Productivity Increase Through the Application of Lean, TQM and SLP Tools in the Peruvian Craft Brewery Cluster

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Abstract

The brewing industry has evolved over the years, attracting many customers. Therefore, due to the diversity of tastes and preferences, craft brewing companies were born, becoming the livelihood of thousands of families in the national territory. However, most of them are empirical or do not have a correct working method, which adds a lot of time and a complicated production process. In addition, there is a lack of efficient plant design and they do not consider order, cleanliness, and organization in their operations due to the precariousness of knowledge of improvement tools. Therefore, the main objective of this investigation is to increase productivity in the areas of supply and production through the development of an integrated model of 5S, Standardized Work, Systematic Layout Planning and TQM framework. Through the implementation of this Lean model and its corresponding simulation in Arena software, it was possible to increase productivity by 15.21%, increasing production and reducing times, in addition to increasing revenues by approximately PEN 24,000

Keywords
Lean, productivity, craft beer, quality management, SLP.

1.Introduction
In Latin America, alcoholic beverages have a strong cultural component in the different countries, as a result of the different habits associated with its consume. Thus, Peru ranks third in this region of the continent with a consumption of 8.1 liters per capita (Moreno, 2015). Now, moving on to the local industry, the most industrialized beer producer is Backus S.A.A., which is the leading company in the country, with a market share around 94.98% (Lizarzaburu et al., 2018). However, despite that, there is an emerging interest in new products, other than the industrial sector, known as craft beers. This market is growing due to the evolution of tastes and preferences of customers, which increases the opportunities for these small competitors, with differentiated products known by the acronym of MSEs that have an important contribution in the industry and national employment, in that sense (Oficina de estudios económicos (OEE), 2017), argues that this business segment represents 99.5% of all formal companies in the Peruvian economy, 94.9% are microenterprises, 4.5% are small and 0.2% are medium-sized (Quispe Orejón & Quintanilla Alarcón, 2018; Toro-Gonzalez, 2017).

It should be added that normally companies in the manufacturing sector, as the case of craft breweries, have a big problem in the management of their operations or activities, since within these, less than 5%, add value to the process, such as, for example, the correct management of resources by the logistic area. The 35% are necessary activities that do not add value, such as long waits, and 60% are unnecessary activities that do not add value, in particular, the 7 Lean wastes (Fallas-Valverde et al., 2018). If we add to this that manufacturing companies waste around 70% of their resources in the whole system, concluding that the main problem is the waste in the production area and the dependence on the import of raw materials, which could generate problems in the supply of MSMEs in the sector (Quispe Orejón & Quintanilla Alarcón, 2018; Vargas Hernández et al., 2016).

This research focuses on a specific company in the craft brewing sector, which shows the sector's problem of limited production capacity and disorganization in supply, caused by operational waste and low productivity in relation to the liters produced by the company. It has been possible to identify a serious problem in the production and inventory design, since there is a great distance between the raw materials warehouse and the production area, which leads to the generation of overtime, resulting in an unexpected productivity rate. Therefore, an improvement model is developed which is the 5SS methodology (5S, SLP and Standardized Work), having a new vision of improvement applied to the processes of the organization, with the objective of reducing excessive or unproductive times, increasing the productivity ratio in the areas of supply and production of the MSME brewery, from this case study This model was developed thanks to the practicality of the tools and the desire to propose a new model in question, thus generating a TQM framework, which aims to optimize the quality of operations, eliminating useless activities and without added value (VA) by applying small improvements, adding the mapping of the value chain as added value (Kumar et al., 2018).

This article will be divided into six parts, which are Introduction, State of the Art, Contribution, Validation and Conclusions.

1.1 Objectives

- Reducing excessive or unproductive times, increasing the productivity ratio in the areas of supply and production of the MSME breweries
- Achieve the objectives of each of the indicators proposed in this article
- Reducing the raw material transportation times and final disposal of barrels with product through the application of SLP.
- Reduce the time of each process by means of the 5s and standardized work.
- Recognize opportunities for improvement for future work, and likewise be useful for associated research.

2.Literature Review

2.1 Lean Manufacturing

Lean Manufacturing is defined as a set of techniques that seeks the improvement of processes through the reduction of waste, defined as processes or activities that use more resources than necessary. For that reason, Lean generates a different way of thinking, which implies a global perspective, involving managers, middle management, and operators(Sanz Horcas & Gisbert Soler, 2017). Lean tools include the 5S, which focuses on improving quality and productivity, maintaining order and cleanliness, supporting the operations (Džubáková & Kopták, 2017; Reyes-B. et al., 2017). As a successful case, we have the one of a Colombian metal-mechanic company, which showed an increase of 85.7% in the safety level of its operations. It also improved the motivation of its personnel by 19.8%. Finally, reworked parts, scrap parts and rejected iron parts were reduced by 62.93%, 82.94% and 71.42%, respectively (Hernández Lamprea et al., 2015). All this is based on a TQM approach, that is used for achieving excellence in production and overall organizational performance. And it has a significant effect on production (Modgil & Sharma, 2016).

2.2 5S – Standardized Work

This typology has the objective of maintaining the production rate in line with market demand, using the takt time concept as the basis of standardized work (Fazinga et al., 2019). In addition, another objective of the tool is to develop procedures to reduce failures, which can be dangerous for production, so standardization is required, since this method is an important element in the Lean methodology, due to the fact that it is linked to continuous improvement, which aims to execute the planned activities to the first time; that is, basically, that no harmful failures occur for the environment, workers and the general public, providing a significant improvement in safety. Also, communication and discipline increase and allows to recognize the problems of the organization and its processes (MĺÍkva et al., 2016).

2.3 Systematic Layout Planning (SLP)

Facility Plant layout design has a major influence on productivity as its objective is to find the most efficient layout in the facility and reduce material handling. It has persisted as an active area of research for the past decades (Ali Naqvi et al., 2016). Previous studies have evidenced that the cost of this material handling has a relevant impact on plant operating costs. According to the American Society of Mechanical Engineers, material handling is defined as the science that deals with the movement and other processes of each form of transportation. The equipment used, influences manufacturing productivity (Jiamruangjarus & Naenna, 2016). It has been estimated that, approximately, the cost of material flow covers between 30% and 70% of the total cost of operations; however, this could be different depending on the industry (Dongre & Mohite, 2015). The cost of operations during manufacturing could be reduced by 15- 30% by well-organized material handling, emphasizing the use of SLP (Tuzkaya et al., 2010).

3. Methods

The present investigation is based on the three tools explained in the state of the art, which together make possible the creation of a new model of process control, quality management, as well as inventory management, proposing a solution to increase productivity through order, cleanliness together with the analysis and proposal of a plant redesign, in addition a correct standardized work method, being able to fulfill the objective already mentioned. Therefore, after the brief explanation, the 5S, SLP and Standardized Work tools will be used, controlling the operations, and assuring the quality of the product through the TQM.

3.1 Proposed Model

The proposed model is based on the 5S, SLP and Standardized Work tools, supported by the TQM methodology, which will be very helpful as it will serve to have a better control of the processes, inspection, and quality control. As in every process, there are both inputs and outputs. The input in this case refers to the indicators resulting from the data collected and indicators of the case study, together with the current status of the site. The outputs of the model in question will be the improvements in the preliminary indicators, productivity and the optimization of the craft beer processes (Figure 1).

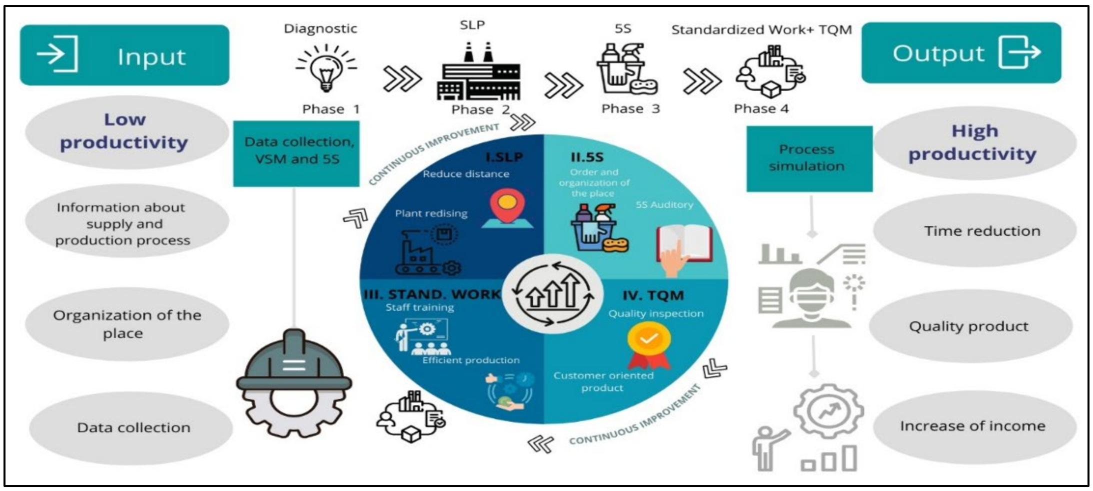

Figure 1. Proposed Model

The following section will describe the phases of the model.

3.1.1 Component 1: Analysis of current situation

A pertinent analysis of the current situation is carried out, in which an initial diagnosis is made through the time-taking method for all the processes. In addition, with the help of Pareto Diagrams, Tree Diagram, Ishikawa Diagram, ranking of factors and preliminary VSM a holistic diagnosis is developed, together with the collection of company data and other pertinent information, to determine the main problems in the operative processes. In addition, the literature is reviewed to find similar improvement tools. This completes the first phase of the model (figure 2).

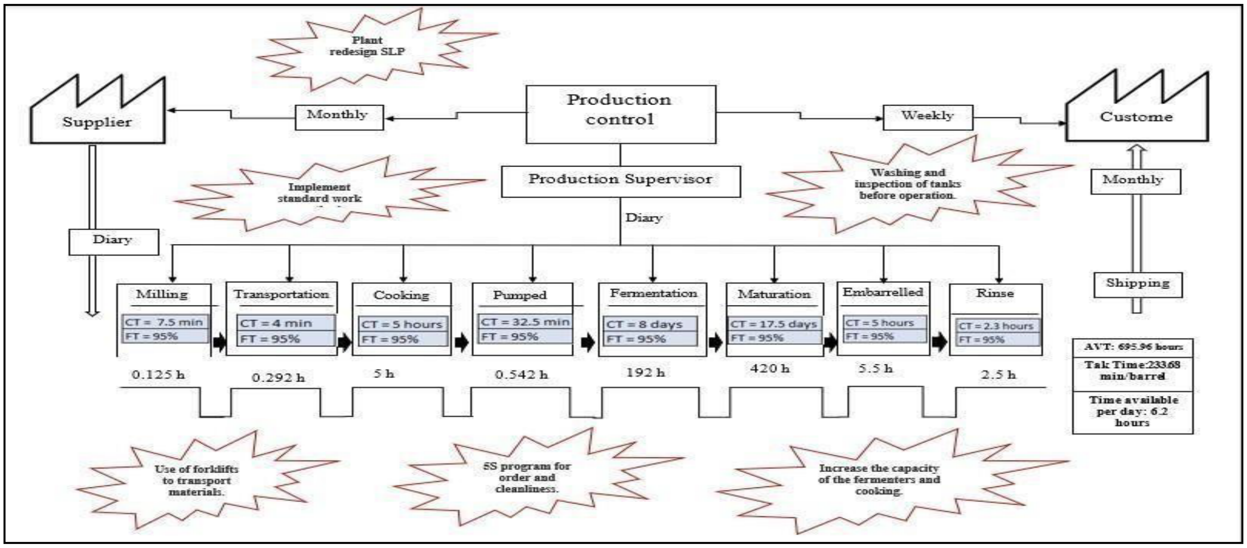

Figure 2. VSM with proposals for improvement.

3.1.2 Component 2: Systematic Layout Planning

For the development of the SLP, the plant is verified in its current state, and through a significant evaluation, a relational analysis was developed. Basically, a double-entry diagram was made, which shows the relevant needs between each area. Once the relational analysis is detailed, a Relational Diagram of Activities is made, in which the relevance and needs of the areas of the organization's plant are shown, in order to subsequently propose improvements for a new optimal distribution of the plant (Figure 3).

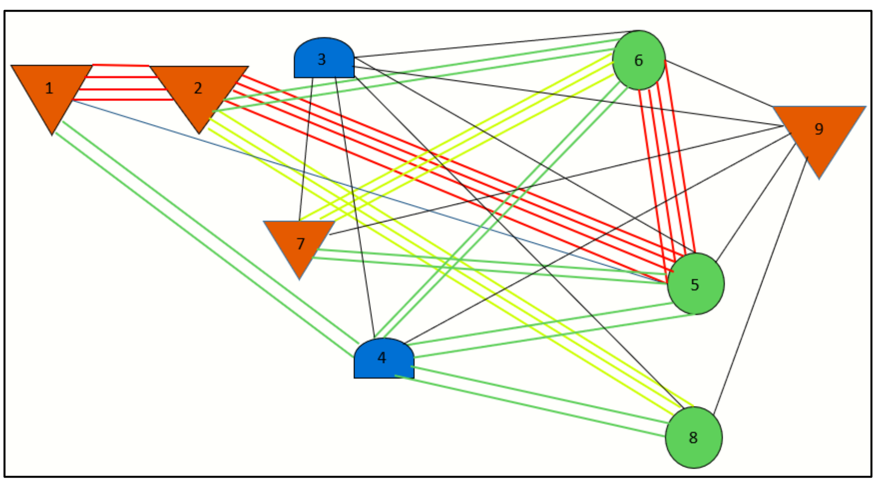

Figure 3. Relational diagram of activities

3.1.3 Component 3: Ordering and process control

This phase of the 5S, aims to reduce production times at the time of preparation and subsequent storage of the product. First, an analysis of the current situation of order and cleanliness of the company that is carried out using a documentation sheet, which will be filled out as objectively as possible, assigning scores to different items. A spider diagram will then be drawn up to identify the variables that need more attention, and any undesirable elements will be eliminated. Subsequently, a 5S checklist will be used to assign the items to their proper place, and then a schedule will be established for the implementation of each variable over the months. Finally, audits are conducted using a specialized automated 5S rating system.

3.1.4 Component 4: Development Standardized Work and TQM

The last phase is composed of the tools Standardized Work and TQM, the objective of which is to propose an efficient work method, which reduces variability and time incurred, thus increasing communication and discipline, obtaining better results, meeting medium to long term objectives, referred to the improvement of production quality and having an emotional work environment, oriented to satisfy the customer's needs.

4. Data Collection

In order to obtain data collection, it is important to emphasize that, in order to obtain results, the data was obtained from a craft brewery, in which the maximum and minimum times of the processes could be obtained, in the case of the arrival of materials, proceeding to the move them in to the production area, the production in particular, the kegging of beers, rinsing them and the washing of the brewing tanks and barrels (Table 1).

Table 1. Process time

Process	Min	Max	Time Unit
Milling	5	10	Minutes
Transport	15	20	Minutes
Cooking	4.5	5.5	Hour
Pump Transfer	30	35	Minutes
Fermentation	6	10	Days
Maturtation	15	20	Days
Packaging	5	6	Hour
Squeezing	2	3	Minutes
Washing of the cooking tank	0.9	1.1	Hour
Barrel washing during maturtation	9	10	Minutes
Lunching		1	Hour

Once detailed the previous information, the data is inserted in the arena, for the simulation before and after the improvements that will be made in this work. For this purpose, 20 replications were simulated, providing the exact number of replications to have more precise indicators with a greater number of replications in the simulation.
For this purpose, the following is presented in table 2.

Table 2. Calculation of number of replicates without improvement

Sample mean	503.85
Sample variance	10.69
Error (Hour)	1
Z (0.05/2)	1.95996398
Number of replicates	439.2448738

After the 20 replicates, the deviation is obtained, the estimated error of one hour and a Z with 95% confidence, gives a number of 440 replicates by the following formula.

$$(\frac{1.95996398 * 10.69}{1})^2$$

For the simulation with improvements, the same procedure was used, emphasizing that in this one, since different times were obtained in the simulation with 20 replicas in question. The following is the reference table for obtaining the number of replicas for the case with the improvement applied, which refers to the use of the 5S, SLP and Standardized Work tools, all under the TQM approach.
For this purpose, the following table 3 is presented.

Table 3. Calculation of number of replicates with improvement

Sample mean	491.12
Sample variance	12.69
Error (Hour)	1
Z(0.05/2)	1.95996398
Number of replicates	618.3498894

After obtaining the mean of the 20 replicates, the deviation, the estimated error of one hour were obtained, also the Z value with 95% confidence, gives a number of 619 replicates by means of the following formula.

$$\left(\frac{1.95996398 \ * 12.69}{1}\right)^2$$

5. Results and Discussion

5.1 Numerical Results

In this chapter, the improvements are presented in a numerical way. We will start by explaining the calculation of the cycle time, which derives in productivity, as well as the calculation of the number of barrels, which are the company's income itself.

First, the annual cycle times of the situation with improvement and without improvement are attached in their possible scenarios since it is a simulation (Table 4).

Table 4. Scenarios without improvement – Cicle Time

No improvement cicle time		
Best scenario	Worst scenario	Average scenario
2,744.82 Hrs.	3,173.76 Hrs.	3,008.88 Hrs.

These results were provided by the arena simulator. With them, it is known that on average, 75 barrels are produced for two months, considering that each barrel has 50 liters, giving a total of 22,500 liters per year.

Thus, giving an example of the calculation of productivity without the improvement in question, we have the division between the liters produced per year, over the cycle time, thus giving the productivity scenarios (Table 5).

Table 5. Productivity without improvement

Productivity without improvement		
Best scenario	Worst scenario	Average scenario
8.20 Lt/Hr	7.09 Lt/Hr	7.48 Lt/Hr.

The same issue is derived to the productivity calculation, but with the improvement. For this, we have the cycle times, after applying the improvements, with respect to the 5S, SLP and Standardized Work tools, all under the TQM framework (Table 6).

Table 6. Scenarios with improvement – Cicle Time

Improved cicle time		
Best scenario	Worst scenario	Average scenario
2,701.08 Hrs.	3,142.44 Hrs.	2,938.44 Hrs.

By performing the same analysis as above, it is possible to increase the production of beer barrels, thanks to the application of the tools, together with a slight change in the Machinery, which will be to replace two brewing tanks of 250 liters of capacity, for one of 500, which will produce 480 barrels per year, giving a total of 24,000 liters, considering 50 liters per barrel (table 7).

Table7. Productivity with improvement

Productivity with improvement		
Best scenario	Worst scenario	Average scenario
8.89 Lt/Hr	7.64 Lt/Hr	8.17 Lt/Hr

To finally obtain the estimate of productivity and the variation it has, we chose, as mentioned, the worst scenario in the case without improvement and the average scenario in the case with improvement, which are 7.09 Lt/Hr vs. 8.17 Lt/Hr.

The percentage variation for the calculation of productivity is as follows

$$\left(\frac{\frac{8.17Lt}{Hr}-\frac{7.09Lt}{Hr}}{8.17\frac{Lt}{Hr}}\right)*100\%$$

The value was an increase equivalent to 15.21%.
To prove the effectiveness of improvements it is necessary to measure them through indicators.

1) Productivity (P): Measures the number of liters produced per hour of work.

$$\text{P} = \frac{\text{Liters produced anually}}{\text{Anual CycleTime (Hours)}}$$

Objective: To increase the productivity by 10%.

2) Cycle time per batch (CT): Measures the total time it takes to produce a production batch, considering standardized work as the prime for its reduction.

$$\text{CT} = \frac{\text{Production process time (ours)}}{\text{Production batch (Liters per year)}}$$

Interpretation: Measures the total time it takes to produce a production batch.

3) 5S Auditory (5S): Measures the fulfilment of the objectives of the application of the 5s tool

$$5\text{s} = \frac{\sum \text{sort+arrange+clean+standardized+sustain}}{5}$$

Interpretation: Measures compliance with the 5s philosophy in each of its pillars.

4) Revenue increase (RI): Measures, using a percentage variation, the increase or reduction of the economic benefit, after the implementation of the improvements. The selling price is 800 PEN.

$$RI = \frac{\text{Final revenues} - \text{Initial revenues}}{\text{Initial revenues}} \times 100\%$$

Interpretation: It serves as a measure to be able to evaluate the economic impact of the simulation.

5) Compliance with production plan: Comparison between actual and planned production on an annual basis.

$$CP = \frac{\text{Total of liters produced}}{\text{Total of liters planned}} \times 100\%$$

Interpretation: Measures in a certain way the fulfilment of the production plan in liters, in contrast to what was planned.

5.2 Graphical Results

In this chapter, some graphs will be shown to validate, in a visual way, the impact of the tools applied in the brewery cluster.

On this case, productivity was obtained, previously explained in point 5.1. To exemplify the difference, which is referred to in the mentioned point, the worst case will be chosen; that is, the one with the longest cycle time and, therefore, the lowest productivity, which is 7.09 Lt/Hr (Figure 4).

Figure 4. Productivity without improvement graph

In the graph with the improvement, the average scenario will be chosen, which has a value of 8.17 Lt/Hr. As can be seen, in the three scenarios, productivity increases significantly, emphasizing that, for these companies in the brewery cluster, it is a great incentive, which means higher income (Figure 5).

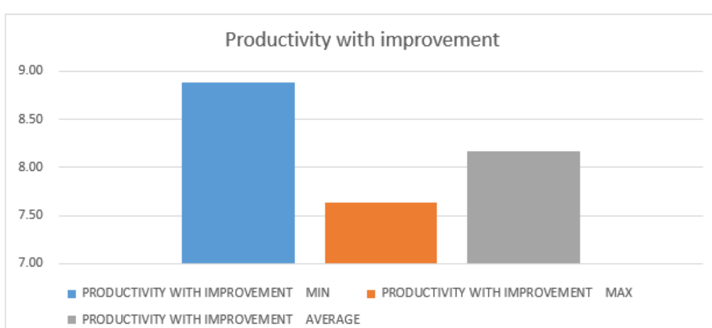

Figure 5. Productivity with improvement graph

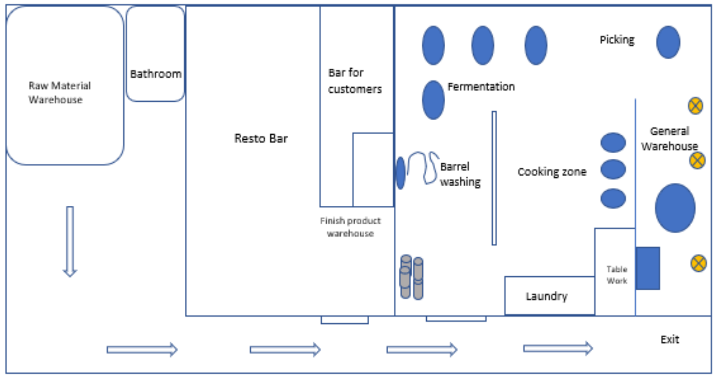

Figure 6. Plant layout prior to improvement

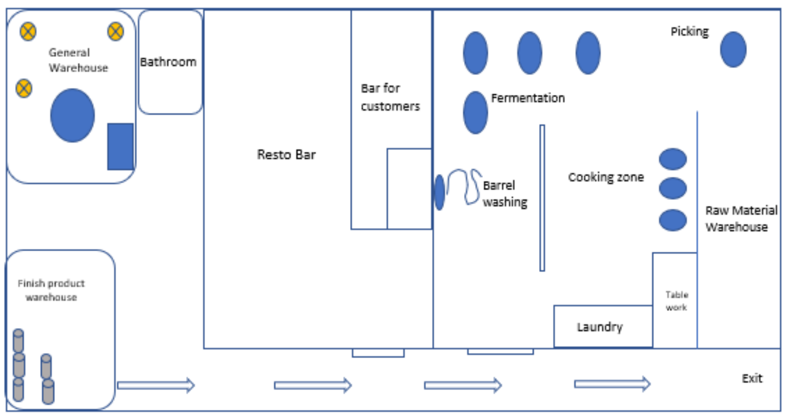

Figure 7. Plant layout after to improvement

Finally, the SLP before and after the proposal is shown in figure 6 and figure 7. The first one is the plant layout, before and after, observing as main changes, as is the case of the finished product warehouse near the customer area, in order to make the transport faster, avoid injuries to the worker, thus reducing unproductive times. Below (Figure 6) are the plant layouts, before and after the improvement

5.3 Proposed Improvement

The model is developed thanks to a simulation in Arena that has as inputs, ground malt, water, and hops to produce a batch of 22, 500 liters per year of beer and as output the final product in barrels of 50 liters each. In order to corroborate the utility of the proposed tools, with the purpose of being able to fulfill the main objective, which is to increase productivity. A simulation was carried out without improvement, that is, no application of the tools, generating 440 replications with 95% confidence and, to apply the tools, together with the TQM and the technological improvement, 619 replications had to be carried out with the same confidence interval. Thanks to the tools, such as 5S and Standardized Work, it was possible to reduce the time of operations thanks to the order, cleanliness, and organization, since before performing the operations, it was confirmed that all the necessary equipment were in perfect hygienic conditions and in the right place, adding a continuous flow, of materials as well as information to assure the continuous flow of work. In addition, material transportation time was reduced, and the plant layout improved thanks to the SLP. All mentioned is complemented by TQM, making use of control charts and quality registers. An increase in productivity of 15.21% was achieved, in addition to a reduction of the cycle time, being 2938.44 hours, adding a reduction of the queue times of the processes of kegging, washing, fermentation and maturation and washing in parallel, having as values 18.36, 69.21 1542.6 and 7. 48, respectively in contrast to 19.58, 132.24, 1219.32 and 44.73 hours respectively.

Observing that there is an increase in one of the processes; however, this does not affect the cycle time and production increases by 30 barrels of 50 liters, giving a total of 480 barrels per year.

5.4 Validation

The objective of this research was to reduce unproductive time, which aims to increase productivity by applying the integrated methodology described above. This model can be applied to any company in the cluster that wishes to increase its productivity, adding that this varies according to the organizational context; however, if improvement is required, the tools mentioned above can be taken into consideration. This study allowed discovering the relevance of lean manufacturing tools, which can positively influence not only the impact on productivity, but also in reducing costs, increasing income, increasing personnel utilization, increasing production, reducing cycle time, among others.The study currently shows that approximately 2,000 liters per month can be produced, for a total of 22,500 liters per year. Adding a high waiting time between processes which leads to not being able to produce at full capacity, so there is a slow production, since it should produce 450 barrels per year, thus obtaining an economic benefit of 360,000 PEN, adding an average cycle time of 3008.88 hours, thus giving the ones that the main causes are the excessive disorder in the production area and in the warehouses, excessive displacements due to poor design and lack of a working method. The proposed modeling focused on the supply and production domains, which caused serious problems to the excess production. In this comparative chart, a contrast can be observed between the current scenario and the improved one thanks to the tools mentioned above, together with the continuous improvement based on the TQM philosophy.

In this case, E0 is presented as the current state and E1, the future state. The indicators are presented as O1: Productivity, O2: Cycle time, O3: 5S audit, O4: Revenue increase and O5: Production plan compliance (Figure 8).

Table 8. Validation indicators

Situation	O1	O2	O3	O4	O5
E0	7.09	3008.88 Hours	50%	360,000.00 PEN	-
E1	8.17	2938.44 Hours	65%	384,000.00 PEN	95%

6. Conclusion

The implementation of the three tools, SLP, 5S and Standardized Work, within the TQM framework in a craft brewing company, were useful and profitable, since, through the simulator, it was possible to increase productivity by 15.21%, along with an increase in annual economic profit of approximately PEN 24,000. In conclusion, it was possible to achieve the objectives of each of the indicators proposed in this article, and the overall performance of the company was correct.

Through the SLP, it was possible to reduce the raw material transportation times from 17.5 min to 4 min and the final disposal of the barrels with the product, since there was a significant approach from the raw material warehouse to the production area and an adequate space was added for the barrels ready for sale, adding the benefit of the 5S and Standardized Work, a reduction in the times of each process between 9 to 15%. For future work, it is recommended to emphasize every part of the supply chain, in order to find improvements in different areas. Furthermore, it is recommended to explore in depth, not only the craft breweries, but also various small businesses and propose substantial improvements, improving the quality of life of the citizens.

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Biographies

José Alonso - Ulloa Durand is a bachelor's in industrial engineering from the University of Lima, with specialized training in quality systems and business sustainability. Partial certifications in Organization and Methods, Business Strategy and Industrial Processes. Excel and Power BI studies at Universidad Nacional de Ingeniería and Pontificia Universidad Católica del Perú. Certification in Desing Thinking by the IEP. Currently working at Proefit Group, as a Jr. Continuous Improvement Consultant.

Ander Fabricio – Vargas Altamirano is bachelor's in industrial engineering from University of Lima, with partial certifications in Business Strategy and Organization and methods. Specialized training in advanced logistics. Currently working as an intern in the logistics area at Je-al enterprises inc. Interested in the development of operations and continuous improvement.

Alberto Flores-Pérez holds a doctorate degree in Education from Universidad de San Martin de Porres. Master's degree in Supply Chain Management from Universidad ESAN. Engineer in Food Industries from Universidad Nacional Agraria La Molina. Currently working as an undergraduate professor at Universidad de Lima and postgraduate professor at Universidad Nacional Agraria. Professional, consultant, businessman and professor with more than 27 years of experience in project implementation, quality management and safety and agro-industrial plants' management. Expert in Supply Chain (supplier management, storage systems, transport modeling and distribution systems), Supply Chain and Operations. Specialization in integrated management system audit and Shortsea Logistics at the Escola Europea Short Sea Shipping. Leader of transformational projects, productivity, and change generator. Specialist in the implementation of Continuing Improvement Projects, PDCA, HACCP, BPM in the agro-industrial sector, trainer of national government institutions and the United Nations (UNDP). Development of high-performance team. Member of IEEE, SCEA Ohio, IOEM and CIP (College of Engineers of Peru).

Martín Collao-Diaz at ESAN University and Industrial Engineer from the University of Lima specialized in supply chain management and operations. Leader with more of 25 years in local and international experience in national and multinational companies at industrial, hydrocarbon and mass consumption sectors. Broad experience in supply chain management (purchasing, inventory, suppliers and supply sources management, logistics: transport, distribution and warehouse management), operations (planning and control of production and maintenance) and integrated system management (ISO 9001, ISO 14001 and OHSAS 18001). Business alignment based on sales and operations planning (S&OP). Besides, continuous search for improvements in profitability based on process optimization and saving projects using tools such as Six Sigma methodology among others, focused to be a High-performance Organization (HPO). Development of high-performance team. Member of IEEE and CIP (College of Engineers of Peru).

Juan Carlos Quiroz-Flores is an MBA from Universidad ESAN. Industrial Engineer from Universidad de Lima. PhD in Management and Business Administration at Universidad Nacional Mayor de San Marcos, Black Belt in Lean Six Sigma. Current is Undergraduate teaching at Universidad de Lima. Expert in Lean Supply Chain and Operations with over 20 years of professional experience in the direction and management of operations, process improvement and productivity; specialist in the implementation of Continuing Improvement Projects, PDCA, TOC and Lean Six Sigma. Leader of transformational projects, productivity and change generator. Capable of forming high-performance teams, aligned to company strategies and programs for "Continuous Improvement". He has published journal and conference papers and his research interests include supply chain management and logistics, lean manufacturing, lean six sigma, business process management, agribusiness, design work, facility layout design, systematic layout planning, quality management and Lean TPM. He is member of IEOM, IISE, ASQ, IEEE and CIP (College of Engineers of Peru).