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CASE STUDY: STANDARDIZATION OF OPERATIONS AND KAIZEN APPLIED, TO REDUCE THE CYCLE TIME OF A PROCESS

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Abstract: The purpose of this paper is to present an operations analysis based on the application of the five-stage standardization method and the Kaizen methodology to eliminate downtime, improve productivity, and reduce the cycle time of a process. The research strategy used was a case study applied to an automobile manufacturing company to identify operations that generated downtime, bottlenecks, and low productivity. With the proposed method, the standardization of the XYZD process, the reduction of the displacement pattern and the reduction of the cycle time was achieved. This research is limited to analyzing and improving the displacement pattern by applying operations analysis to reduce cycle time. Designing a new displacement pattern that eliminates downtime, low productivity, and reduces cycle time. The key contribution of this paper focused on optimizing the displacement pattern to improve cycle time and productivity (considering the human factor), applying the main concepts of method engineering and Kaizen methodology.
Keywords: method engineering; displacement pattern; Kaizen methodology; cycle time; productivity; tack time

1. INTRODUCTION

Competitive advantage is achieved through a quality product. To obtain a competitive advantage, continuous improvement must be carried out constantly in the manufactured products, using, among other options: technological developments, and industrial innovations, with high quality standards, permanence in the productive sector is achieved. (Cárdenas & Toledo, 2012)

Competitiveness is also achieved by developing well-structured manufacturing procedures (a series of steps sequentially arranged), those allow the implementation of continuous manufacturing flows and even mass customization of products (Salazar, 2020). To achieve competitiveness, the operations and times required to perform a task with a certain speed must also be defined. Each company in favor of its competitiveness applies these systems to achieve its objectives, depending on the characteristics of its products (Meyer, 2005).

When procedures are not standardized, or different work procedures are available in a single product or process, without adequate standardization, the quality characteristics desired by the customer are not met. In addition, not having standardized procedures and lack of updating or training makes workers establish their own work routine (method) generated by custom. The above situation produces different problems, the most notable of which are bottlenecks; ignorance of the order in the sequence of operations and hierarchies of the process, not complying with the times established in the work method, delaying, or advancing the production line, in addition to reducing the quality of the product.

To eliminate bottlenecks, operations standardization (OS) is one of the best solution alternatives, because it unifies the procedures so that each work operation is carried out in the same way, with the same order, regardless of whether it is the same person or different, if it is a work shift or three work shifts (Gibb, 2001).

The OS is the analysis of the times and movements, applying to detect waste due to unnecessary movements in a procedure, eliminate activities that do not generate value to the operation. As a result of the analysis, the task is made more efficient, a safe working environment is guaranteed; provides performance measurement indicators; help so that the worker does not fatigue too much (fatigue would cause him not to perform his functions as he should be) achieving savings in the cost of production or increases in the efficiency of the operation (MÍkva, M., Prajová, V., Yakimovich, B., Korshunov, A., & Tyurin, I., 2016; Münstermann, B., & Weitzel, T. 2008).

This work was carried out a car manufacturing company, focused on the standardization of door production, specifically in the sub-assembly area, which is the area where a bottleneck is generated. In this area, it was detected that there is no standard working method for the displacement pattern. The worker of each work shift has a different displacement pattern, which causes the cycle time to vary in each of the shifts.

Research has been carried out on the issue of standardization of operations, but few have been applied and reported from a production chain; Castiblanco reports in his article that this type of study shows a notable trend towards the health sector (Castiblanco & Aguirre, 2016).

There are different techniques, tools, and philosophies (methodology) to solve an operations analysis, but most or almost all companies do not have that culture of solving their problems through a methodology to achieve effective results; some managers want immediate results, and they get desperate when they must follow a methodology and omit some steps in the methodology that can lead to a safe solution of the problem.

This study was carried out to determine the time a worker requires, to carry out an assembly operation through the analysis of displacement patterns, applying a methodology supported by the Kaizen philosophy, as a tool that guarantees the application of an orderly work method and, with feasible results at each stage (Martínez, Montoya, Vélez and Oliveros, 2005; Bonilla-Muñóz, 2015; García, 1997). The research question we ask is: If we apply the methodology of the five stages of standardization and Kaizen to an assembly operation, including this analysis of displacement patterns, will we be able to improve the cycle time of the assembly operation?

We present a study of the times and movements, applying the methodology of the five steps of standardization and an analysis of the displacement pattern, relying on the Kaizen philosophy to detect those activities that do not generate value for the product or the process and affect the cycle time of the process. The study was carried out in a car assembly company.

2. LITERATURE REVIEW

Frederick Taylor, contributed to what is now as the scientific administration of labour which, among other situations, affirmed that employers and employees have common objectives: quality, productivity, and competitiveness. Taylor carried out studies within companies to select employees according to their abilities and aptitudes, and assigns them to work according to these studies, to produce more and with quality (Carro & Caló, 2013).

Taylor was also the forerunner of the study of the times and movements that promote the optimization of production processes. The study of times and movements is made up of techniques that are used to calculate the time it takes to perform a given task with an already defined method and by a qualified worker (Torres, P., Pérez, A., Marmolejo, LF, Ordóñez , JA, & García, 2010).

The study of the times and movements can identify the best method of operation (standard operation) to accomplish the objectives of quality, cost, and timely delivery, guaranteeing the safety of each of the operations that make up a process. Standardization begins by observing the processes, which will allow the development of standards that specify the correct execution of tasks, eliminating the useless (MUDA), the variation (MURA) and the difficult (MURI) (Nissan, 2015).

The benefits that can be obtained from the standardization of processes include the reduction of the downtime of a process, modifying of work area, reducing "cycle time", increasing production efficiency and improving product quality. Standardization also reduces the displacement pattern, making the worker is more efficient in his work and is less fatigued (Niebel & Freivalds, 2009).

Standardization drives improvement in processes; There is a wide diversity of tools to work on continuous improvement (Dos Santos, 2015), for this project the Kaizen methodology was chosen, its application aims to improve quality results, also prevent defects or failures or even accidents in the process (Berger, 1997). Kaizen has been translated as "continuous improvement"; some consider it a method, others a methodology and some more as a strategy. (Conesa, 2007).

The principle on which the Kaizen method is based, is to integrate the workers of a company in the continuous improvement processes, through small contributions (changes) that, simple as they may seem, have the potential to improve the efficiency operations and succeed the participation of staff in a constant search for solutions. (Salazar, 2020) (Otsuka & Sonobe, 2018).

Developing Kaizen does not imply large investments, all the employees must participate, and quickly implement the proposed improvements in a systematic and orderly manner. Kaizen has helped the development of industries, reducing production costs, the incidence of accidents, machinery breakdowns, delivery delays, among other benefits. Proper Kaizen implementation reduces ambiguity, work overloads and inequalities in the workloads (Dandin & Mench, 2015).

In the industry, Kaizen has had a wide application, some examples of this: (Dandín, 2015) described it was possible to reduce the cycle time of a manual assembly line. [Berger] applied Kaizen to succeeded improvements in their processes with respect to the standardization of processes and work design. (Knechtges & Decker, 2014) and (Karkoszka & Honorowicz, 2009) they applied it to achieve a positive influence on the performance of their staff, achieving acceptance and adoption of the method, increasing the productivity of their companies.

It is important to mention that there is no Kaizen without having a standard, since through the standardization of work and its compliance it is easier to detect anomalies and problems, when a Kaizen is carried out successfully must be modified the standard operation sheet of the process (SOS) (Maurer, 2015).

3. RESEARCH METHODOLOGY

The proposed research study is descriptive in nature and was carried out in an automobile manufacturer company located in the Mexican Republic. The work strategy is based on the methodology of the Five Stages of Operations Standardization made up of the following phases:

1. Current Status of the operation: the analysis of the operation to be improved was performed, checking that it complies with the procedure established in the documents for the assembly of the operation
2. Observation: of the operation in the work area, identifying the differences with the procedure established in the operations sheet.
3. Improvement: once the study of the times and movements was done through therbligs, a work proposal was developed where the improvements were included respecting the procedure established in the operations sheet.
4. Standardization: training of personnel for the 3 shifts based on the new work standard.
5. Respect for the standard: conducting audits to the staff to verify that they follow the new standardized work procedure and prevent any deviation.

This analysis includes the application of the Kaizen philosophy to develop improvements in the performance of the process.

— **Current Status of the operation**

The operation selected to analyse was identified as XYZ-D (for reasons of company confidentiality), to do the analysis we reviewed the documents of operations sheet, standard operations analysis sheet, standard operations distribution sheet and the operations distribution sheet. We started with the review of the operation to eliminate all the deviations that existed and once the operation was normalized, we proceeded to do the analysis of the displacement pattern.

The XYZ-D operation has 4 standard operations: placement of welding points, crimping, double placement of welding points, and hinge placement, which are performed by 3 workers, this area is not 100% automated because due to the complexity of the operations, these are done manually.

After reviewing the operational documents, we proceeded to go to the work area, to observe the way in which the worker performs the operation and verify the degree of compliance with the standard established in the documentation. All the findings were recorded in a registry that was the basis for forming the "Findings Solution Program", shown in Figure 1.

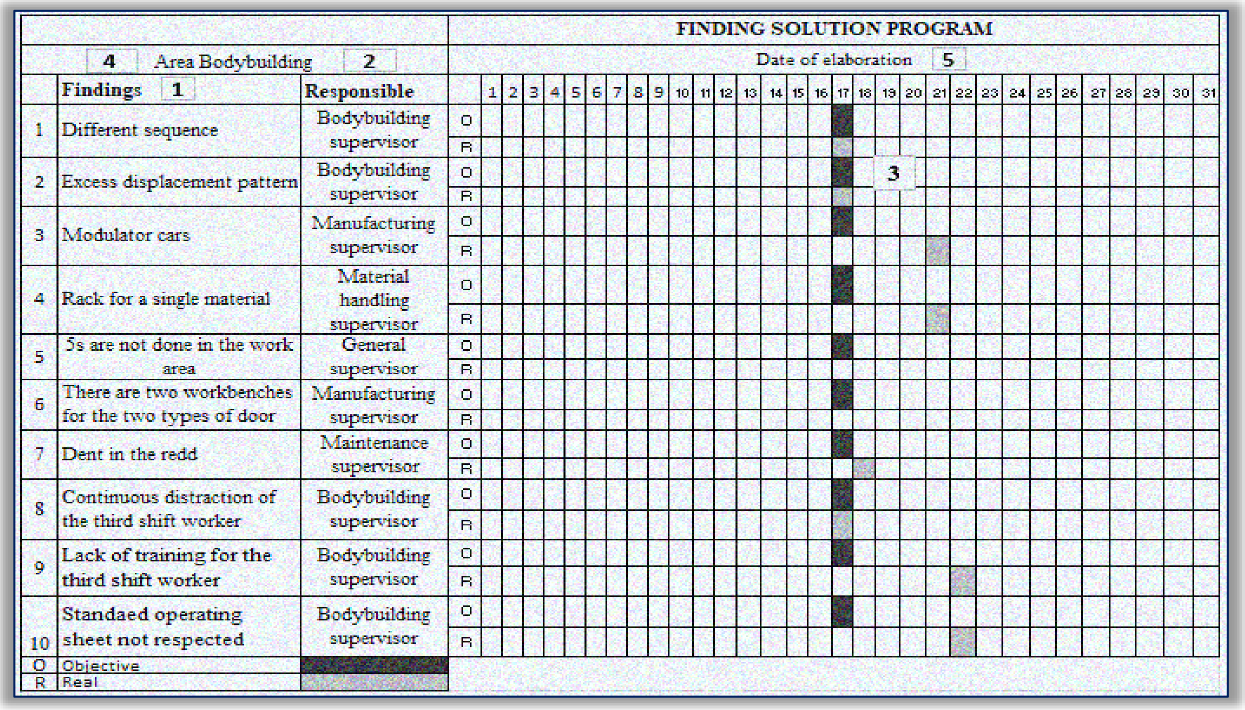


Figure 1. Finding's solution program (Ocampo, 2018)

The findings record has three main columns: to record the process deviations found [1], to record those responsible for the process in charge of solving the finding [2], the date the anomaly was detected and the date on which that was solved [3].

The black colour defines the deadline to solve the finding and the grey colour the date in which it was solved. In addition, this register has the data of the area [4] and the date on which the review was made [5]. The analysis of Figure 1 shows ten findings found and the dates on which they were solved.

The findings (4 and 6) required the design of a Kaizen activity to improve the performance of the processes in the standardization of the displacement pattern; the finding (3) and the defects (7) are not considered in this work as they are not part of the study.

After the review, a study was carried out to analyse the time and the movements of the operation, identifying how many steps the worker takes per cycle, how long it takes to finish a cycle. For a better analysis, a video of worker performance was taken. Three complete cycles of operation were filmed for each shift.

Before filming began, in the first shift several problems were detected that affected the development of the operation, the workers of the first shift complained about the conditions in which they found the work area daily: there were shortages and / or defects in the material and they blame for this reason the workers of the third shift; in addition, on Monday there is no raw material, and the operators must look for the supervisor to request material.

In the second shift, there were also complaints because the workers of the first shift did not carry out their daily production quota. In the third shift, production is lower, and they meet their production quota. Second shift workers worked faster to meet daily production and supplemented the daily production quota for all three shifts. All these problems were solved before starting the observation of the operation to eliminate any deviation from the procedure.

— **Observation of XYZ-D operations**

In the analysed work area, the distribution of operations for the three workers is respected, the supervisor assigns the personnel of the three shifts, places two workers for the placement of welding points and the third operator does the rest of the operations (crimping, double placement of welding points, and hinge placement).

The filming of the operation was done thirty minutes before the end of the shifts, it was considered that worker fatigue would affect the studio because they were about to finish their shift but obtaining a production estimate with the data obtained from the video found that the information is in line with the production indicator despite being evaluated at the end of the shift.

The filming was done at that time by indications of the production management.

Each filming consists of 3 cycles per shift, the operation was broken down into tasks to have a better analysis of the process and to calculate the cycle time. Their analysis allowed to make an improvement in the area through a Kaizen that allowed to identify the origin delays of the process come from and the way how they were solved. This Kaizen is presented later.

≡ **Analysis of XYZ-D standard operations**

During the filming of the three shifts, the activities of the internal assembly of the XYZ-D described in the operations sheet was confirmed, the times for the execution of all operations are presented in the following table. In Table 1, the averages of the measurements (in minutes) are presented, for the standard placement of welding points operation of the three cycles per shift.

Table 1. Average filming results for three cycles for each shift

#	Inner assembly (placement welding points) XYZ-D	First shift	Second shift	Third shift	Average (minutes)
	Total	4.817	4.041	3.879	4.245

The cycle time (it is a parameter defined as the time that the product remains in each workstation). Table 1 shows the cycle time for the placement of welding points, for the first shift average of 4.815 minutes is obtained, 4.041 minutes for the second shift and 3.879 minutes into the third shift. On average, the cycle time of the operation is 4.245, which will be used as a basis for making a proposal to improve the work.

The next standard operation is crimped, in this operation an external canvas is applied, which is a metallic sheet where the door is assembled.

From Table 2, the cycle time for the first shift of the crimping operation was determined by a value of 1.184 minutes, 1.390 minutes for the second shift, and 1.614 minutes for the third shift. On average, the cycle time of the operation is 1.396 for the three shifts. In this operation, it was detected that the standardization of operations in the activity of applying the stamp is not fulfilled in the second shift, and in the third shift the worker was still in training, both findings were corrected after the report.

Table 2. Average filming results for three cycles for each shift

#	Crimp XYZ-D	First shift	Second shift	Third shift	Average (minutes)
	Total	1.184	1.390	1.614	1.396

The third standard operation is the double placement of welding points, in this operation six points (which are for that the door is well sealed) are applied to the door window frame with the canvas, the robot only crimps the contour.

Table 3. Average filming results for three cycles for each shift

#	Double placement of welding points XYZ-D	First shift	Second shift	Third shift	Average (minutes)
	Total	0.805	0.885	1.314	1.001

Table 3 shows the average cycle time for the first shift of the double placement of welding point operation with a value of 0.805 minutes, 0.885 minutes for the second and 1.314 minutes for the third. On average, the cycle time of the operation is 1.001. Once again, in this operation, it was detected that the standardization of operations in the third shift was not met because the worker was still in training, a situation that was later corrected.

The fourth standard operation is hinge placement which allows the door to be attached to the body of the car in the next process.

Table 4. XYZ-D operation hinge placement cycle times

#	XYZ-D hinge placement	First shift	Second shift	Third shift	Average (minutes)
	Total	0.718	0.701	1.161	0.860

Table 4 shows the cycle time for the hinge placement operation, for first shift the average value is about 0.718 minutes, 0.701 minutes for the second shift and 1.161 minutes for the third shift. On average, the cycle time of the operation for the three shifts is 0.860 minutes. It is observed that lack of getting trained of the third shift worker impacts on the calculation of the cycle time.

≡ Calculation of the operation cycle time XYZ-D

Table 5 shows the average times (in minutes) of each of the operations analyzed.

Table 5. Cycle times of the standard operations of operation XYZ-D

Placement of welding points (tapping)	average	4.245
1 Crimp	average	1.396
2 Double placement of welding points	average	1.001
3 Hinges placements	average	0.86
Average standard operations (1-3)		3.257

In the analysis of the value chain, the comparison of the cycle times of the process, against the takt time (tact time) allows to evaluate if the process in its current state can satisfy the customer's demand. Figure 2 shows the graph corresponding to this analysis, where it is observed that the cycle time is greater than the takt time and warrants an improvement of the process.

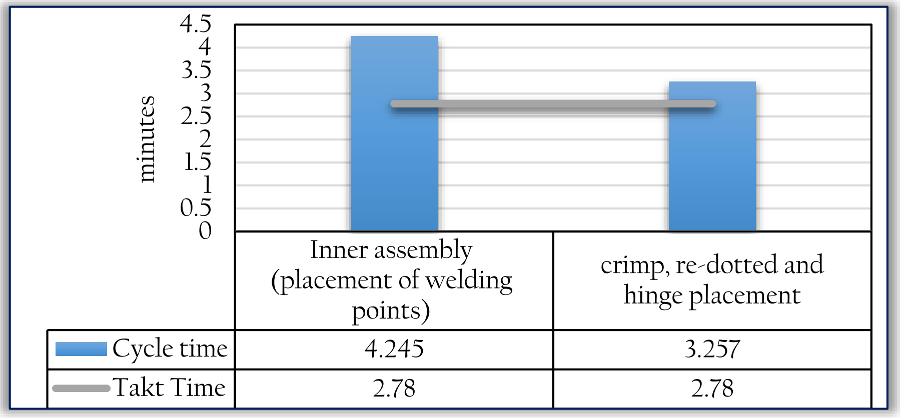


Figure 2. Cycle time vs Takt time

This first stage of the analysis made it possible to eliminate some deviations from the process derived from the administration of the operation. A second stage was carried out to analyse the Displacement Pattern (DP). The objective was to make the movement more efficient, using the Kaizen method as an improvement tool.

≡ Analysis of the walking pattern operation XYZ-D

The analysis was carried out by applying the Kaizen MU's: muda (Waste, activity that does not generate value), mura (When one of the people on the production line takes longer than the others to carry out the work, is the result of the action) and muri (stressful conditions for workers).

Implementation of Kaizen was started analyzing double placement of welding points operation. In the three shifts there are two workers, one assembles the door of the double cab truck and walks 21 footsteps. The other worker assembles the door of the single cabin truck and walks 19 footsteps during the work cycle, each step has a calculated time of 0.01 minutes, adding the number of steps to the average cycle time of 4.17 gives a total of 5.07 and 5.27 minutes per cycle of each worker. Workers 1 and 2 perform the same activities with the same procedure for both doors, but first worker walks more steps, because the material is further away from his workplace.

For the second and third shift, workers 1 and 2 also walk 19 and 21 steps respectively, their cycle time in the second shift is 4.252 minutes (worker 1) and 4.49 minutes (worker 2), for the third shift its cycle time is 4.11 minutes (worker 1), and 4.072 minutes (worker 2). Here there was a noticeable difference between the skills of both workers from the two shifts. The displacements are shown in Figure 3. A touch time of 2.78 minutes was calculated for this operation.

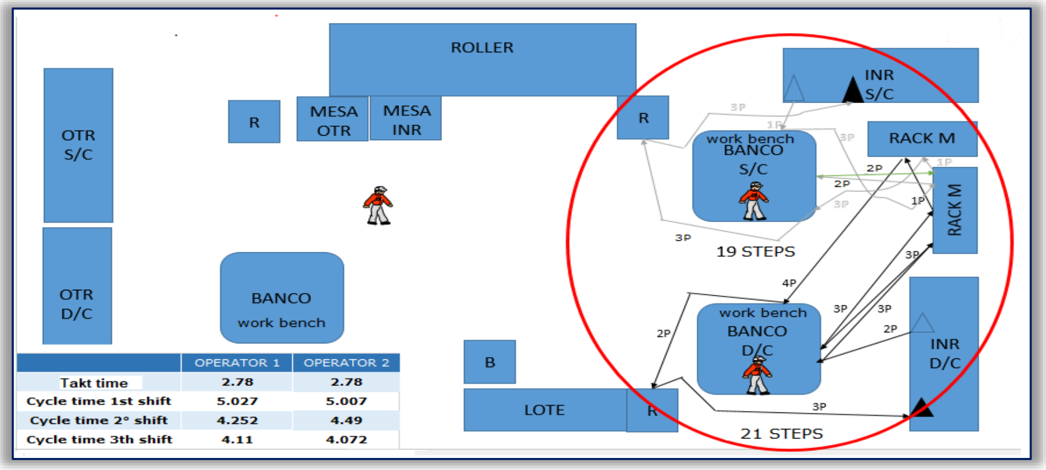


Figure 3. Displacement pattern, equal placement of tapping operation for the three shifth

Worker 3 performs the remaining 3 operations for door finishing, he walks more because he has more operations, the distance between workstations add 10 more steps. First shift worker 3 walks 61 steps, for a total of 3.318 minutes per cycle. The second shift worker walks less: 48 steps, the difference is because his operating procedure is different, with a total of 3.456 minutes per cycle. The third shift worker, the one in training, also walks 61 steps with a cycle time of 4.701 and his work procedure is the same as that of the First shift. The tact time of this operation remains at 2.78, Figures 4 and 5 show the difference in the working procedure.

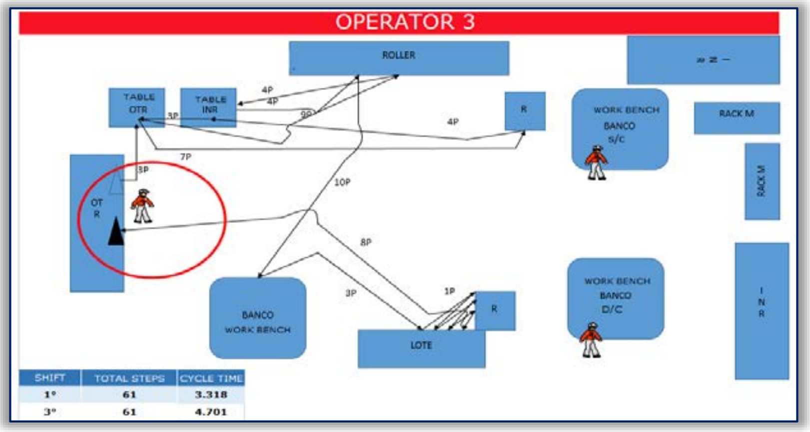


Figure 4. Displacement pattern, crimping operation , double placement of welding points and hinges placement, first and third shift

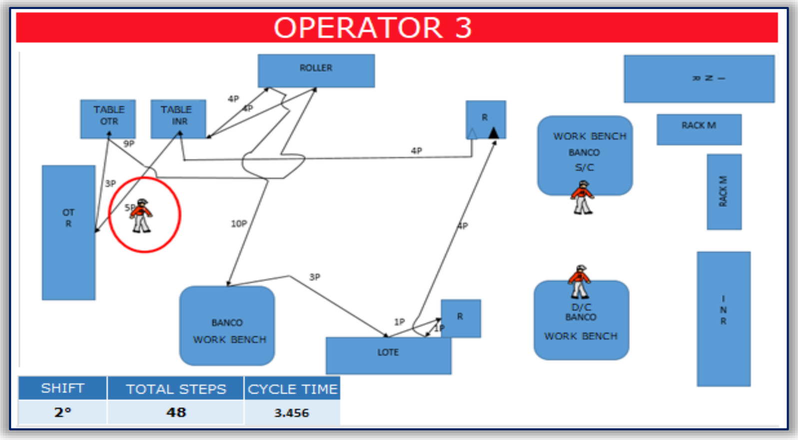


Figura 5. Walking pattern, crimping operation, double placement of welding points and hinges placement, second shift

≡ Improving XYZ-D operations

To reduce the cycle time of each operation, it was necessary to analyze the displacement pattern, which was reduced by reorganizing the racks and modifying the work benches (Kaizen development, presented later), so that both benches produce the 2 types of doors and not just one. In this way, a door can exit approximately every 2.78 minutes. The procedure was also modified so that one of welding workers, stops doing his operation for a few minutes and goes to help worker 3, thereby avoiding the bottleneck. This action reduced the fatigue of worker 3, a change in the attitude of the workers was noticed and the teamwork was to their liking. The following figures show the change made in the work area for the 3 shifts, with this the standardization of the operation was achieved and the three shifts performed the same procedure. Figure 6 shows the new walking pattern tapping area operator 1, with a step reduction ranging from 21 to 15 steps per cycle.

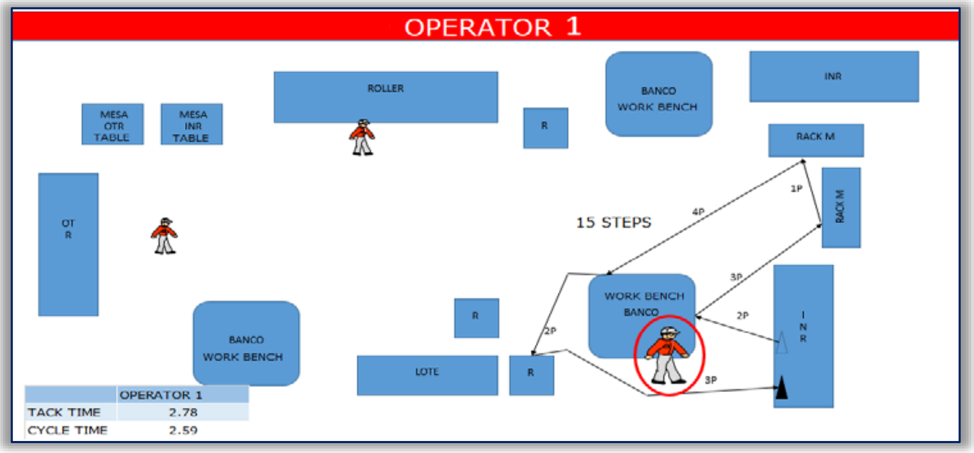


Figure 6. New displacement pattern for placement of welding points area, operator 1

With the modification made, the cycle time was reduced to 2.59 minutes for the three shifts, below the touch time calculate of 2.78 minutes. Furthermore, the workers (1 and 2) took turns to assist for a period of ten minutes to operator 3 with his work, each time interior door stock accumulates.

In Figure 7, worker 2 is shown doing his work, while operator 1 supports operator 3 with the crimping tool. There was also a reduction of steps from 19 steps to 12 steps.

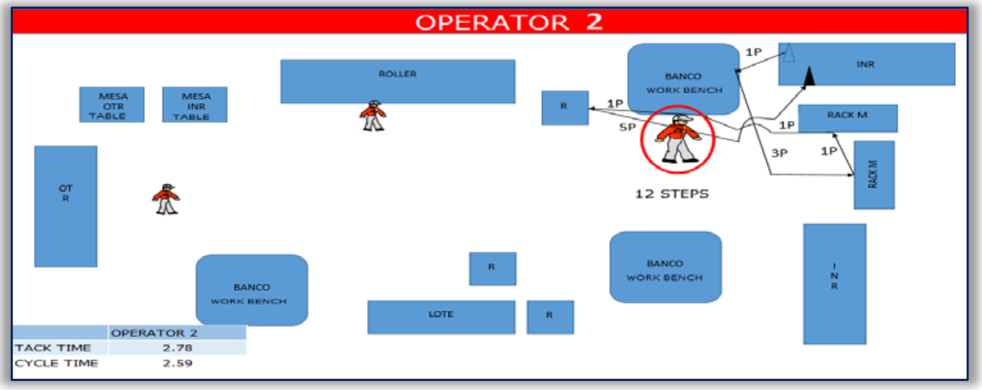


Figure 7. New walking, placement of welding points area, operator 2.

Figure 8 shows the process to be performed by the worker (1 or 2) that assist operator 3, the cycle time is 1.77 minutes, with a total of 28 steps, this activity must be carried out for 10 minutes each time a stock of more than 12 door accumulates.

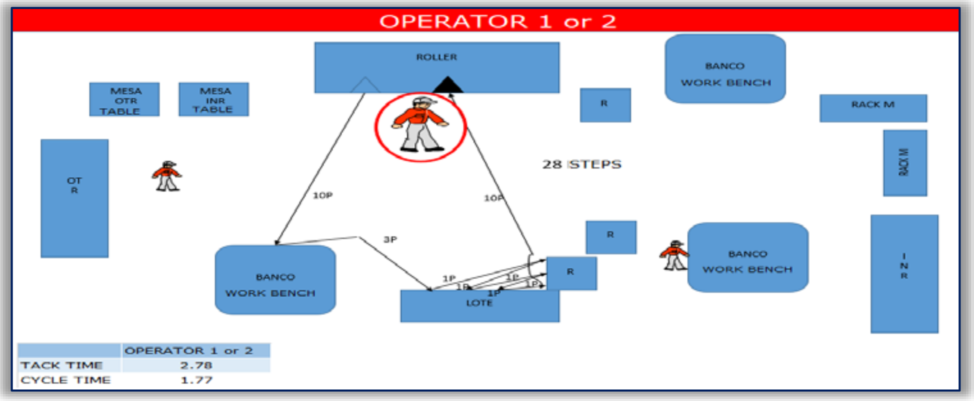


Figure 8. New walking pattern, crimp area, operator 1 or 2

Figure 9 shows the new displacement pattern for worker 3, which reduces his walk from 61 to 41 steps per cycle, now a finished door leaves every 2.59 minutes and previously it was finished in 4.7 minutes.

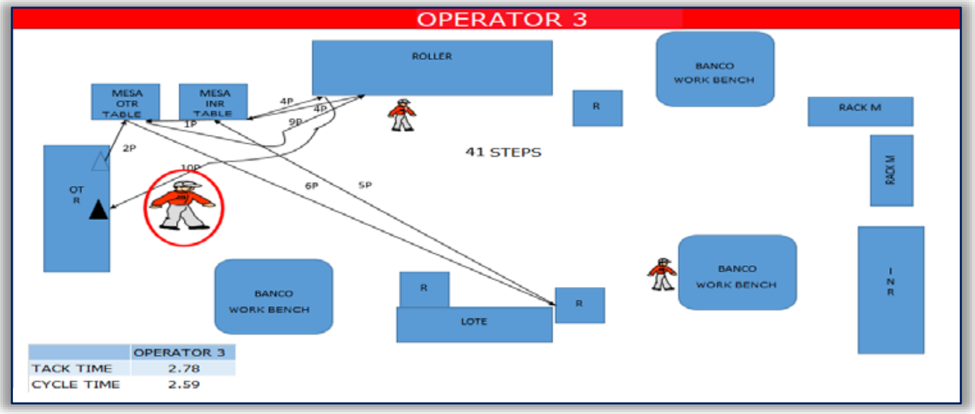


Figure 9. New walking pattern, tapping and hinge placement area.

— **Standardization of XYZ-D operations**

Once the improvement was made, changes were made to the process documentation, new formats were designed to record the changes made. For the crimping operation, the worker must work with a robot and a man-machine diagram was designed that defined what the worker does while the machine works, this relationship is important to keep track of the worker, this sheet did not exist and was prepared for future reviews.

— **Respect for XYZ-D operations standard**

The supervisor monitors the standardized operations to verify that they are respected. For the follow-up, the supervisor observes the operation with the support of the modified and created Standard Operation Sheets (EOS), also with the support of the Technical Training Program (TTP) where the training of each worker is supervised monthly.

4. KAIZEN´S DEVELOPMENT

To improve the performance of the process and reduce its cycle time, the Kaizen philosophy was applied. Following its methodology, an analysis of the current process was made, an action plan was generated that were executed and a new work standard was created.

<table>
<tr><td colspan="3">Title. Modification of the racks of the placement of welding points area, XYZ-D operation.</td></tr>
<tr><td colspan="2">The Reason for selecting the topic or problem:
1) Increases the displacement pattern.
2) Optimization of the use of the rack, pieces do not fit in a single rack, they are placed in different racks.</td><td>Effect 1) Reduction of the displacement pattern: worker 1 from 21 to 15 steps, and worker 2 from 19 to 12 steps.</td></tr>
<tr><td colspan="2">Countermeasure
1) To Modify the dimensions of the rack to be able to place materials of different measures and sizes.</td><td>Future actions
1) Production: scheduled reviews of the operations</td></tr>
<tr><td colspan="2">Confirmation of results</td><td rowspan="3">Assurance to prevent recurrence.

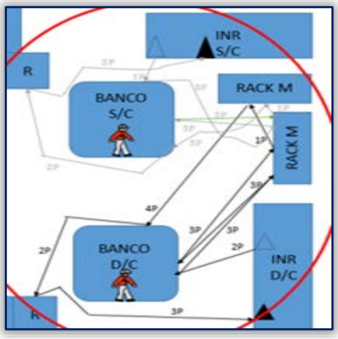
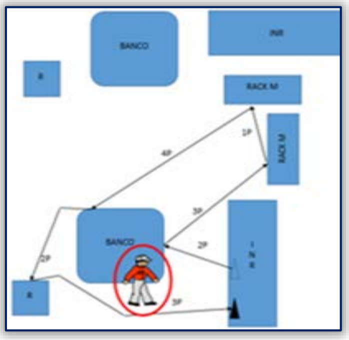
1) Production: Modify standard operation worksheet of the assembly. Respect the standard of operation.
2) Processes: Modify process control sheet</td></tr>
<tr><td>Before</td><td>After</td></tr>
<tr><td>
</td><td>
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Figure 10. Kaizen Applied to racks in the placement of welding points area, operation XYZ-D

A multidisciplinary team comprising workers, supervisors, and middle managers, (8 people), was formed to prepare the reports. The team members identified and discussed the problem to be solved, developed a schedule of activities, documented the relevant data of the process, analysed them, and presented solutions which they verified, and with the above implemented the new work standard. The solutions were focused on the findings detected in the process analysis program, shown in Figure 1, referring to material racks and assembly benches. The result of their work is shown in the Kaizen reports in Figures 10 and 11. The report format was designed by the company.

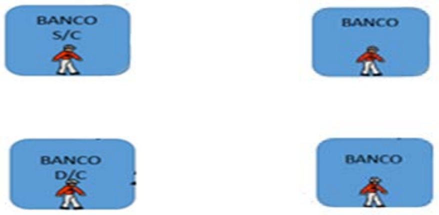
<table>
<tr><td colspan="2">Title: Modification of the welding banks of the placement of welding point area, XYZ-D operation.</td></tr>
<tr><td>Reason for selecting the topic or problem.
1) Decrease cycle time.
2) Reduction of the operation time, there are two welding benches where it is only possible to weld a single type of door (single or double cabin).</td><td>Effect 1) Elimination of the bottleneck that was generated in the placement of welding points area, to reduce the cycle time of the operation.</td></tr>
<tr><td>Countermeasure
1) To modify the welding benches so that the two types of doors (single or double) are manufactured in the same process.</td><td>Future actions 1) Production: scheduled reviews of the operations</td></tr>
<tr><td>Confirmation of results
Before After
</td><td>Assurance to prevent recurrence.
1) Production: Modify standard operation worksheet of the assembly with the new procedure. Respect the standard of operation.
2) Processes: Modify process control sheet</td></tr>
</table>

Figure 11. Applied Kaizen a spot weld banks, XYZ-D operation

5. RESULTS

Table 6 shows the increase of the efficiency of the workers, based on the cycle time and the improvement applied in the operations of placement of welding points and crimping, also considered the time that the worker 3 works alone.

Table 6. Percentage improvement in cycle time efficiency

IMPROVEMENT WITH OPERATOR SUPPORT 3 (first shift)			
	Cycle time minutes (after improving)	Cycle time minutes (before improving)	Efficiency
operator 1	2.59	5.027	49%
operator 2	2.59	5.007	49%
operator 3	2.59	3.318	22%

The graphs in Figure 12 and Figure 13 show the improvement of the Operating Cycle Time for the three shifts. A total of 30 cycles were analyzed, before and after improvement, shown in vertical lines, displacement pattern before improvement and in horizontal lines after being standardized. The values indicate the average cycle time of each turn.

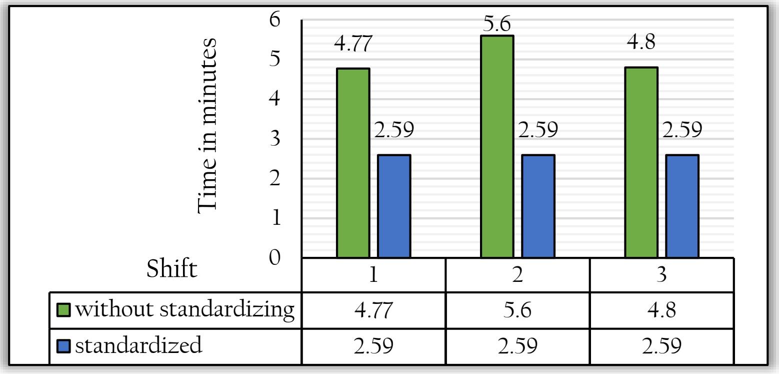


Figure 12. Cycle time before and after improvement

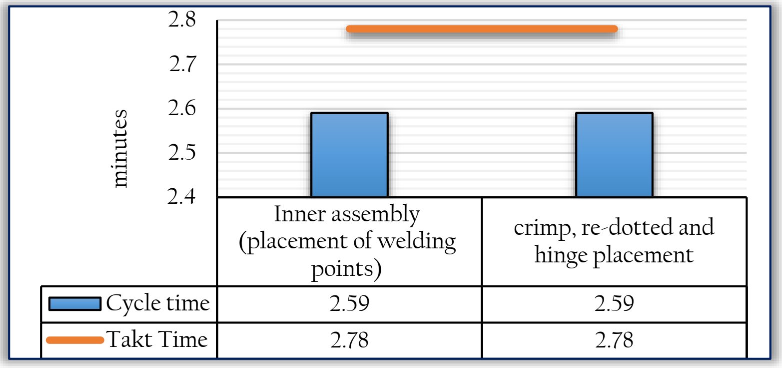


Figure 13. Cycle time vs Takt time after improvement

With respect to the application of the Kaizen philosophy, it was possible to identify two activities that did not add value to the process and were not essential. Improvements were made according to the analysis carried out, which resulted in the improvement of the process.

6. CONCLUSIONS

Regardless of the size of the company, the standardization of production processes is a key action to minimize costs. The use of working methodologies in a sequential and orderly manner, such as the Five Stages of Operations Standardization and Kaizen, provides benefits such as planning the analysis of activities, documenting operating manuals or procedures, record activities so that the work team knows what to do (how, with what, with how much and with whom) among other activities that make up the administrative process and make it possible for the customer to receive a quality product.

An important point for the Kaizen is that it should not be imposed, it is necessary to listen to the work team, it is fundamental for the success the communication and disposition of the information between the work team, as was demonstrated in this work.

Both methodologies allowed to eliminate downtime, improve productivity, and reduce the cycle time of a process.

Implement a value chain analysis throughout the body building process to detect activities that do not generate value, plus a Six Sigma analysis to the process.

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