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Implementation of Multifunctional Fixture for Automotive Painting Line

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Abstract

To focus the effort to achieve a reduction in production costs, increase the quality of the product and have a short delivery time to the client, an investigation applied to the start-up of a production line of painting for automotive parts is presented. Under this scheme, it is necessary to produce 10,000 sets per week of 4 different models, so it is intended to make a fixture with applicable capacity for the 4 available models. To implement this improvement, it was necessary to analyze the baking capacity of the painting booths, as well as their entrances and exits, the distance that the fan has from the paint application gun was also considered, in addition to the scope of the vision camera. used within the paint line and the cycle times of each thread. Taking these preferences into account, the final design of the fixture was determined, as well as the number of fixtures to be used within the line based on simulation of line balancing.

Keywords: *Paint booth, cycle time, fixture, automotive line start-up.*

1. Introduction

This project was developed in a manufacturing plant in the automotive sector located in the south of Aguascalientes, Mexico. Inside the plant, there is a painting line for automotive interior parts, considered one of the most important processes due to the aesthetic value of the parts finish. Three stages of the process are carried out on the line, consisting of cleaning, base coat application, and topcoat application. Baking is carried out between each stage to accelerate the drying and curing of the products used.

The development of this project considered a goal of mass production of 10,000 car sets per week, with four different part numbers per car set, and each of which must enter the painting line. The design of the painting production line allows each part number to enter different fixtures, which fills the capacity of the line to 100%, preventing parallel work with another project. Therefore, a study was carried out to develop an optimizing design that allows maximizing the capacity of the painting line and reaching the production goal of 10,000 car sets per week, also gaining space to enter another project within the line in such a way that synchronous. Table 1 shows the original capacity of the line when a fixture is used for each model.

Table 1. The original capacity of the painting line where the values of the different variables that show the productive capacity are shown. The units are different according to each variable.

Description	Specification	Daily capacity
Workdays	3shift*8hr	----
Workweek's year	48	----
Workday's month	24	----
Model #1 (cavity)	3	14%
Model #2 (cavity)	2	78%
Model #3 (cavity)	6	7%
Model #4 (cavity)	6	7%
Cycle time	75seg	----
Scrap	10%	----
OEE	80%	----
Output conveyors per day(12*2)	1075	----
Output conveyors per day (3*8)	1022	----

A fixture is a clamping, positioning, location, and/or support device that is integrated into the line either at the beginning, during, and/or at the end of an assembly, machining, welding, etc. operation. The correct use of these devices allows reducing production costs, maintaining quality, maximizing efficiency, and has the versatility to manufacture a wide variety of parts with correct specifications [1]. Due to the above and since the production line is sequenced by a conveyor, a continuous improvement was made to the fixture applied to its design.

Both in the manufacture and the improvement of a fixture, some factors must be considered such as 1) the production requirements, 2) the location of each of the pieces, 3) uniform distribution, 4) restriction of movement of the workpiece, 5) speed of loading and unloading, 6) fast action fasteners, 7) diagnosis and estimation of vibrations and 8) fastening security in the installation.

This research focused on the analysis of each of the existing models, intending to increase production and available capacity in the painting line, maximizing it through fixtures while preserving quality.

For the research, the Deming cycle was used, which is used by many companies that seek to increase their quality standards and function more efficiently. A cycle consists of four phases plan, do, check, and act. For that reason, it is also known by the acronym PHVA in Spanish and PDCA in English. [2]

The hypotheses of the project:

H1. Is possible to modify the design of the fixture already used in the paint plant, guaranteeing the quality of the product, and producing 10,000 car sets per week.

H2. A PDCA continuous improvement system can be used to achieve compliance with an engineering change in paint plant fixtures.

H3. Is possible to use a single fixture design for 4 subassembly models.

2. Methodology

The methodology selected in this project was the use of a continuous improvement system called the Deming cycle and/or PDCA (Plan, Do, Verify and Act), this tool has techniques for solving and analyzing problems, in addition to improving the indicators. Figure 1 describes the sequence used in the development of the project according to [3].

As already mentioned, the methodology used in this project was the Deming cycle or better known as PDCA which is divided into four phases which are, 1) Plan: recognize an opportunity and plan a change. 2) Do: test the change and/or conduct a small-scale study. 3) Verify: review the test, analyze the results, and identify what has been learned. 4) Act: Act based on what was learned in the study step. If the change doesn't work, the cycle repeats with a different plan. If successful, you incorporate what you have learned from the test into broader changes. In the end, what is learned is used to plan new improvements, starting the cycle again. [4]

2.1. Phase 1: Plan

In this stage, the problems are identified, the objectives are established (including the form of measurement) and the methods to achieve the established objectives are defined. [5]

Based on the monthly production record shown in Figure 2, it is defined that our production is adjusted to the requirement of 42,500 pieces of the four models per month. In Figure 3 with the mentioned production, the capacity of the line was at maximum (106%), from this observation arises this project and the analysis to increase the production capacity so that others can be entered. projects to the line simultaneously.

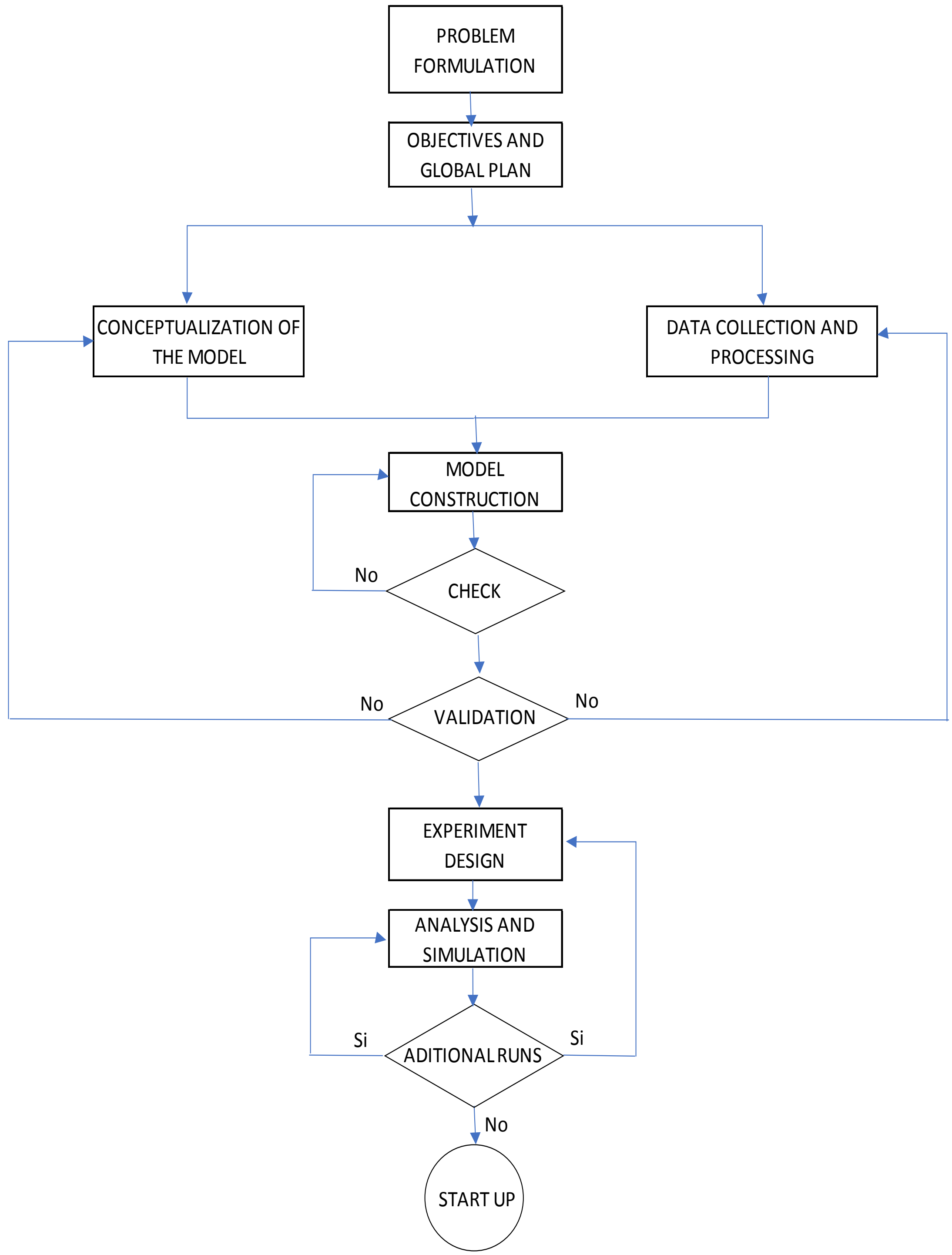
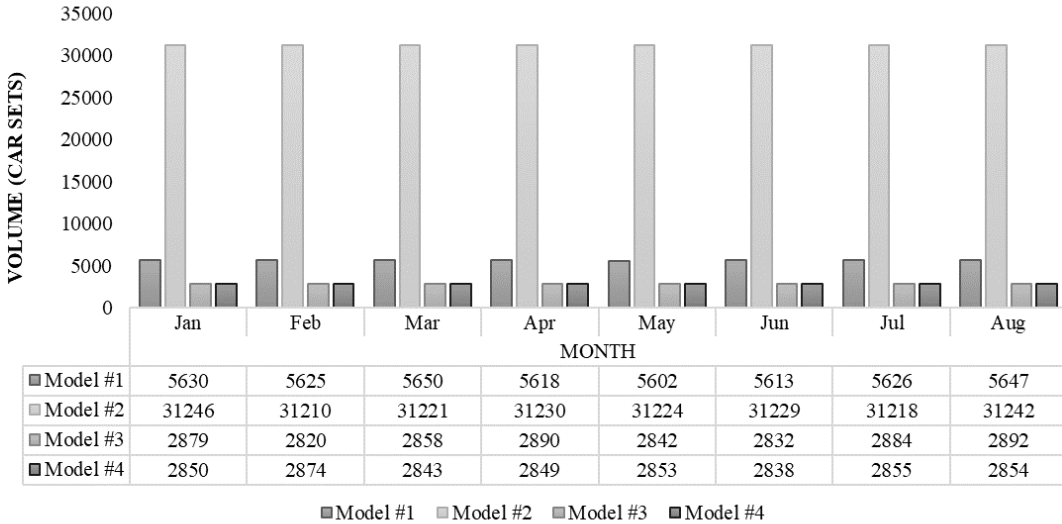


Figure 1. Stages of a simulation ordered according to the sequence applied in this project.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Model #1	5630	5625	5650	5618	5602	5613	5626	5647
Model #2	31246	31210	31221	31230	31224	31229	31218	31242
Model #3	2879	2820	2858	2890	2842	2832	2884	2892
Model #4	2850	2874	2843	2849	2853	2838	2855	2854

Figure 2. General monthly production (four models) of the painting plant.

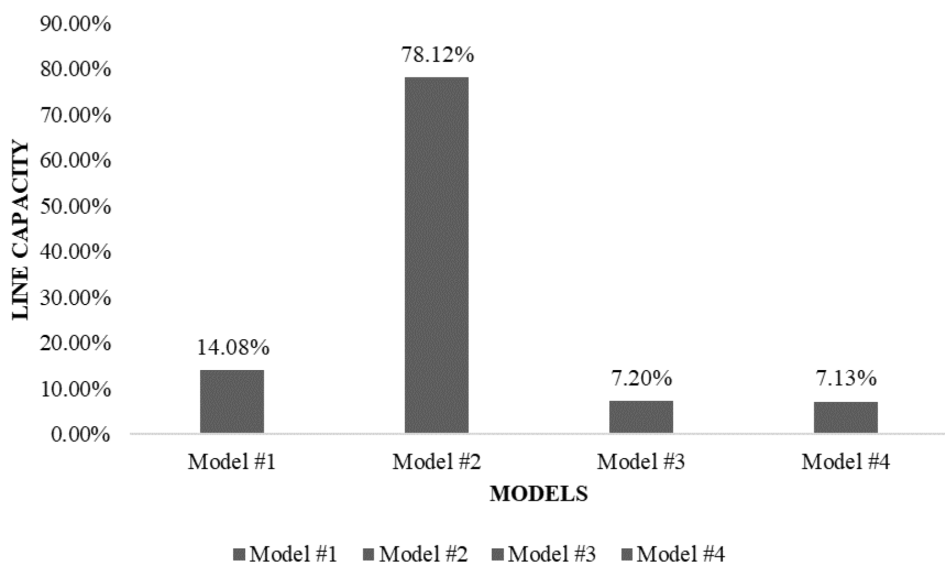


Figure 3. Monthly production capacity per paint line model compared to 10,000 car sets.

The next step was to analyze the method to increase the efficiency of the production process so that there would be available on the line for simultaneous projects. Therefore, a "5why" (five whys) type scheme was made. The five whys strategy consists of examining any problem and asking the question: "Why?" The answer to the first "why" will generate another "why", the answer to the second "why" will ask you another one, and so on, hence the name of the five why strategy. [6]. Based on the five questions posed in Table 2, an analysis was carried out by a multidisciplinary team, which determined that making improvements to the production fixtures so that they had more cavities to insert pieces could increase the number of parts with the same cycle.

Table 2. Phase 1. Identification of the root cause, using the five-cause methodology elaborated with the multidisciplinary team of the plant.

<table>
<tr><td rowspan="7">Phase 1: Plan</td><td>Problem
describe and quantify</td><td colspan="2">Identify Root Cause of Problem
using the 5 whys</td><td colspan="2">Countermeasures</td></tr>
<tr><td rowspan="4">Was the standard being followed? Yes □ No □

We have a 100% to capacity in the painting line.

We do not have paint other projects</td><td>Why?</td><td>Produce 10000 car-sets for one project and have space for other projects</td><td colspan="2">Option One
Change fixture design</td></tr>
<tr><td>Why?</td><td>Do not have space for other projects</td><td><u>Pros / Benefits:</u>
Increase de production</td><td><u>Cons / Challenges:</u>
Less space to paint</td></tr>
<tr><td>Why?</td><td>Have four models</td><td colspan="2">Option Two
Increase the conveyor speed</td></tr>
<tr><td>Why?</td><td>Have fixture per part</td><td><u>Pros / Benefits:</u>
Increase de production</td><td><u>Cons / Challenges:</u>
No good quality</td></tr>
<tr><td>Goal
specific, measurable, achievable, results-focused, time-bound</td><td>Why?</td><td>Do not have multifunctional fixture</td><td colspan="2">Option Three
Increase the conveyor speed</td></tr>
<tr><td>Reduce 30% of capacity
Increase de production</td><td colspan="2">Root Cause
Do not have multifunctional fixture</td><td><u>Pros / Benefits:</u>
Increase de production</td><td><u>Cons / Challenges:</u>
Bad quality in parts</td></tr>
</table>

Based on the determination of the root cause, we proceeded to consider and determine the measures that would make it possible to remedy the problem identified. Continuing with the use of the PDCA, we proceeded to the next phase called “Do”, which tells us about executing the chosen action and eliminating the causes of the problem [7], for which the following questions are posed and answered: 1) Why is it necessary to modify the fixtures?, 2) What is the objective of the modification?, 3) In which part of the plant will the modification be applied?, 4) What are the times and costs required for carry out the modification?, and 5) What are the methods to carrying out the modification of the pieces?

2.2. Phase 2: Do

It is in this phase where the strategies considered because of the questions posed are applied and that are aimed at implementing changes in the fixture devices. For small and medium-sized companies the application of this pilot test is not necessary [8]. For the application of the strategies envisaged in this phase, an order of implementation shown in Table 3 was followed.

Table 3. Phase 2. The order of actions to be implemented considered by a multidisciplinary group and with a focus on improving fixtures is systematically presented.

Phase 2: Do	**Containment *immediate action***	**Implementation Tasks for Long-Term Countermeasure**			**Criteria to Determine Effectiveness *cost, time spent, manpower, etc.***
		Task	**Assigned To**	**Deadline**	
	Do new fixture	Do design	F. Puerta	3-Sep-21	Daily capacity & daily production
		Review design	Multi-team	4-Sep-21	
		Modifications & review	F. Puerta	15-Sep-21	
		Simulate & fabricate	F. Puerta	19-Sep-21	
		Start up	F. Puerta	1-Oct-21	

For the implementation of improvements in the original fixture models (Figure 4, Figure 5 y Figure 6), the characteristics already existing in the device were considered, mainly those of: a) material: the original material is carbon steel so which is considered to be a suitable material that can be replaced by stainless steel in the new models to generate less static and a longer duration of the fixture. b) The design of each of the models, each of the models was analyzed in all its dimensions, for which each of the critical measurements was taken as a reference in each of the fixtures. As for figures 4a, 5a, and 6a you can see the front view, figures 4b, 5b, and 6b the back view, figures 4c, 5c, and 6c the side view, and the rest of the figures the part of the plastic insert that is where you feel the fixture.

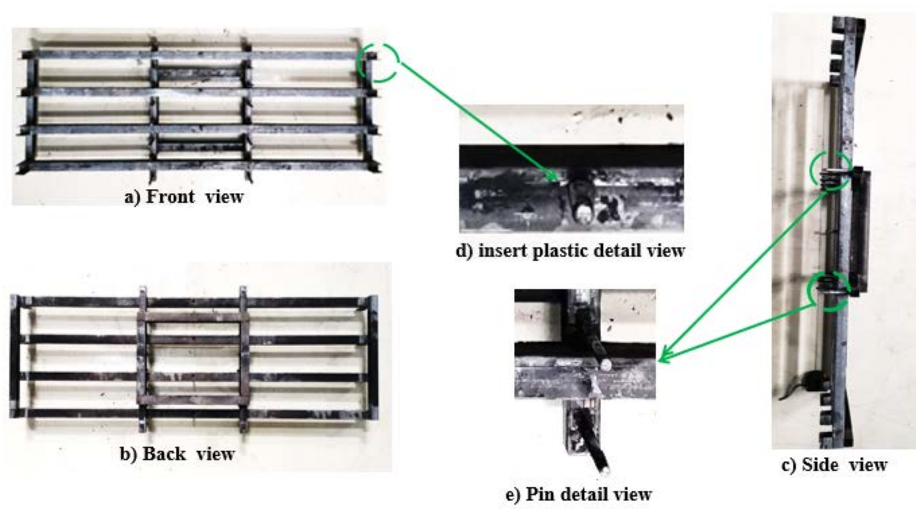


Figure 4. Original model # 1 is detailed in each of its views. a) front view of the fixture, b) back view of the fixture, c) side view of the fixture, d) and e) detail views of the fixture showing the parts where the plastic tube is inserted.

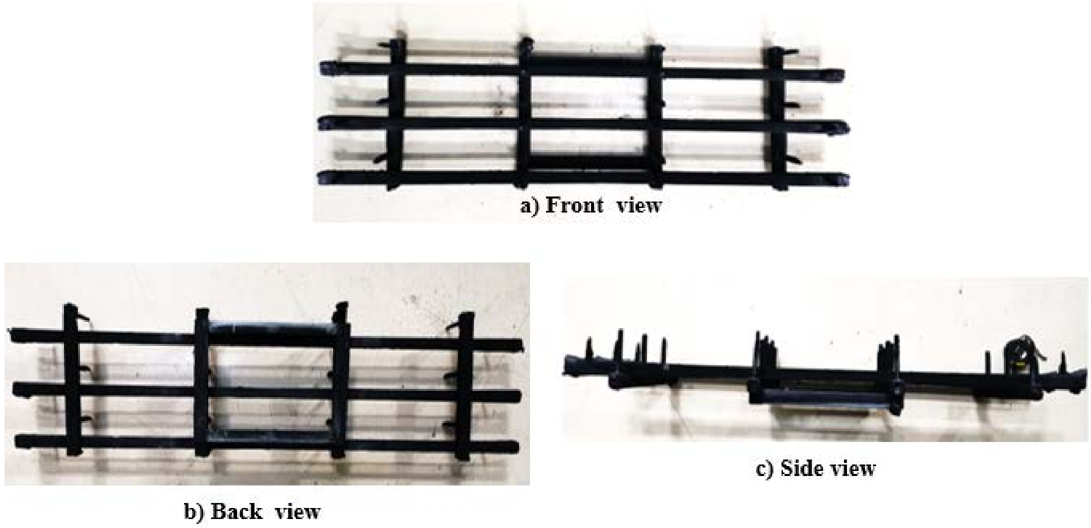


Figure 5. Original model # 2 is detailed in each of its views. a) front view of the fixture, b) back view of the fixture, c) side view of the fixture.

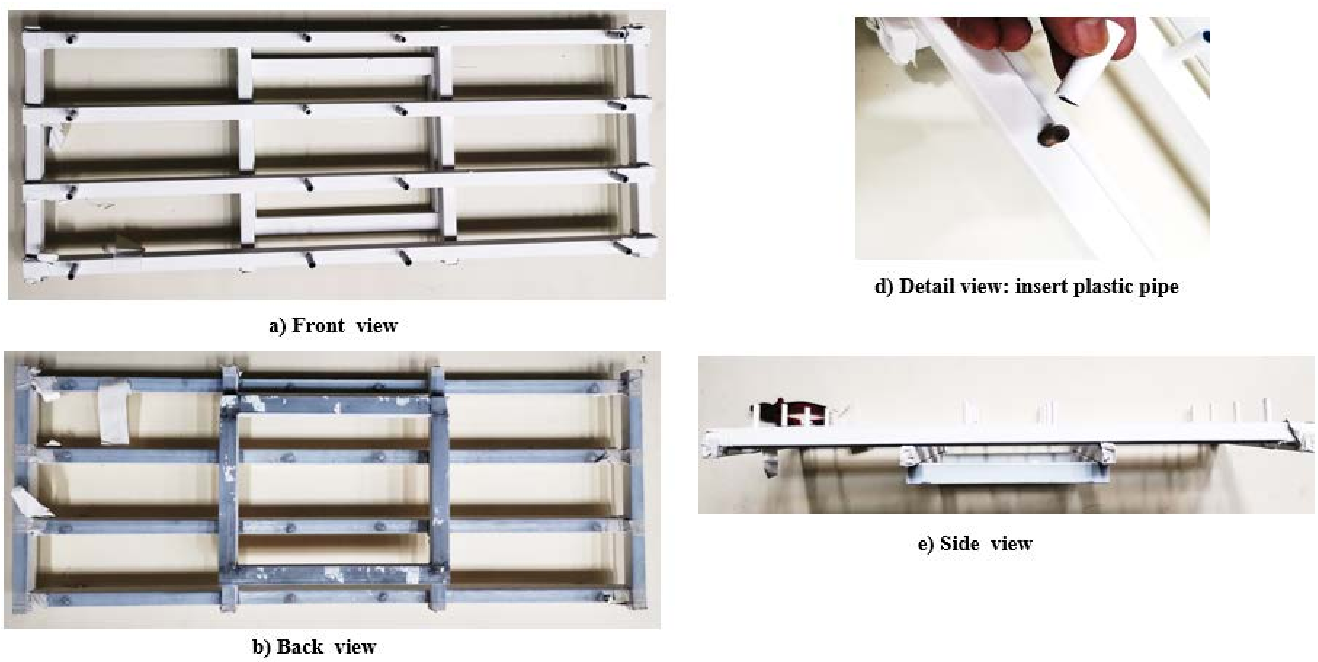


Figure 6. Originals model # 3 and # 4 are detailed in each of its views. a) front view of the fixture, b) back view of the fixture, c) side view of the fixture, d) detail views of the fixture showing the parts where the plastic tube is inserted.

When analyzing each of the four existing models, the following improvement opportunities were found: a) unnecessary plastic insert, b) the distances between model and model are very wide, c) the seating pins have a lot of material, and d) they are not used when maximum each of the spaces in the entire quadrant available.

After having the opportunities for improvement, a design called prototype no.1 was made using SolidWorks software, this design contained the four models in a single fixture. See Figure 7.

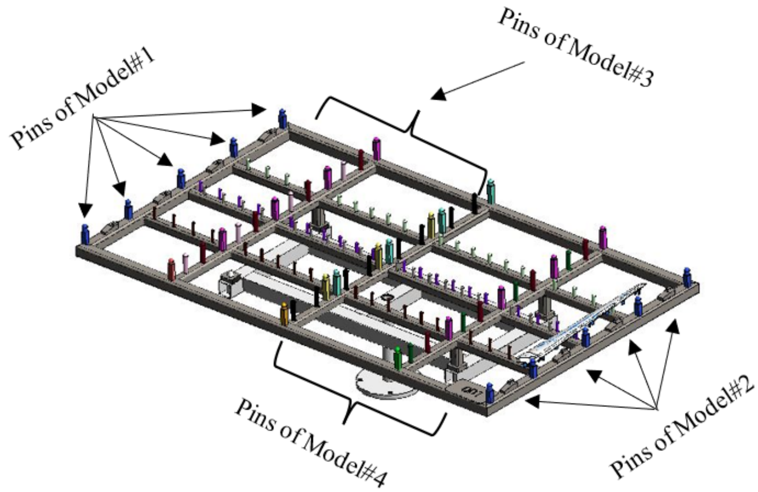


Figure 7. First multifunctional design (4 models in the same fixture) made in SolidWorks software.

Once the new fixture design was finalized, a review of it was carried out (Figure 7) in conjunction with the multidisciplinary team. Once the team agreed with the changes, they proceeded to their manufacture, resulting in the prototype presented in Figure 8 with more closed spaces in each of the models, adding error prevention devices to avoid misplacing, this device already had a greater number of pieces in each of the models due to its sophisticated design.

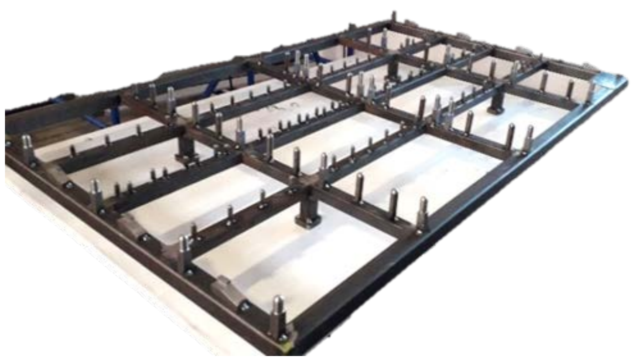


Figure 8. First multifunctional physical design. Space for 5 pieces model # 1, 4 pieces model # 2, 10 pieces model # 3- and 10 pieces model # 4.

In the first design presented, it was found that its weight was greater than it should have, in addition to its dimensions not being initially considered concerning the size of the furnace inlet and the range of the vision camera (used within the line), so the design was readjusted with the new specifications, considering a dimension of 1500mm long x 550mm wide x 600mm high.

In addition to the new specifications, the second design considered the following aspects:

- The part-to-part separation distance for models # 3 and # 4 was 200mm.
- Model # 2 can be angled to be able to add more than 2 pieces in the same fixture
- Model # 1 must be 500mm apart.
- It is required to make a hole to identify each fixture by putting a sequential number and in it a symbol which will indicate what type of model each fixture has.

After the review and feedback process, as well as an extensive evaluation of each of the restrictions, it was decided to make three different fixture models called Model No. 1, Model No. 2, and Model No. 3. Figure 9 shows model # 1 merging characteristics of model # 3, acquiring the ability to put four pieces of model # 1 and 14 pieces of model # 3. Figure 10 shows model # 2 with the capacity to hold four pieces and finally, in Figure 11 it is possible to see model # 4 with a capacity of 14 pieces.

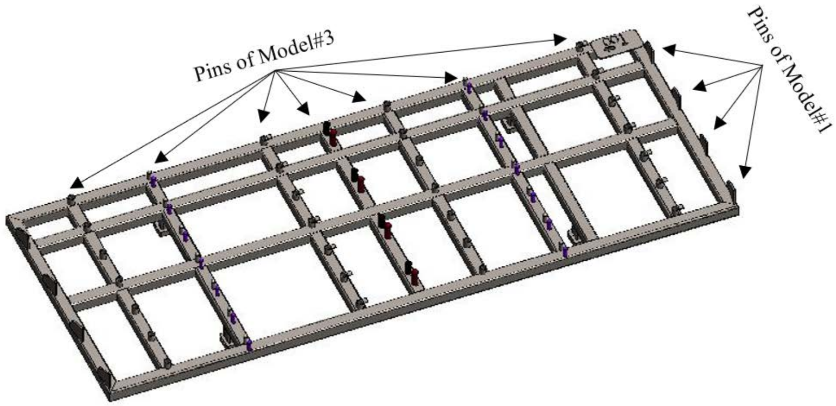


Figure 9. The second design of model # 1 (4 pieces) and # 3 (14 pieces).

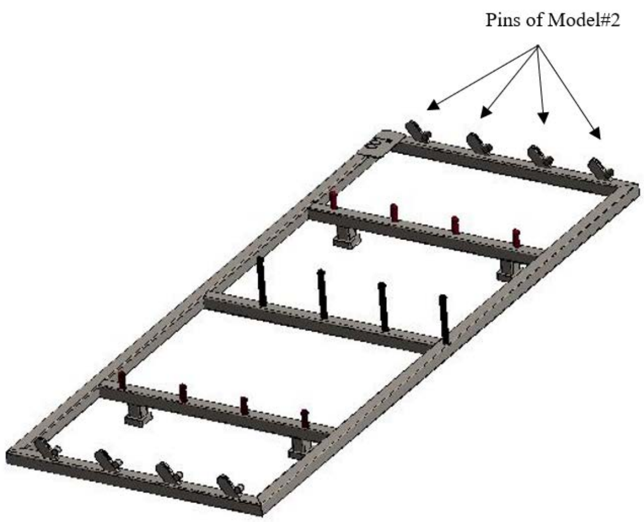


Figure 10. The second design of model # 2 (4 pieces).

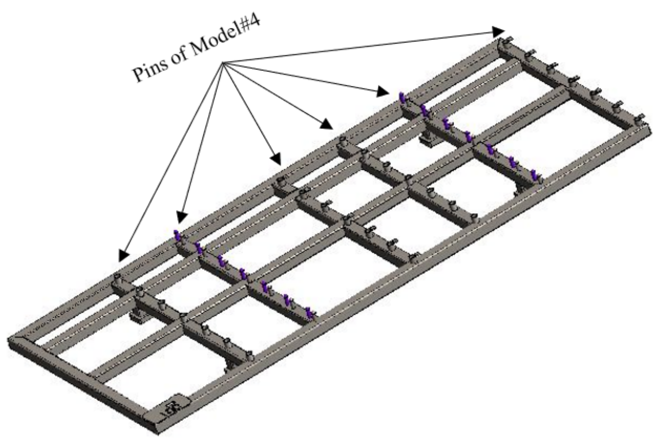


Figure 11. The second design of model # 4 (14 pieces).

Once the proposal was finished, it was shown to the multidisciplinary team, who, upon giving their authorization, could proceed to the physical manufacture of the prototypes. In Figure 12 you can see each of the three fixtures physically already finished and ready for testing with some assembled parts (Figure 12a, Model No. 2; Figure 12b, Model No. 4; Figure 12c, Model No. 4; & Figure 12d, Model No. 1).

Figure 12. The second physical design shows the four models in three types of fixtures.

Once the prototypes were manufactured, the number of fixtures required for each model was calculated to achieve the production target of 10,000 car sets per week, the result obtained from this calculation is presented in Table 4.

Table 4. Total fixtures needed.

Fixtures	No. fixtures proposal
Model #1 y #3	140
Model #2	252
Model #4	40
Total	**432**

2.3. Phase 3: Check

This phase allows to corroborate the effectiveness of the improvements implemented to the fixtures to determine if the prototype has reached the objective, for such evaluation control tools are used such as: Pareto diagram, which is a graph that allows assigning an order of priorities for decision-making of an organization and determines which are the most serious problems that must be solved first [9]; Checklists, are formats created to carry out repetitive activities, control compliance with a list of requirements or collect data in an orderly and systematic way [10]; o KPI's, acronym in English, for Key Performance Indicator, refers to a series of metrics that are used to synthesize information on the effectiveness and productivity of actions that are carried out in a business to be able to make decisions and determine those that have been most effective in meeting the objectives set in a specific process or project. [11]. It is important to have control of critical causes such as the quality of the product or the operation of machines and equipment. [12]. The results of this phase are presented in Table 5.

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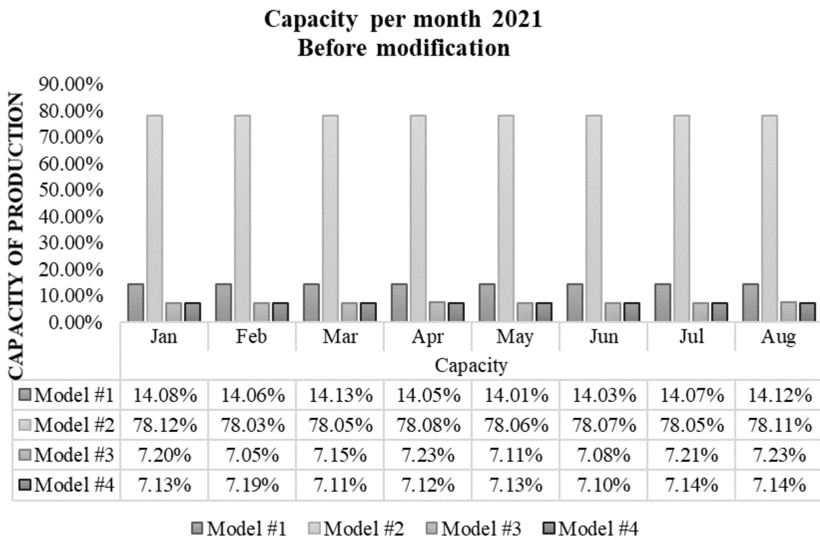
Table 5. Phase 3. Modification results.

	Test Results	**Did your plan succeed or fail? *show back-up data***	**Areas for Improvement**
Phase 3: Check	Daily capacity 60% Line availability 40%	Succeed	Constant fixture Maintenance

The results obtained when comparing the original fixture models against the improved models exceeded expectations, as 40% availability of the line could be achieved for simultaneous projects even with the previous capacity covered. The comparison of the original capacity with the capacity achieved after the implementation of improvements is presented in Figure 13 the before and Figure 14 the after.



Capacity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Model #1	14.08%	14.06%	14.13%	14.05%	14.01%	14.03%	14.07%	14.12%
Model #2	78.12%	78.03%	78.05%	78.08%	78.06%	78.07%	78.05%	78.11%
Model #3	7.20%	7.05%	7.15%	7.23%	7.11%	7.08%	7.21%	7.23%
Model #4	7.13%	7.19%	7.11%	7.12%	7.13%	7.10%	7.14%	7.14%

Figure 13. Production capacity before modification is separated by models. Registration from January to August.

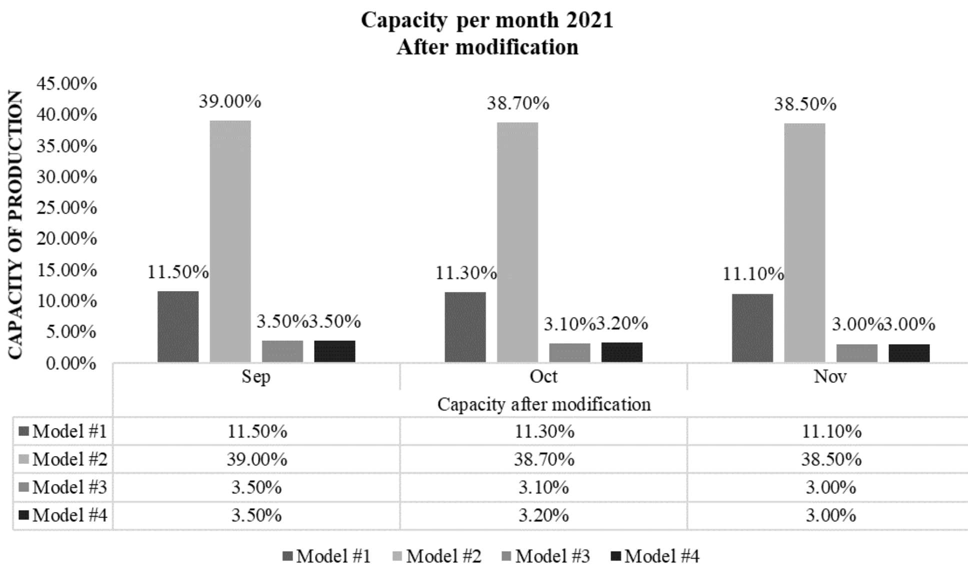


Figure 14. Production capacity after separate modification by model from September to November.

As part of this phase, the Work Instruction in the parts loading and unloading area was modified, since an additional operator was required to place the unpainted parts in a fixture outside the line, so that now after downloading it was possible to immediately change from a painted fixture to an unpainted fixture already prepared with the pieces to be painted.

3. Analysis of results

According to the results obtained, it was observed that the project provided the expected efficiency to the painting process and that the use of tools such as the five reasons and methodologies such as PDCA for solving problems, provide logical analysis and ease of follow-up to each project stage. With this project, results were obtained that increased the capacity of the painting line by up to 40% of its production, which provided the opportunity to incorporate simultaneous projects in the painting line, without affecting the quality of the product, the production goals, and customer delivery commitments.

4. Conclusions

The hypothesis proposed in the first stage of the PDCA was satisfactorily fulfilled since with the changes implemented, the painting line will have free space for new projects of up to 40% of its capacity.

It was also shown that the use of the Deming cycle or better known as PDCA continues to be an effective tool for the development of continuous improvement.

Bibliography

[1] C. Manufactura, "CYSE MANUFACTURA," 2021. [Online]. Available: https://cysemanufactura.com/servicios/fixture/.

[2] Economipedia, 2021. [Online]. Available: https://economipedia.com/definiciones/ciclo-de-deming.html.

[3] R. G. M. F. S. R. Isaías Simón Marmolejo[a], "Etapas de un modelos de simulación y la modelación con FlexSim," 2021. [Online]. Available: https://repository.uaeh.edu.mx/revistas/index.php/sahagun/article/view/1358/4640.

[4] A. S. f. Quality, "asq," 2021. [Online]. Available: https://asq.org/quality-resources/pdca-cycle.

[5] I. d. Calidad, "Ingeniería de Calidad," 2011-2018. [Online]. Available: https://www.ingenieriadecalidad.com/2020/02/ciclo-de-deming.html.

[6] P. LEAN, "PROGRESSA LEAN," 2021. [Online]. Available: https://www.progressalean.com/5-porques-analisis-de-la-causa-raiz-de-los-problemas/.

[7] Mecalux, "Mecalux," 2021. [Online]. Available: https://www.mecalux.com.mx/blog/ciclo-deming-pdca.

[8] innovayaccion, "innovayaccion," 2021. [Online]. Available: https://innovayaccion.com/blog/metodo-deming.

[9] R. Content, "Rock Content," 2021. [Online]. Available: https://rockcontent.com/es/blog/diagrama-de-pareto/.

[10] c. y. m. c. PDCA Home - El portal de la gestión, "PDCA Home," 2021. [Online]. Available: https://www.pdcahome.com/check-list/.

[11] M. P. Blanco, "logicalis," 29 09 2017. [Online]. Available: https://blog.es.logicalis.com/analytics/kpis-qu%C3%A9-son-para-qu%C3%A9-sirven-y-por-qu%C3%A9-y-c%C3%B3mo-utilizarlos.

[12] E. E. Ingenieros, "envira," 2021. [Online]. Available: https://envira.es/es/el-ciclo-deming-que-consiste-y-como-ayuda-gestion-procesos/.

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