Process Improvement in A Company Manufacturing Computer Assembly to improve the service level indicator using SMED, Six Sigma and Poka Yoke

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Abstract

This research sought to improve the assembly process, specifically from the desktop computers of the Infotec company, from the implementation of lean tools that allow diagnosing, measuring, and implementing new improvements or modifications in certain stages in order to improve both the level of service and the lead time of the total process. Each stage of the process had to be analyzed together with the company's technicians in order to obtain information on the current situation. Among the main findings, the lack of updated work tools, poor organization of the workshop and a moderate amount of lead time were identified, this through the use of the Pareto Diagram, DOP, VSM, DAP and photographic evidence. In addition, a high expense was found in complaints that represents 30% of the fixed costs, which corresponds to the internal failures of the computer, due to the poor assembly of the components, the overtime, and the poor organization of the workshop. Therefore, the lean tools used were Six Sigma, SMED and Poka Yoke. These allowed to propose new improvements and modifications both in the assembly process and in the work area. The Arena software was used to capture the current situation and later a new one, with the improvements implemented, evidencing an improvement of approximately 20 minutes. This investigation had certain drawbacks at first, as the company made it difficult to collect data to obtain the current situation. However, it was managed to settle it through negotiation.

Keywords
Assembly; process improvement; six sigma; Poka Yoke; smed

1. Introduction
The different sectors that Peru represents are distributed mainly in 3, which are the primary sector (7.6%), secondary (32.7%), and tertiary (59.9%), "The manufacturing sector is within of the secondary sector which grew by 13.3% in 2021" (MEF, Evolución del Sector Manufacturero, 2021). "Peru ranked sixth in the manufacturing position with 1.6% in Latin America in 2022, with positive expectations for 2025 with 2.1%, ranking fifth in Latin America" (FocusEconomics 2022).

The way in which it operates and carries out its activities in this case study is the Make to order (MTO) type, since it produces products based on customer orders. This way is defined by Kalpakjian & R. Schmid (2014) as:
"The total assembly operation is usually broken down into other individual ones, with an operator assigned to execute each stage. Traditionally, assembly involves a lot of manual labor and therefore contributed significantly to the cost of the product"(p.14)

The GDP in Peru according to the BCR in 2023 is 223.2 billion dollars, and according to MEF forecasts, it will continue to grow. "The GDP will greatly exceed what we had programmed. Although the percentage of growth comes out a little less than the forecast, it must be considered that it is on a greater amount" (MEF 2023).

The Infotec company offers products such as computers, computer components, and services such as maintenance and assembly of PCs. The goal of the Infotec company is to provide high-quality technological products, with full

guarantee, through excellent personalized attention. The computer assembly process currently lasts an average of 3 hours, and there are complaints from customers about the warranty, since the average time to fix the problems of a PC during warranty time takes between 15 to 20 days. The company's solution to factory failures is to provide a credit note from the product brand so that they can purchase a different or the same product for the same value.
Sin embargo, existe una serie de problemas en la empresa, que representa una desventaja que es frecuente en este tipo de negocios de ensamble de computadoras. Principalmente se refiere en las demoras que hay para la entrega del producto, asimismo fallas en algunos componentes y finalmente demora en la atención del proceso de ensamblado. Esto repercute en los clientes.

Some problems that may exist within the metallurgical sector, specifically in the assembly, were described below, some possible causes of the problem will be described:

- A disorganized work area for assembly.
- There is no replacement of tools with new ones for years.
- Delays in the operating system installation processes.
- Inefficient light.
- Lack of technical training.
- Lack of monitoring of sales made.

Finally, this research is divided into introduction, state of the art, methodology, validation, results, conclusions and references.

1.1 Objectives
The objective of this work is to correct, eliminate and improve the deficiencies in the maintenance operations of a computer to increase the level of service, and to do so through SMED, Lean Six Sigma, and Poka Yoke tools, and also the optimization of resources, eradicating idle and unnecessary time in operations, and seeking harmony between its areas. In addition, it is intended to determine the times, resources, and routes of each activity with different diagnostic tools for subsequent analysis and thereby develop improvement proposals for the Infotec company, with engineering tools such as Six sigma, SMED and Poka Yoke. In addition, implement a simulation with the Arena software capable of testing before the improvement, to verify the current situation of the company and make subsequent changes to implement the improvement, including reducing costs by optimizing certain process activities.

2. Literature Review
Competitiveness in the globalized environment highlights the importance of being more efficient in the execution of the company's operational and administrative processes to improve the level of customer service, delivery times, the quality of products or services, as well as optimizing the resources. "Making the company more competitive in delivery time, improving the level of customer service and reducing inventory, is one of the challenges that every manufacturing company has" (Rodríguez-Méndez et al. 2015).

According to a paper focused on the improvement of production of a sub-assembly line of a medium-sized industry, they used lean tools such as Six Sigma and simulation software with the purpose of improving productivity through the study of methods, the study of times and the VSM. Punna R. et al. (2019), defined the following concepts as:
“The lean tool as a methodology that mitigates the waste of resources and workspace despite the increase in manufacturing and competition; Kaizen is a process that is driven by employees and supported by managers in which employees make efforts for continuous improvement; and VSM is a manufacturing technique used to document, analyze, and improve the flow of information or materials needed to produce a product or service for a customer.”(p.229)

Another precedent found was in a case study that was based on the use of the SMED and JIT methodologies to develop a continuous flow of stampings, to make the company more competitive with respect to delivery time, improve the level of service of the customer and reduce inventory. These tools have resulted in the savings of hundreds of thousands of dollars, elimination of unnecessary parts and storage. Therefore, this study presents the methodology and the benefits obtained with the forecast demand, the planned methodology and the synchronization of some techniques to have successfully achieved their objectives. (Rodríguez R. et al. 2015).

According to Concepción R., et al. (2017) with their research focused on improving the quality and productivity of steel cable assemblies, in which the objective of the study was to optimize the production process so that it can meet the demand of customers during the time of greatest production volume. This was achieved by improving equipment and reducing waste in various areas, increasing productivity by 41%. Likewise, in the case study on the SMED and JIT methodologies for the stamping process, the application of lean tools, resulted in the reduction of assembly time from 39 minutes to only 9 minutes, which is equivalent to an improvement of 77% in terms of time saved by each tool. (Rodriguez R., et al. 2015)

As it has been observed, according to the antecedents, the results in terms of time reduction is a constant in each investigation, so that when applying the lean solutions, it is intended to reach results as in the last three mentioned investigations, that is a reduction of times greater than 50%. Well, it is this point that most affects the company studied.

On the other hand, according to Guo et al. (2022) who used the Poka Yoke tool, evidence that the assembly process directly affects the performance and reliability of the product, this means that it is highly related to the problems of the assembly of thin wall structures and the optimization of parameters, such as the time of the assembly process. Therefore, this accumulation of errors should be reduced, the quality of the assembly improved, and a virtual assembly simulation performed in this investigation using Arena Simulation.

3. Methods

Based on the collected papers, engineering tools such as SMED were proposed to differentiate external tasks from internal ones and convert some internal ones into external ones and thus save time in the assembly process, SIX SIGMA to generate quality in each of its processes, and finally POKA YOKE with which errors are avoided.

Table 1. Comparative Matrix

	Components		
Authors	Assembly Time	Assembly quality	Error Reduction
Punna, G., Nallusamy, S., Raman, P. (2019).		Lean six sigma y 5S	
Rodriguez, R., Sanchez, D., Martinez, J., Arvizu, E. (2015).	SMED y JIT		
Guo, F., Xiao Q., Xiao S., Wang Z. (2022).			POKA YOKE
Conceição, R., Silva, F., Ferreira, L. (2017)		Lean y PDCA	
Rohania J., & Zahraeea S. (2015)	5S Y JIT		
(Manzanares et al., 2022).		LEAN SIX SIGMA	
Proposal	**SMED**	**LEAN SIX SIMA**	**POKA YOKE**

3.1 Proposed model

The model of the process was presented in Figure 1, which was carried out for the investigation in which the stages are shown from the entrance of the problem to the objectives that are to be reached.

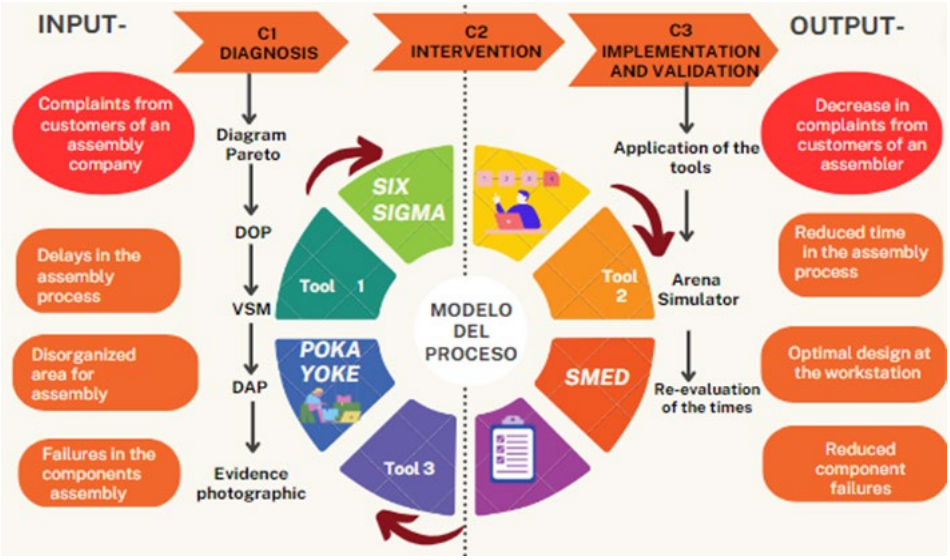
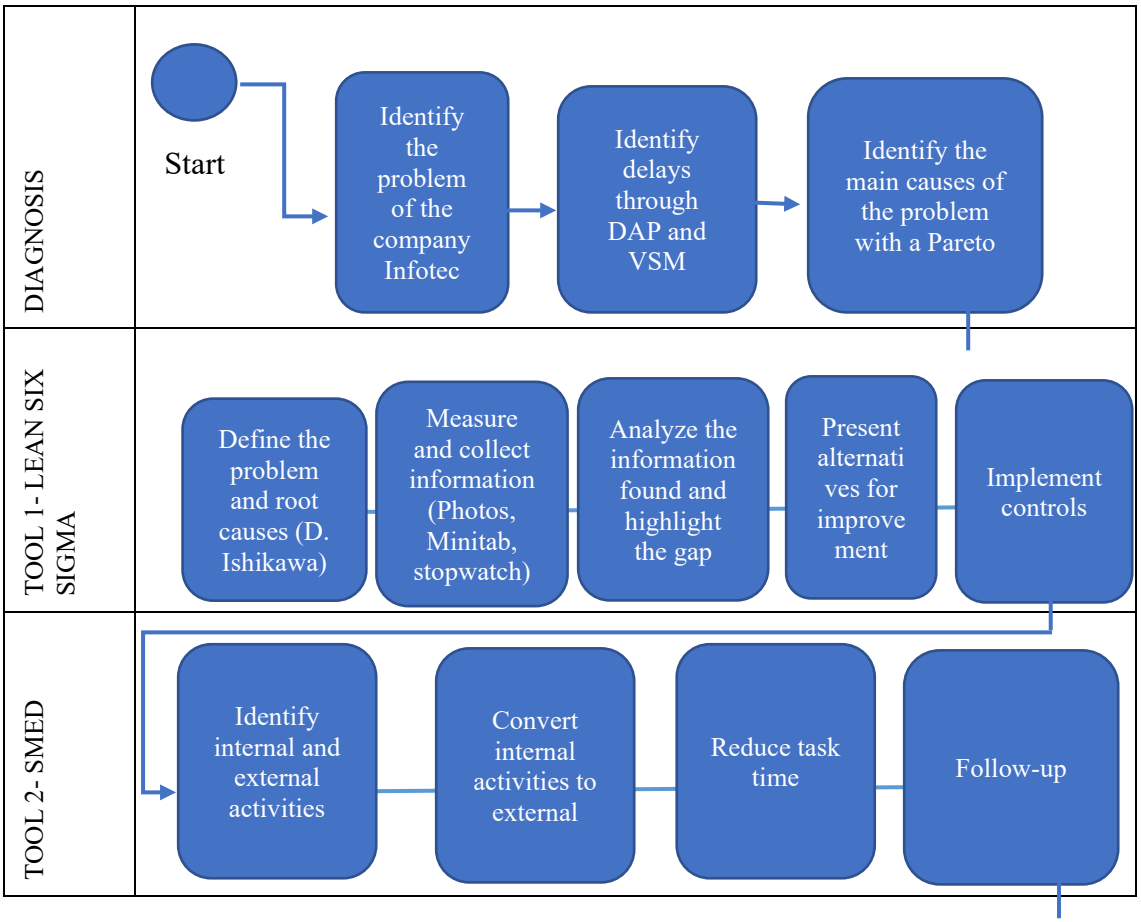


Figure 1. Process model



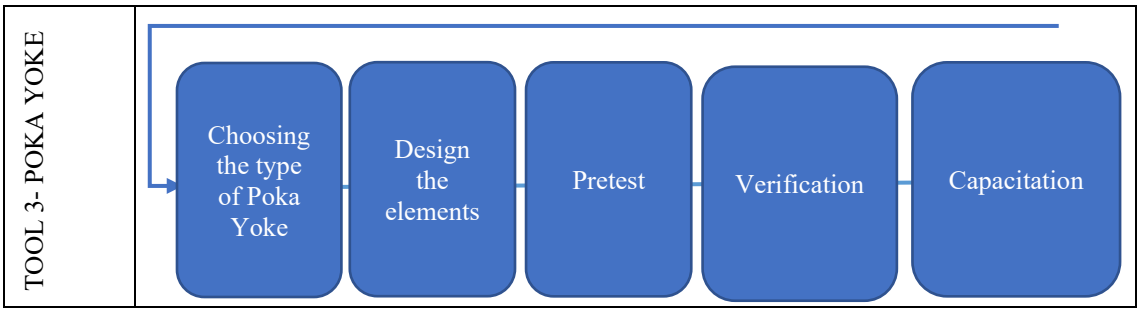


Figure 2. Process sequence

3.1.1. Phase 01- SIX SIGMA

Proposes the reduction of defects in products. This method is based on data that analyzes the processes that are repeated in companies and aims to improve quality as much as possible.
The difference between this technique and others is that it statistically analyzes and corrects problems before they occur. The phases to use the technique are to define, measure, analyze, improve, and control the new measures applied.

3.1.2. Phase 02- SMED

In phase 2, it is based on the SMED tool, in which what is sought is to reduce the reference change time in the machines, in order to reduce the total process time from 30% to 40%. This tool is divided into 4 phases, of which first the internal and external operations are recognized, then the operations are separated, then the internal operations are converted into external ones so that the operations are carried out without the need to stop production and finally improvement of all setup operations.

3.1.3. Phase 03- POKA YOKE

In phase 3, it is based on the POKA YOKE tool, which will be used to create devices to avoid errors. A sequence of steps is used, such as identifying potential errors, and implementing one of the 3 types of poka yoke (informative, sequential, or clustering. In this case, it was decided to implement an informational and clustering poka yoke.

The indicators are shown at the bottom:

Assembly service quality: Measures the times that a certain number of failures/complaints are repeated as a percentage of the total assembly services.

$$Assembly\ service\ quality\ = \frac{\#\ Assembly\ Service\ Complaints\ x100}{\#\ total\ assembly\ service\ orders}$$

Assembly Efficiency: Measures each of the components with respect to its characteristics that affect assembly or time.

$$Assembly\ efficiency\ (\eta) = \frac{N*T}{Ttot}$$

Where:
N= Number of parts
T= ideal assembly time
Ttot= total assembly time

Mean Time to Repair Defective Assemblies: Measures the time spent for complaints of failed assemblies over the Mean Time to Complete Assembly Repairs.

$$\textit{Mean time to repair defective assemblies} = \frac{\textit{Repair time for failed assemblies x100}}{\textit{Average time for total repairs of the assemblies}}$$

% Revenue growth rate: It is the process of a business that can be evidenced by measuring the revenue growth rate. This allows you to measure the progress of the project month by month.

$$\textit{Revenue growth rate} = \frac{\textit{\$ income month B - \$ income month A}}{\textit{\$ income month A}}$$

4. Data Collection

Para la realización del trabajo se empleó distintas formas de búsqueda de la información que ayuden a recopilar los datos y términos exactos para apoyar a sustentar la tesis denominada "Mejora de procesos en una empresa manufacturera de ensamble de computadoras para mejorar el indicador de nivel de servicio empleando SMED, Six sigma y Poka yoke. Se empleó repositorios que contiene artículos científicos tales como Scopus, Dialnet, ProQuest y Ebsco con años desde 2020 hasta el 2023 como se muestra en la Figura 3. Por otro lado, se emplearon palabras claves como effective tool, assembly, Kaizen, trabajo estándar, work desing, computer programming, wornking station.

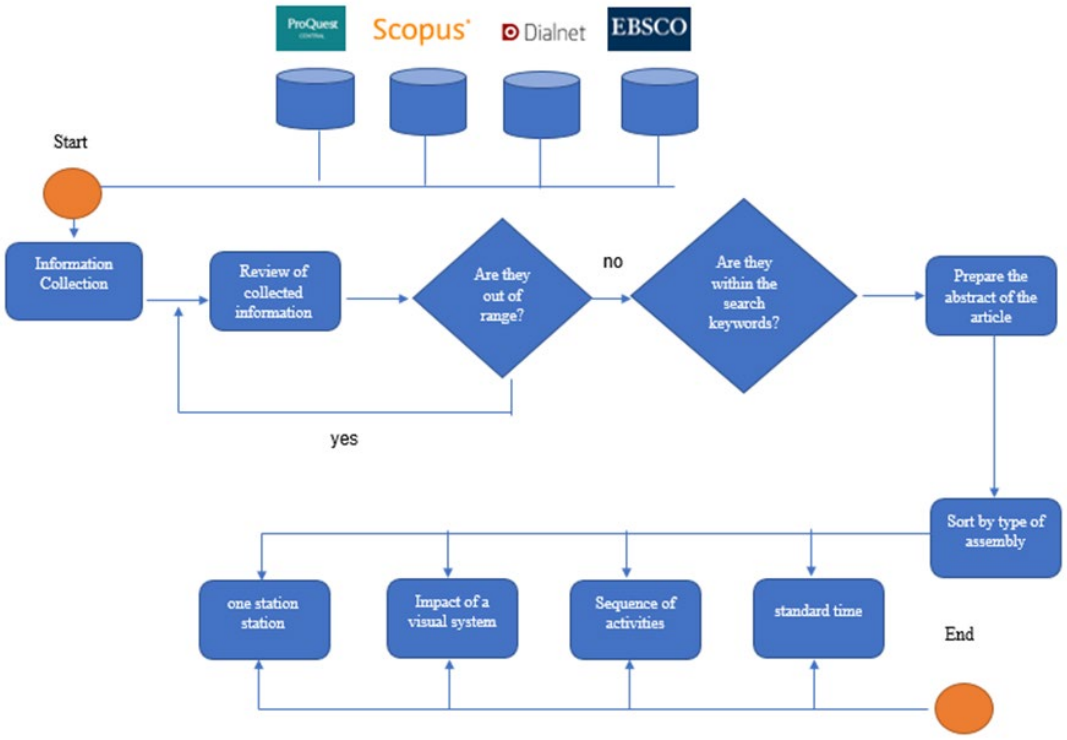


Figure 3. Flowchart of the research article review process

5. Results and Discussion

5.1 Numerical Results

In the development of the tool 1 - Six Sigma: To eliminate the problem of the lack of renewal of work tools there are two complementary solutions. The first is to make a renewal schedule or the useful life of the current tools used in order to know the date to be modified. The second option is to automate the tools. We were able to improve the time by approximately 20 minutes. In the case of the lack of lighting, it is intended to improve by restructuring the position of the spotlights and adding two, to have the required lumens and avoid shadows in the work area, eliminating delays and avoiding the strain on the technicians' eyesight. For the last step of the Six Sigma tool, that is, the control stage, in the case of lighting, it can be controlled by taking a luxmeter to the workshop to verify that the parameters established by the Ministry of Labor are being met. On the other hand, with respect to the work tools, they can continue to be controlled, timing the processes in which each one is used to see the improvements or if there is any ergonomic aspect involved that was not taken into account.

In the development of the 2-SMED tool, the phases of measurement, separation of internal and external activities, conversion of internal activities to external, and finally the optimization of internal and external operations were carried out. In the present investigation, 20 internal and 3 external activities were obtained at the beginning, with 75 minutes in internal activities and 65 minutes in external activities, which is equivalent to 87% and 13% of the total activities, respectively. The total assembly time was reduced to 120.6 min, based on this, the assembly process went from 87% of internal activities to 83% of internal activities and the external activities went from 13% to 17%. It is evident that there was not much change in terms of the number of internal and external activities, however, thanks to the methodology it was possible to reduce the time of internal and external activities. The new time for internal activities was 55.6 minutes and external activities 65 minutes. Finally, the time reduction was approximately 20 minutes in total with the application of the SMED tool; in percentage terms, it decreased by 14% of the total initial time.
In the development of the tool 3- Poka Yoke: In the last stage the Poka Yoke tool is used to avoid making mistakes in the assembly process, to carry out the process must be known, then the errors are identified, then the errors are controlled and finally the improvements are standardized. The main mistakes that were made during the assembly process were: Forgetting the steps to perform the assembly, Confusion of placing the components in the wrong way and Disorder of the necessary tools. In order to counteract each of the errors, a sequential and informative poka yoke was implemented in which a visual aid was made available to the technicians, reminding them of the assembly steps as well as the proper arrangement of each of the components, in addition, In order for the Poka Yoke tool to work, a complement is proposed that would provide the security to avoid any error in the position of each component, it would be the implementation of a dimension sensor, since this would detect if the position in which the operator is placing the part is correct and avoid going to the next steps with a part in a bad position. On the other hand, the type of grouped Poka yoke was implemented a station of colored separators according to the function of the tools, and these would be located in a visible area to take them in a quick and orderly manner.

5.2 Validation

For the implementation and validation of each of the tools carried out, the Arena software was used with the purpose of demonstrating the improvements in a visual way and proposing a fictitious scenario for the study of the investigation. The scope of the simulation goes from the moment the technician opens the components that he will use in the assembly process to the invoice made by the client. The items that will pass through the entire system for each activity of the process were determined, in this case they are the materials, parts and components of the PC. The Arena software was used with the input data, a confidence level of 97%, standard deviation of 4.19 and a margin of error of 0.05, obtaining a number of runs of 632.

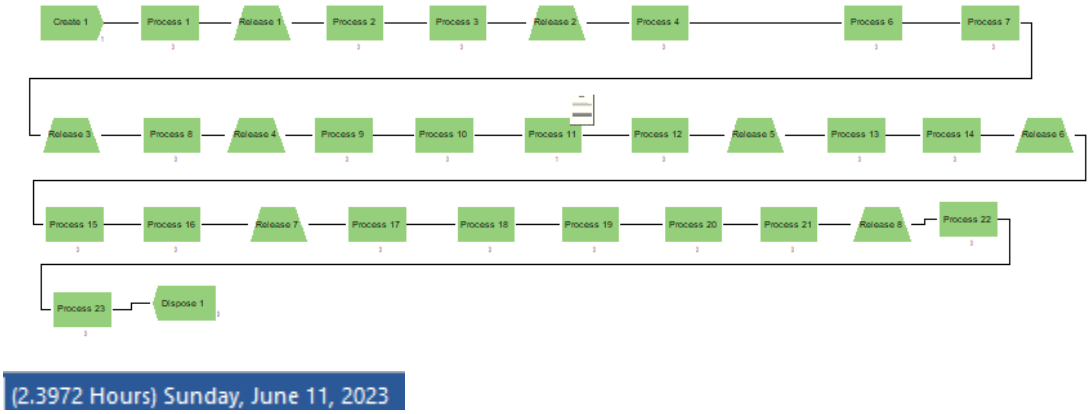


Figure 4. Current version

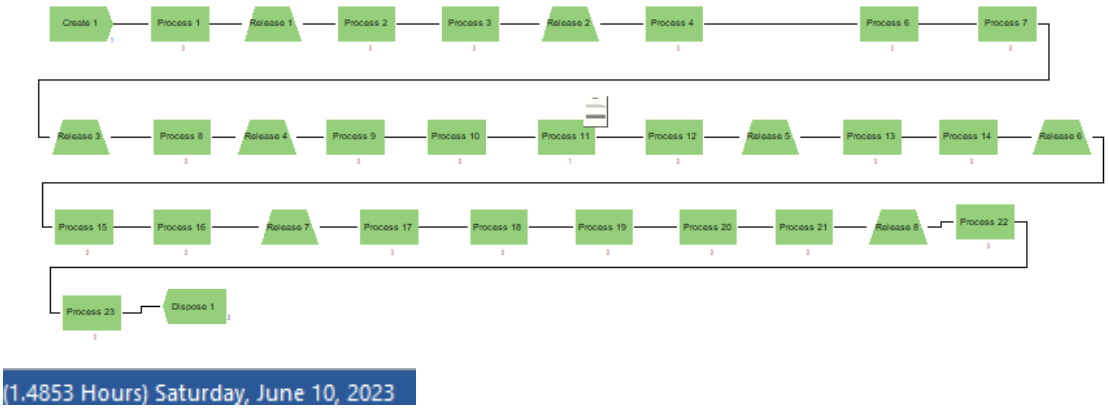


Figure 5. Improved version

The improvements compared to the current situation were made with the Arena software, in which it was observed that the time could be reduced due to the Six Sigma and SMED tools, in an initial time of 2.39 hours, which went to 1.48 hours, which leads to a reduction of 38.07%. Next, a summary table will be presented in which the expected results are compared with the results of each tool used in the work.

Table 2. KPI

Tools	Indicator	As it	To be	Improvement
Six Sigma	Mean time to repair	40%	28%	-12% ▼
SMED	Assembly efficiency	70%	80%	10% ▲
POKA YOKE	Assembly service quality	75%	90%	15% ▲

It can be concluded that by applying the proposed tools associated with the root cause, the percentage of complaints from customers will be considerably reduced. In this way the percentage compared to the technical gap will decrease even much more than 3%.

The income is determined by the impact that was left to have and the expenses by the cost of the implementation.

6. Conclusion

With the present investigation, the objectives of correcting, eliminating, and improving the operational deficiencies of the assembly of a computer were achieved in order to be able to witness the increase in customer satisfaction. The times, resources and routes of each activity were determined with different diagnostic tools for further analysis, with this improvement proposals were prepared for the company Infotec, with engineering tools such as Six sigma, SMED and Poka Yoke. Finally, a simulation was implemented with the arena software capable of carrying out tests before the improvement to verify the current situation of the company and to be able to make subsequent changes. In the first instance, the costs of the main problem were S/ 25,830 per year and the implementation of the improvement for this project is S/ 5,116, which includes S/ 1,600 for the sizing sensors to implement the Poka Yoke, S/ 3,000 for the electrical restructuring of the luminaire and finally the 4 automated tools that would give an equivalence of S/ 516. By making these improvements, the Infotec group would be committing itself to sustainability and this can be verified by its actions, the economic impact that had reduced the costs of optimizing certain activities of the process, the social impact, which includes the company's workers in the improvements that would be implemented, as they would feel part of the change and achievements of the company, and the environmental impact of the implementation of led spotlights, it would be contributing in a safe and competitive environment, improving the reputation of the company against the competition. Finally, it is concluded that the improvements that occurred were improve the total time of the process, improve the organization of the workshop and reduce the expenses of the company. However, some continuity or consistency must be established with the long-term improvements to determine the reliability of the improvements implemented in this project, so that new complementary tools can be implemented and that the research can work in a better way.

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Biography

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