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Improvement model to increase efficiency through the use of 5S, TPM and SMED tools in a plastic SME company

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Abstract*– Over time, the manufacturing industry has evolved enormously, requiring increasingly efficient processes, with reduced repair times and fewer defects. In this sense, in the case study a low efficiency in the production process was identified, given that the percentage in the plastics sector is 73%. Therefore, a more detailed analysis was carried out and it was found that high repair time and reprocessing due to defects are the main causes. Consequently, an improvement model based on 5S, TPM and SMED tools is proposed with the objective of reducing the costs of the described problem, which are equivalent to 7.45% of revenues. In addition, it seeks to reduce reprocesses due to defects by 43%, while repair time is reduced by 77%. Applying the presented model, it was obtained a decrease of the presented 5S deficiencies by 11.50%, increase of efficiency to 73.65%, improvement of machine availability to 85.46% and reduction by 1.36% and up to 39.24 of the effects of burn marks and setup time, respectively. Thus, it is expected that companies belonging to the plastics or related sectors will use the results obtained as a reference for improvement.

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I. INTRODUCTION

The plastics sector over time has shown an increase in its production both globally and in Latin America. It is also noted that in the period 2021, it represented 4% of global plastic production, surpassing the Commonwealth of Independent States (CIS). On the other hand, specifically in Peru, production rates have been increasing by 2.2% each year. This is due to the fact that Peru consumes approximately 30 kg per person [1]. Additionally, it is known that there has been an increase in the creation of plastic companies by 31.5% since 2015[2]. Then, as such a competitive market is presented, it is necessary that companies do not present problems in their production processes. However, the most common ones identified are low efficiency and high amount of waste.

Accordingly, this research focuses primarily on solving the problems related to time and defect waste, which contribute in some way to increase the efficiency of SMEs companies. In the same way, it is important to highlight that there are studies that have dealt with the above-mentioned problem by means of the implementation of different methods; however, in companies of this size of the sector, improvements have not yet been proposed using the techniques described together, thus providing a contribution to the research project.

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As a consequence, some approaches are mentioned below, for an industrial company where 5S was implemented with two pillars of TPM an increase in efficiency was obtained up to a value of 89% while in another micro-company when applying 5S with SMED efficiency was increased up to 73% [3,4].

Under the context presented, a model based on 5S, TPM and SMED tools is proposed to solve the problem in question. The main goal is to achieve objectives such as the optimization of resources through a reduction in the number ofmachine failures, reduction in the number of defects that generate reprocesses and a better monitoring of the productionprocess.

In reference to the above, the motivation of the study is to address the gap between the improvement of efficiency through the use of the model based on the three tools. That is why the document is divided into a section 2 that develops the state of the art by typologies and the sources consulted. Section 3 explains the contribution methodology and the combination of tools with their respective procedures. Finally, section 4 presents the validation of each technique and section 5 presents the conclusions of the project.

II. STATE OF THE ART

A. Organization of the environment through 5S in small and medium-sized plastics companies

The 5S tool mainly provides users with a more organized and cleaner work environment, contributing to the improvement of the production flow. However, to achieve this, some authors argue that the technique in question must be implemented in conjunction with other Lean methodologies. Reference [6], for some case studies where different implementation methodologies were used, similar quantitative improvements were obtained. One result that stands out is the increase in productivity, as evidenced in the study of a plastics company where productivity increased from 1.36 to 1.84 and efficiency improved from 42% to 75.8%. Finally, the effectiveness of the tool can be assured by means of audits, given that references [7,8] a case study, applying the audit in a range of period improves between 80 and 90% the compliance with the steps of the tool.

Reduction of set-up time through SMED in small and medium-sized plastic companies

The SMED technique allows the reduction of time spent on tool or configuration changes. Likewise, through the distribution of tasks (internal and external) it is possible to identify the current state of the activities and the level of improvement required to optimize time. In this sense, there are precedents where SMED has been applied together with other Lean tools as well as with those of diffuse origin, however, the main results did not differ, since all of them obtained a considerable reduction in the configuration time between 40% and 50%, besides showing the applicability for plastic companies [9,10,11].

B. *Increasing efficiency by implementing TPM*

This tool constitutes 8 pillars focused on improving machine operation and overall efficiency, taking into account different perspectives. Based on this, the autonomous maintenance pillar can contribute to the training of operators, as evidenced in a study that reduced the number of defective parts by 27.8% and increased efficiency by 44% [12].Similarly, the reference [12, 13] it is emphasized that, to obtain even greater results, it is necessary to implement the 5S as an initial phase, which also contributes to decrease the MTTR from 6% to 5.84% and increase the MTBF from 38.77% to 39.96%. In addition, according to different authors, an essential point to consider in the application of this tool is the choice of the pillars, since depending on the implementation context, the most appropriate and suitable ones should be chosen.

C. *Additional solution tools to increase efficiency*

Due to the new trends that have emerged over time, the solutions proposed now also consider the environmental factor, without losing the objective of improving efficiency [16]. In this sense, the Kaizen approach contributes greatly to achieve this goal, in addition to generating cost savings of up to 137 million as mentioned in a study [17]. On the other hand, reference [18] increasing efficiency is not the only indicator that is improved, but also productivity or the routes traveled depending on the purpose of each case study, by for example, in one of them, the combination of the FLD method with some Lean tools was implemented, which resulted in a 13.7% increase in productivity while the distances were reduced by 12.7%.

III. CONTRIBUTION

A. *Basis*

The increase in defective products has an impact on the overall production efficiency rate. Also, this contributes to the increasing repair time due to mechanical failures, nonproductive times and production costs [6]. The proposed model was initially developed based on the SMED tool to reduce setup times as in one case [11], with a 42% reduction of the initial time. Then, the use of 5S was proposed with the aim of being able to organize and propagate a culture of performance improvement for an organization and culture propagation both qualitative and quantitative [8]. Finally, in relation to the third root cause of injection burns, the autonomous maintenance pillar is used, since developing the pillar with the 5S [12] allows reducing the rate of defective parts and other improvements are obtained in relation to the performance of the company. In addition, it should be noted that the model to be used is a "light TPM" [3], in which only some pillars that are convenient to the study are used.

B. *Proposel Model (General Contribution)*

The proposed model is visualized in Fig. 1, its main objective is to increase efficiency based on the implementation of 5S, TPM and SMED tools appropriately distributed in two components: Organization of the environment and configuration activities, and improvement in machine operation. In that sense, the present study will manage to implement the mentioned components in a company sector with limited exploration. The development of each one will have the purpose of decreasing the impact of problems such as: high setup times, repair times for mechanical failures and the high rate of products with injection burn marks.

C. *Detail in relation to the model*

Component 1: Organization of the environment and configuration activities

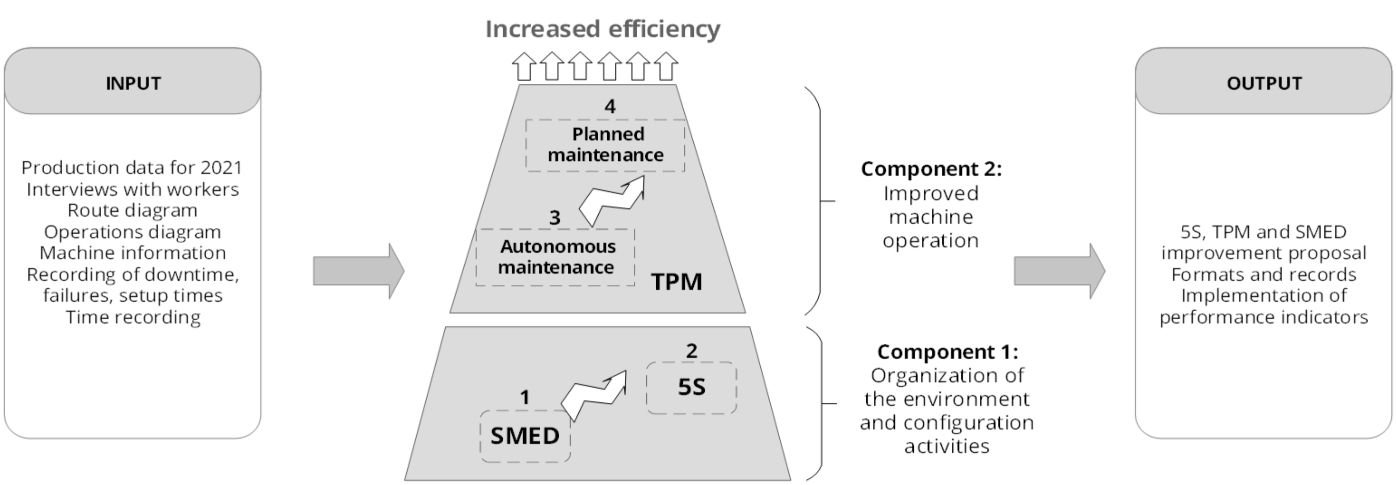

Fig. 1. Proposed general model

It is constituted by the tools: SMED and 5S (Visual Management), which are considered together due to the considerable improvement effects they provide [19]. On the other hand, it is established that the so-called "Lean principles" ranked SMED, 5S and visual control as the most widely implemented techniques together for several consecutive years [20].

1. SMED Development

The SMED is divided into 4 stages. It starts with the identification of internal and external activities. To do this, roles are assigned to each worker involved in the configuration and a spaghetti diagram is drawn by a manager to classify the activities. Then, the separation of internal and external activities is continued by reviewing recordings and discussing the current classifications of each activity. Subsequently, a conversion from internal to external activities is performed by analyzing the previously recorded activities. Likewise, a format is used to record tools by activity and changes are made accordingly. It should be noted that the "Configuration time" indicator should be measured. Finally, the optimization of the activities takes place, where the tool board is installed anchored in the production area so that the mold cleaning is faster. This will be done in parallel when the second "S" is implemented.

2. 5S Development

It begins with the scheduling of an initial meeting with the company's employees and management. It continues with the launching of the 5S training program to be executed on two dates according to the progress of the stages. Subsequently, the work team is formed taking into account the years of seniority of the workers in the company, who will guide the others during the development of this tool. Then, the current diagnosis of the company is carried out, where an audit record is stipulated based on a case study, the total scores are placed, the percentage is estimated and it is placed on the radar. Now, we start with the implementation of the 5S:

I. Seiri (Select)

Materials or products from the production and warehouse areas are classified using red cards to indicate those to be eliminated.

II. Seiton (Order)

We start with the arrangement of the necessary materials by using boards in the case of tools and shelves. Then, the areas are demarcated with green, yellow and red ribbons as appropriate.

III. Seiso (Cleaning)

The use of a daily cleaning schedule is proposed until Saturday, according to working hours.

IV. Seiketsu (Standardize)

In principle, labels are assigned to the machines. In addition, records are kept to keep track of what has been implemented.

V. Shitsuke (Discipline)

A final meeting is held with all employees to inform them of the improvement decisions that have been made. Finally, the final audit is carried out to evaluate the level of improvement.

Component 2: Improved machine operation

It consists of two TPM pillars, the autonomous maintenance (MA) pillar and the planned maintenance (MP) pillar [12].

1. Development Pillar Autonomous maintenance

In the case of the autonomous maintenance pillar, it starts with a meeting to explain the pillars and the designation of responsibilities. Likewise, the lubrication and cleaning schedule is mentioned. Through the process, the abnormalities are going to be discovered and the operators are going to write them down by means of white cards. Then, the detected annotations are divided by 4 types of problems and the metrics to be followed are assigned. Next, the cleaning standards are designated. For this purpose, two primers are used, one for lubrication and the other for cleaning. In the case of both primers, the understanding of the same is helped by means of some basic training. Subsequently, to corroborate compliance with the measures, a checklist of the activities is made and an initial inspection sheet is used at the start of production. As a penultimate step, a record of the evaluation of primers and a new template will be developed to evaluate the generated procedure. Finally, the most important indicators will be evaluated as the MTBF and a final audit will be given.

2. Development Pillar Planned Maintenance

On the other hand, for the development of the planned maintenance pillar, the equipment will be initially evaluated by means of an initial audit. Also, a meeting is held to explain to the superiors the purpose of the audit and the application of the PM pillar. Then, by means of the scores of the audit, the restoration of the equipment is used, for which a report of failure prevention actions is made. In addition, all possible failures of the devices will be represented by means of a FEA. Based on this, a corrective maintenance plan will be established. As a next step focusing on information management, the company being a SME does not have many resources so it will be developed through the Excel platform an information management by templates, increasing to 6 new templates with relevant production data. Subsequently, a procedure in relation to the corrective plan and two trainings with concepts of corrective maintenance for injection molding machines will be carried out. Also, preventive maintenance situations. A maintenance work order is applied to verify compliance with the steps or activities to be considered. To finalize the whole pillar, a procedure is used in relation to the corrective plan and about two trainings with concepts of corrective maintenance for injection molding machines. In addition, preventive maintenance situations. A maintenance work order is applied to verify compliance with the steps or activities to be considered.

D. Proposed Process

As described in the previous section, the following flow chart is shown in Fig. 2, which summarizes the stages or steps mentioned for each tool to be implemented.

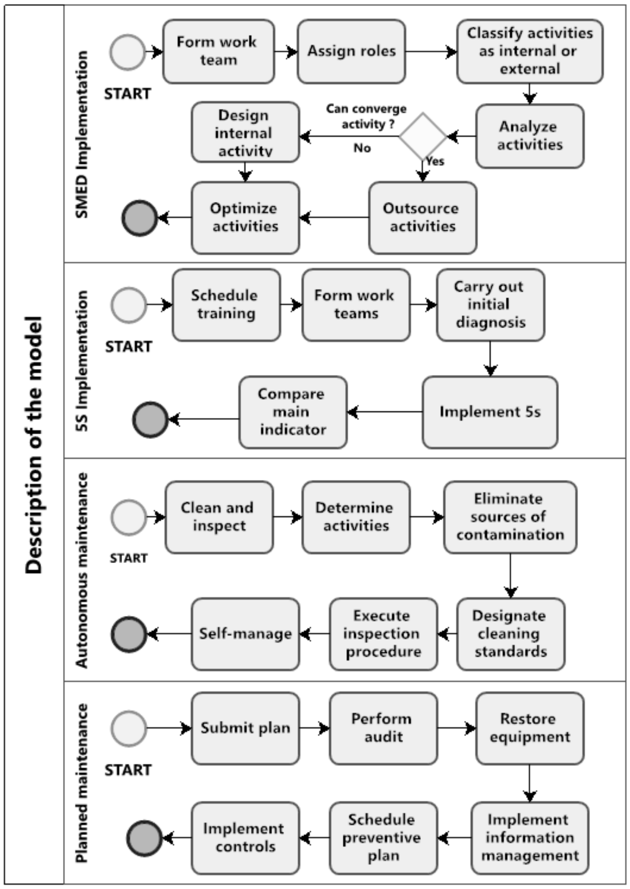

Fig. 2. Proposed process

E. Main indicators

For the validation we use the indicators that presented in the Table I, II, III and IV.

TABLE I
EFFICIENCY INDICATOR

1. Indicator name	Efficiency	
2. Objective of the Indicator	Allows to measure the level of execution of the process	
3. Mathematica l expression	$\frac{Actual\ production}{Actual\ capacity}\ x\ 100$	
4. Henchmark level of compliance	Critical	Less than 60%
	Risk	Between 60% and 73%.
	Suitable	Greater than 73%

TABLE II
DEFECTS INDICATOR

1. Indicator name	Number of reprocesses per burn mark	
2. Objective of the Indicator	Control and verify the quantity of caps with reprocessed burn defects in the production area	
3. Mathematical expression	$\frac{N°\ of\ caps\ with\ defects}{Total\ number\ of\ caps\ produced}\ x\ 100$	
4. Henchmark level of compliance	Critical	Greater than 2.30%.
	Risk	Between 1.81% and 2.30%.
	Suitable	Less than or equal to 1.80%.

TABLE III
CONFIGURATION TIME INDICATOR

1. Indicator name	Set-up time per machine and per batch	
2. Objective of the Indicator	Measure and control the time spent in the configuration of injectors in the area. productive	
3. Mathematic al expression	$\left[\frac{\frac{Sum\ of\ setup\ times\ (min)}{month}}{\frac{\#\ of\ total\ batches}{month}}\right]$	
4. Henchmark level of compliance	Critical	Greater than 50 min
	Risk	Between 41 min and 50 min
	Suitable	Less than or equal to 40 min

TABLE IV
MTTR TIME INDICATOR

1. Indicator name	MTTR	
2. Objective of the Indicator	Verify and control the duration time for each repair	
3. Mathematical expression	$\frac{Total\ time\ to\ repair\ failures}{\#\ failure}$	
4. Henchmark level of compliance	Critical	Greater than or equal to 7 h
	Risk	Between 4.56 h and 7 h
	Suitable	Less than 4.56 hours

IV. VALIDATION

A. Description of the validation scenario

The validation method chosen in the case of the 5S tool was the development of a pilot program due to its effectiveness in different referenced cases [7,21], where the improvements obtained were remarkable. In addition, it is established that through the pilot sample it is possible to strengthen the commitment on the part of the operators, as well as with the total implementation program, establishing a sense of belonging and collaboration [22].

In relation to the other two tools SMED and TPM (2 pillars) the simulation method with the Arena program has been considered, due to the time factor since the limited time would avoid completing the tool [12]. Likewise, in the case of SMED the most feasible validation is by simulation due to the effectiveness of the programs that exist to perform it [13]. However, in reference [23] an application of SMED in pilot format is not so convenient due to the manipulation of the machine configuration according to the type of production batch for a constant period, which could complicate the production process.

B. Initial diagnosis or previous studies

The plastics company under study is mainly engaged in the production and sale of plastic caps. In the initial analysis that was performed, it could be evidenced a low efficiency of its general process equivalent to 61.06%, while the standard in other companies is 73% [24]. For this reason, the root causes that had the greatest impact on the problem were evaluated.

The 5S validation methodology was selected because, in two previous studies, this approach is considered the most adequate compared to a simulator, and technical aspects are also contrasted, and flexibility [7]. Likewise, the effectiveness of the application of an audit during the 5S is mentioned, since it allows identifying deficiencies with greater accuracy, improving the overall result by 11.50% [8].

In the case of the SMED and TPM validation methodology (2 pillars), a simulation program in Arena was chosen. Time was considered as a main factor, since the estimated average implementation time is between 2 to 3 months. Also, focusing on each tool, for greater effectiveness most of the studies employ simulation programs [13].

C. Validation design

The indicators are shown in Table V below that have been considered for each type of validation as a tool, which were chosen according to the literature review.

TABLE V
VALIDATION INDICATORS

Tool	Validation	Indicator
5S	Pilot	Audit
SMED	Arena Software	Setup time
		Availability
TPM		MTTR
		Number of reprocesses

1. Pilot implementation

Initially, a meeting was held with the team members to designate those responsible for implementation. Additionally, an audit was conducted after the 5 stages.

I. Select: Red and green cards were placed to divide the objects that are used from those that correspond to other areas.
II. Ordering: The UNE-EN 15878 guide was used as a reference to locate the materials.
III. Cleaning: The weekly cleaning plan for each operator was posted.
IV. Standardize: Labels were placed on the machines.
V. Disciplinary: A final audit was used. This is shown in Fig. 3.

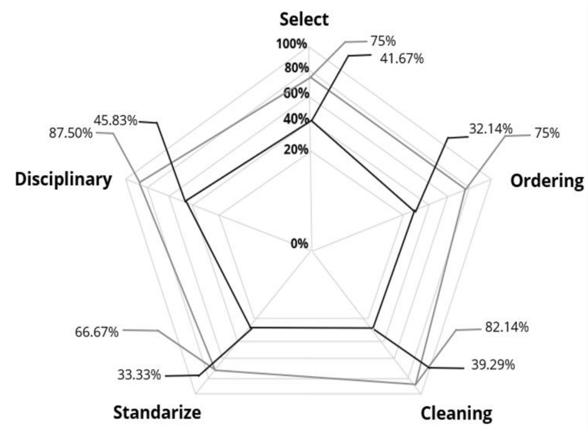

Fig. 3. Final audit

2. Simulation implementation

First, data sample to be considered in the simulation was established. Next, the graphical representation is developed and the types of distribution that the Input Analyzer program has are indicated. Table VI below shows the distribution types.

TABLE VI
TYPE OF DISTRIBUTION FOR EACH STATION

Inputs	Distribution
Time of arrival OC	CONSTANT
Injector time 1	TRIAN (3634;3645;3648)
Injector time 2	TRIAN (3486;3488;3490)
Weighing time 1	NORM (141;0.91)
Weighing time 2	NORM (64.2;0.785)
Shredder time	TRIAN (551;552;555)
Time to fold and cut	TRIAN (2638;2641;2643)
Mixer time	TRIAN (71;72.5;76)

Subsequently, the system is represented in the Arena program, considering production times and reprocesses. This can be visualized in Fig. 4.

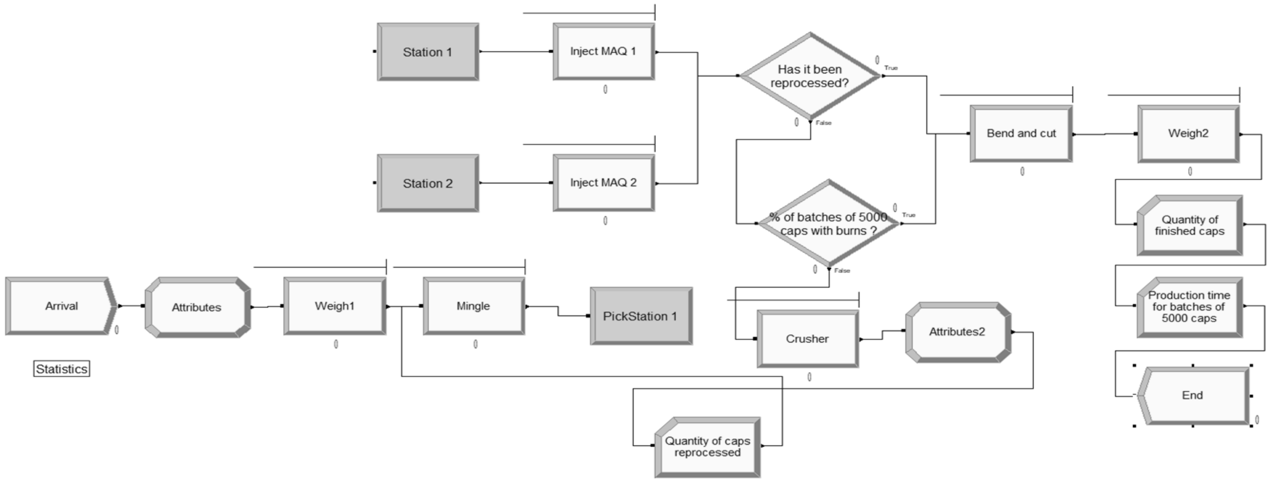

Fig. 4. Arena model

Finally, the ideal number of replications is estimated and the results of the TO BE state are obtained. It should be noted that three scenarios were simulated (pessimistic, optimistic, and moderate). However, in most studies it is recommended to opt for a moderate scenario, since it has a higher probability of being closer to reality.

D. *Comparison with initial diagnosis*

In conclusion, after running the simulation model as the pilot, a comparison is established as shown in Table VII, where the improvement in relation to the current situation is mainly evidenced.

TABLE VII
AS IS - TO BE POST VALIDATION

Indicator name	Situation AS – IS	Situation TO – BE	Post Validation	Source
Avaibility	74.27%	85%	85.46%	[15]
Burn mark defects	2.20%	1.80%	1.36%	[5]
Time of configuration	110 min	40 min	39.24 min	[25]
MTTR	5.314	4.560	2.69	[13]
Result of audit	38.45%	70%	77.26%	[13]
Efficiency	61.06%	73%	73.65%	[24]

V. CONCLUSIONS

With the development of SMED tools and the two pillars of TPM, it was possible to improve the production process, specifically in the injection molding area. Also, the indicators related to the root causes: high repair times and high setup times were optimized, since the availability indicator and MTTR increased, generating an efficiency of 73.65%. Also, among other improvements that would be obtained is the formation of an organizational culture in the company, where the collaborators have a greater disposition in the execution of their activities through collaborative work.

Overall, the machine availability indicator was increased from 74.27% to 85%, the set-up time was reduced by 70 min and the number of defects due to burn marks was reduced from 2.20% to 1.80%.

On the other hand, the model proposed for this case study is focused on a SME and is limited to large companies, so that future projects should consider the application space and new tools that complement the development.

Finally, it is concluded that the project is profitable according to a financial analysis since a positive Net Present Value (NPV) of S/. 19,974.40 was obtained and the benefit-cost ratio (BCR) equivalent to 0.110 is greater than zero, making the project acceptable.

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