efforts on defining the current situation, the frequent problems, as well as their causes, and establishing clear and concrete objectives to be achieved. Once the necessary data has been collected, the crucial KPIs will be pointed out, to develop the project around them. It is important to note that the company should be asked for these indicators as historical background if it has them. Finally, the diagramming will be carried out not only of the processes themselves, but also of them applying the lean VSM or Value Stream Mapping tool, to define cycle times, take time, among others., see Fig. 2.

2) *Planning (C2)*

The next step in the model is the planning of what will be carried out. The first thing that should be done once the VSM has been carried out, and having defined the cycle times and waiting times, will be to design the model that you want to follow to achieve the objectives set. Once this is oriented towards this end, it can only be modified. In this modified stage, the lean tools mentioned above will be used to reduce waste in the value chain and in the company in general.

Subsequently, the resources that will be required to carry out the project will be defined. This aspect includes economic resources, necessary personnel, time invested, among others. Those who are selected, must be discussed with the management of the company, to ensure the availability of these, and the approval of the company in this regard.

3) *Validation (C3)*

In the execution stage, everything proposed in the strategy or planning stage will be carried out. It is in this phase, in which the chosen lean tools will be put into use and application. The implementation phase will have three main parts. The first is to standardize the work and / or processes of the company, to have greater control over them, and make better decisions about them. The second will be to design and carry out a TPM plan in the medium and long term, to optimize the overall efficiency of the company's equipment (EGE). Finally, the last tool to be implemented in the company will be the 5' s to seek to better order and organize the areas of this. All this will be done through the redesign and restructuring of the processes carried out by the company.

4) *Monitoring (C4)*

Finally, the monitoring phase refers to the control that will be taken in the company over the changes made. The importance of this lies in the fact that at this stage it will be demonstrated if the proposed solution or improvement also yields fruits in the long term and is sustainable over time.

This stage must be sustained over time, so at least one monitoring per month of each proposed improvement must be carried out, to have a broad record to analyze. In these monthly controls, a factor must be specifically appreciated, which the fulfillment of the objectives is set in the first phase, diagnosis.

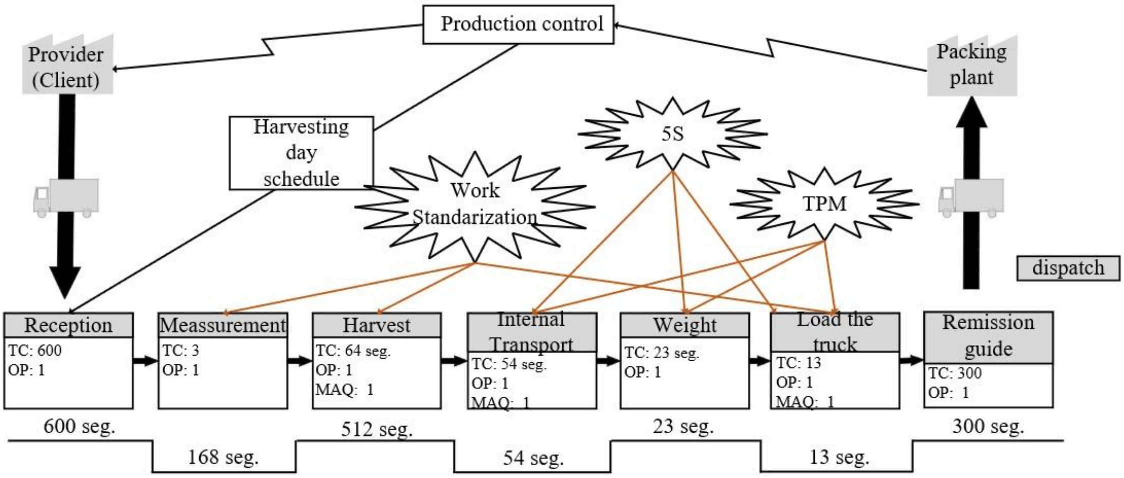

Figure 2. Value stream mapping.

D. Indicators

- Total productivity (Kilograms / $): measures the ratio of product achieved for each dollar used.

Goal: To match the productivity of the sector 8.89kg/$.

$$T\ Productivity = \frac{Harvested\ kg}{Total\ production\ cost}$$

It is the relationship between the monetary resources used and what was obtained with them.

- Labor productivity (Kilograms / Man-Hours): measures the ratio of product achieved by each resource used.

Goal: Increase utilization to 90%.

$$Handwork\ productivity = \frac{Harvested\ kg}{Man - Hours}$$

It is the relationship between the resources used and what was obtained with them.

- 5s level: Calculates the performance of the tool application.

Goal: Increase the 5s level by 30%.

$$Level\ of\ 5s = \frac{a}{50} \times 100$$

It is the relationship of compliance and objective of the application of the 5s tool in the process.

- Machinery availability: calculates the time in which tractors are operational. It's expressed as a percentage.
- Objective: To increase availability until reaching the ideal of Nakajima (90% annual availability).

$$Availability = \frac{Tt - Tpp - Tpnp}{Tt - Tpp} \times 100$$

It is the percentage that indicates the probability of finding the machine operational in a period. Where Tt is the total time, Tpnp is the time of unplanned stoppages, and Tpp is the time of planned stoppages.

IV. Validation

After developing the components of the proposed model, validation is presented. A pilot test was conducted for a month to collect the necessary information to analyze the proposed improvements.

A. Initial Diagnosis

Analyzing the information shared by the company studied, it was found that the main problem is the productivity of the company when producing oranges. This is directly related to the mismanagement of labor, machinery, and resource costs.

The main effect of low productivity is economic losses, delays, and errors in production, as well as missed targets. Productivity index is 4.32 kg/$ compared to market 8.89 kg/$.

B. Design Validation and Comparison with the Initial Diagnosis

A pilot test was conducted for one month, October 2022, to evaluate the impact of the proposed model on the main problem presented. The implementation was conducted in the department of Lima, Peru, and for the development the current information of the agro-industrial company was collected.

With the information obtained, the implementation was carried out. First, we proceeded to make a diagram of the flow of the process since the company did not have one,

In this way, through a Value Stream Mapping Diagram, the current process, and the improvements to be implemented were identified. The model components were then deployed. To implement the standardization of the work, an analysis of the times and activities that the harvester carried out during the harvesting process was carried out. Through a thorough observation, it was possible to identify activities that did not generate value and improvements to reduce times. Then, when implementing TPM, first they were given an introduction about it to the operators in charge, then, they proceeded to divide them into two groups, and make a review of what should be done. Finally, they were given a form, and defects could be found to be fixed before becoming breakdowns that cause the machine to stop.

Regarding the application of the 5s, the materials were classified according to the established criteria, the warehouses of instruments and materials were ordered. In addition, the work area was cleaned according to the proposed cleaning plan. Then, the materials were labeled according to the proposed system to keep everything in order. Finally, to discipline the staff and create a new habit in them, achievement templates, monthly meetings and a training and evaluation plan was established to monitor the indicators.

The company's indicators of the current versus expected situation are presented in Table II.

TABLE II. INDICATORS

Indicators	Current Value	Expected Value
Total Productivity (kg/$)	4.32	8.89
Handwork Productivity (kg/HH)	11.43	12.35
Level of 5s	54%	100%
Equipment availability	85.63%	90%

C. Improvement–Implementation of the Proposal

Regarding the table of results, it can be affirmed that there were improvements in the harvesting process of the company. The cycle time was reduced by 9.72% and the activities by 14.23%, which achieved a reduction in harvest time and work time of harvesters, eliminating additional burdens on the worker, consequently, the productivity of labor (harvesters) increased by 10.76%. On the other hand, with the application of the 5s tool and its compliance standards, it increased from 54% to 80% as a final result. Finally, thanks to the implementation of the TPM, it was possible to increase the availability of the machinery to exceed the goal of 90 percentage points. Given all this, total productivity increased from 4.32 kg to the dollar to 6.97 kg per dollar.

Company indicators of current value versus improved value are presented in Table III.

TABLE III. CURRENT VS. IMPLEMENTATION

Indicators	Current Value	Improved Value
Total Productivity (kg/$)	4.32	6.97
Handwork Productivity (kg/HH)	11.43	12.66
Level of 5s	54%	80%
Equipment availability	85.63%	96.49%

As a general result, it can be said that in all cases, the selected lean tools achieved their objective of increasing the productivity of the company, both in terms of machinery, personnel utilization, and warehouses. This is reflected in the improved value achieved in productivity, as it exceeds the initial growth, demonstrating the benefits of the tools applied.

V. CONCLUSION

In conclusion, it is obtained that the adequate implementation of lean tools for standardization and maintenance, as well as order and cleaning, are beneficial for companies in the agro-industrial sector, being able to increase the availability of their machinery, as seen in the case study, to exceed the Nakajima ideal of 90%, as well as reduce operation cycle times by almost 10%, and increase the level of use and management of the space of the warehouses and areas of the company. In turn, all this manages to generate greater productivity in the company, reducing its production costs.

Similarly, the previous training of the staff, as well as the commitment of the management and managers of the company, such as the engineer in charge, are essential for the correct implementation of lean tools. Also, making every worker part of the processes, such as the maintenance plan, and making them know that their contributions where listened to, make them want to participate more in the company.

Finally, for future research, research should be conducted with other crops, as well as larger groups of people. Similarly, the implementation of the model can be carried out a longer time interval, a period of six to twelve months is recommended, in order to collect more specific and real information, and specifically the TPM tool should be measured monthly for 3 years, in order to observe more precise changes in retrospect.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Brunella Carlini-Camaiora conducted the research; Isabella Zapater-Matos analyzed the data; Brunella Carlini Camaiora, Isabella Zapater-Matos and Martin Collao-Diaz wrote the paper; all authors had approved the final version.

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