Proposal for the Optimization of the Manufacturing Process of Integral Kitchens of the Casa Madeira Company Across to Lean Six Sigma Methodology.

Luis Fernando Pedraza Ruiz
Industrial Engineer and Master in Design and Management of Technological Projects
Popayán University Foundation
Popayán – Cauca – Colombia
luis.pedraza@docente.fup.edu.co

Laura Cristina Carvajal Benítez
Industrial Engineer
Popayán University Foundation
Popayán – Cauca – Colombia
lauracristinacarvajal@hotmail.es

Alexandra Bustamante Pizo
Industrial Engineer
Popayán University Foundation
Popayán – Cauca – Colombia
alexandra_037@hotmail.com

Daniel Sandoval Aristizabal
Industrial Engineer
Popayán University Foundation
Popayán – Cauca – Colombia
daniels9305@hotmail.com

Abstract

This article developed an optimization proposal for the manufacturing process of integral eight-meter linear kitchens in the CASA MADEIRA company, using the DMAIC method (Define, measure, analyze, implement and control). The work was carried out in order to solve the delay in the manufacturing process of integral kitchens of eight linear meters, since its operation was not adequate and presented deficiencies in its production stages.
During the diagnosis of the situation, it was possible to determine that the whole kitchen manufacturing process had an efficiency of 58% with respect to the installed capacity, given errors in the planning and programming of tasks.
As alternative solutions, the following was carried out instructions and standardization documents of the process, as well as training of personnel. Of this way it was possible to achieve 91% in the efficiency of the production process, offering a comprehensive solution to the problem presented, thus maximizing the effective production times and covering the demand for integral cooking, allowing maximum optimization of the process performance and generating greater Annual income for the company.

Keywords
DMAIC, Efficiency, Productivity, Six Sigma, Statistical control.

1. Introduction

Nowadays, the manufacturing industries are in search of optimizing and improving the process stages, thus satisfying the consumer's requirements with a higher profit margin for the manufacturer. CASA MADEIRA is a company dedicated to the manufacture of home furniture to order (kitchens, closets, bathroom furniture, doors, desks, bookcases) with the specifications given by the customer; the company was founded in 2001 and has as its main pillar the commitment to quality and customer satisfaction. The problems encountered in the company are based on its production line of 8 linear meters integral kitchens, where it is observed that they have a stipulated time for each activity that makes up the manufacture but do not meet the required time, since there is no planning or scheduling of tasks, to minimize delays that affect or delay production, in order to avoid non-compliance with customers, which has an impact on penalties and even loss of good business relationships.
It is essential for the company to develop controlled processes that allow it to comply with the quality, cost and safety standards established by the plant for the production of its products. The purpose of this study is to develop a proposal for the optimization of the manufacturing process of 8 linear meters integral kitchens, which represents the 70% of the demand of integral kitchens since april to august of 2018, to identify the flaws in the process and the possible solutions that can be used to address them and thus contribute to increasing the company's productivity.
In search of reducing process variation in order to improve processes, "Six Sigma was born in the mid-1980s. This tool has a statistical basis and is intended to achieve levels of the organization's processes and products close to zero defects, it is a systematic methodology to reduce errors, focusing on process improvement, teamwork and management support. The stages of the DMAIC tool are Define, Measure, Analyze, Implement, Control, with emphasis on the measurement and analysis process. DMAIC projects (CALECTEC, n.d.) must have a limited duration in time and arise under the leadership of the management, who identifies the areas to be improved, defines the construction of the equipment and guarantees the focus on the customer and its needs and economic savings. CASA MADEIRA is in need of a study to be able to use all the means of production in a more effective way having quality production and process improvement.

2. Methodology

The work begins with the proposal for the optimization of the manufacturing process of eight linear meters integral kitchens. Specifically, the steps to be followed for the development of the proposal for the optimization of the manufacturing process of 8 linear meter integral kitchens using the DMAIC tool of the six sigma methodology (Conexionesan, 2016).

By means of the methodology, the proposal of optimization in the manufacturing process of integral kitchens of 8 linear meters was made, the steps to follow for the development of the work by means of the Six Sigma methodology.

The following steps are used to achieve the first specific objective:

Define: The problems that afflict the manufacturing process of 8 linear meter integral kitchens were defined by means of interviews with the production manager and operators, mainly through visits to the plant, data collection and observation of the operation of the line using the Project Charter Format as a tool. (Garcia, 2014)

Measure: A detailed study was carried out in each of the stages of the manufacturing process of integral kitchens of 8 linear meters, recording the variables that were considered of interest for the ideal achievement of the project. In the data collection, the stages of manufacture of the integral kitchens are predominant, which are: material selection, cutting, edging, veneer, assembly and installation by means of the data collection format, Process Map.

The following step is used to achieve the second specific objective:

Analyze: For data analysis, statistical analysis, graph generation, calculation of metrics, efficiency indicator and application of engineering tools were used to estimate performance, capacity, efficiency, utilization, in order to quantify the criticality of the process, what is the focus of the problem and what could be the solution to recommend in the manufacturing process of integral kitchens.

The following step is used to achieve the third specific objective:
Improve: After establishing the causes, a list of improvements or strategies that attack the improvement opportunities found after the process analysis is generated, prioritizing the most critical causes that generate greater delays in the process, and identifying direct activities that allow a decrease in nonconforming product (Garcia, 2014).

3. Results and discussion

The development of this project was carried out based on the lean Six Sigma methodology, in the production line of integral kitchens, following the DMAIC phases during this structured procedure it was possible to determine the causes that originated the delays during the process of 8 linear meters integral kitchens, this was possible thanks to the use of statistical tools recommended in the Six Sigma methodology. The steps and activities carried out in the company are presented below. The Six Sigma methodology includes 5 phases that help to create a bank of information about the behavior of the processes, and it is much more useful when the objective to be achieved refers, as in this case, to improve a process that already exists in the company that can provide us with all this information.

These five phases are known as the DMAIC cycle (define, measure, analyze, improve and control), it is important to emphasize that for reasons of time and resources of the company CASA MADEIRA this proposal of optimization of the manufacturing process of 8 linear meters integral kitchens is carried out to the stage of improvement.

Each of the activities and the information obtained during the process will be specified below.
The following phases are used to achieve the first specific objective:

3.1 Phase 1: define.

The first part of the study was the identification of the problem, as well as the delimitation of the scope and time horizon of the proposed goals, the impact on the company, the customer and the projected savings. The work team and the people who would collaborate during the implementation of the Six Sigma methodology were also defined.

During the first phase, a detailed study was made of the process of manufacturing eight linear meter kitchens in order to identify the variables that affect the process, and a project chart was drawn up (Recursos enprojet management., s.f) n which each of the situations that justify the need for an intervention in the manufacture of integral kitchens is set out. See Table 1 Project chart.

Table 1 – Project chart.

<table>
<tr><td colspan="4">Project Name:
Proposal for the Optimization of the Manufacturing Process of Integral Kitchens of the Casa Madeira Company Across to Lean Six Sigma Methodology.</td></tr>
<tr><td colspan="3">Team members
Name | Role | Time commit
Luis Fernando Pedraza | Green Belt (without certification) | 4 hour per week
Laura Cristina Carvajal Benítez | Yellow Belt (without certification) | 20 hour per week
Alexandra Bustamante Pizo | Yellow Belt (without certification) | 20 hour per week
Daniel Sandoval Aristizabal | Yellow Belt (without certification) | 20 hour per week</td><td>Sponsor:
Casa Madeira
CTQs:
Low productive, High internal cost, Raw material waste
Financial drivers:
Casa Madeira</td></tr>
<tr><td colspan="2">Stakeholders:
• Administrative personal
• Production chief
• Maintenance chief
• Investors
• Customers
• Operators
• Suppliers</td><td>In scope:
Integral kitchen’s eight meters
Out of scope:
Other kind of integral kitchens</td><td>Internal customers:
Casa Madeira kitchen makers, sales personal.
External customers:
All customers interesting in integral kitchen of eight lineal meters</td></tr>
<tr><td colspan="4">Problem statement:
• Delays in delivery dates
• Material waste
• Manpower surcharges
• Low profitability in the final product</td></tr>
<tr><td colspan="4">Objective/goal:
Improve customer satisfaction levels by increasing productivity and reducing delivery times for 8-meter kitchens.</td></tr>
</table>

Identifying the problem.
The company CASA MADEIRA is located in the city of Popayán, Cauca, which manufactures mainly integral kitchens, closets, bathroom furniture, doors, desks, library, tables and bed set; it has 17 years in the market and 13 workers including 3 administrative and 10 operators.

From the month of April to August 2018 it was evidenced that the production of integral kitchens of 8 linear meters presents an efficiency of 58% which indicates that the production process is deficient, finally it is aimed to make a proposal with the objective of increasing the efficiency in the production line of integral kitchens, Taking into account the problems presented, it is observed that they have a stipulated time for each activity in order to fulfill the manufacturing objective, but they do not comply with the determined time, because the planning and programming of tasks is not done to minimize the delays that affect or delay the production.

Process map.

The process map is a tool for the graphic visualization of the process in question that helps us to understand the sequence of the process. For the elaboration of the process map it was necessary to elaborate the flow chart and the SIPOC (Ingenioempresa, 2017).

This will allow us to make the measuring stage more efficient, having defined and identified all the stages of the process, and in the same way allowing us to establish and identify the input and output variables of the process. The construction of this process map was carried out based on the observations made to the process and its different activities.

The following is a general flow diagram of the activities of the integral kitchen process (See figure 1).

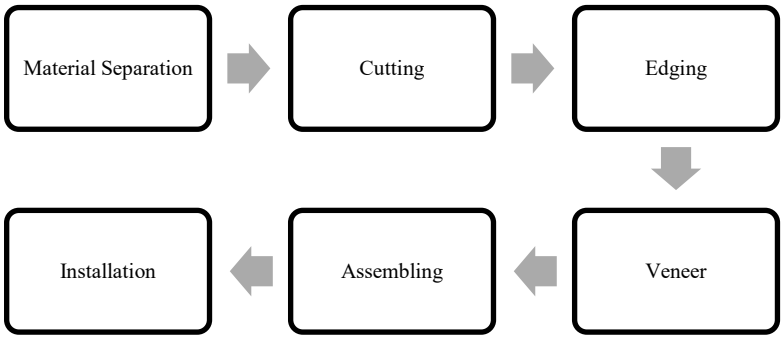


Figure 1. General flow diagram of integral kitchens.

After the construction of the process flow diagram it became necessary to use the SIPOC (Ingenioempresa, 2017), The graphic that comprises the scope of the process from start to finish, identifying the suppliers, inputs, process, outputs and customers of the process. Identifying in each of them the different variables involved in the process (Ingenioempresa, 2017).

Following, the general flow diagram was joined with the SIPOC of the process and the process map was generated by recognizing the variables in each of the stages of the process for the manufacture of 8 linear meter integral kitchens, identifying the inputs and outputs of the stages. (See figure 2)

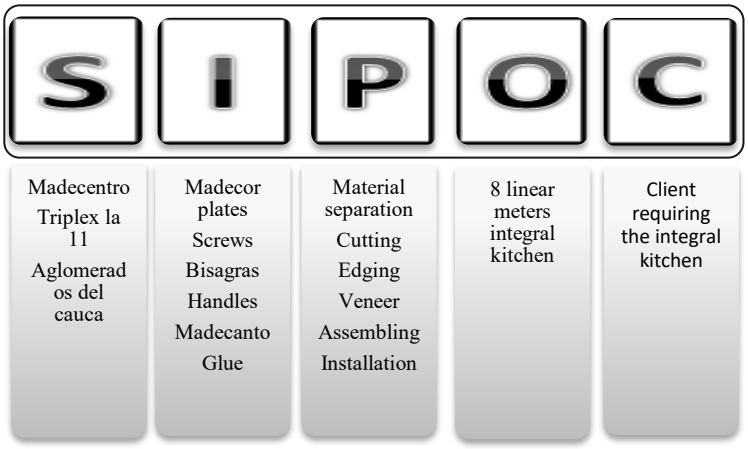


Figure 2. Map of the manufacturing process of 8 linear meters integral kitchens

3.2 Phase 2: Measurement

Data collection
The data collection and measurements were carried out, a collection strategy was designed through the data collection plan, in which the measurements to be carried out are defined. Here, very important aspects that need to be measured are mentioned, such as the times in each stage of the process, as shown in Table 2.

Table 2 – Data collection plan

Name:	Laura Carvajal - Alexandra Bustamante - Daniel Sandoval				**Date:**	September 21st, 2018		
Project:	Develop a proposal to standardize the manufacturing process of integral kitchens of the Casa Madeira company using the DMAIC method.							
Plan de recolección de datos								
Variables	**Type of Variable**	**Type of Datum**	**Operational Definition**	**Responsible of Collection**	**Collection Method**	**Measurement Frequency**	**Fuente datos**	**Metas**
Time	Process	Continuous	It measures the time of manufacturing of a kitchen.	Laura Carvajal Daniel Sandoval	Chronometer	Every hour	Process	2 days
Product by time	Departure	Discrete	Measure the number of finished products weekly.	Alexandra Bustamante	Counting	Weekly	Process	3 kitchens

Subsequently, the historical production data of the Casa MADEIRA company were reviewed, where it was evidenced that from April to August 2018, a total of 35 integral kitchens of 8 linear meters were made. Where variation is observed in each of the months obtaining a use of 58% of the installed capacity.

The efficiency of the integrated kitchen manufacturing process is shown below.

$$Eficiency = \frac{produced\ units}{planned\ units}\ x\ 100$$

$$Eficiency = \frac{7}{12} = 0{,}58$$
$$Eficiency = 0{,}58 * 100 = \ 58\%$$

The following shows the historical productivity data for the year 2018 of the Integral Kitchens manufacturing process, as presented in Table 3.

Table 3. Historical production data

Months	Weeks	Kitchens delivered	Delivered per month
April	Week 1	1	7
	Week 2	2	
	Week 3	1	
	Week 4	3	
May	Week 5	4	8
	Week 6	1	
	Week 7	2	
	Week 8	1	
June	Week 9	2	7
	Week 10	3	
	Week 11	1	
	Week 12	1	
July	Week 13	1	6
	Week 14	2	
	Week 15	1	
	Week 16	2	
August	Week 17	3	7
	Week 18	1	
	Week 19	1	
	Week 20	2	
	Total	**35**	

Measurement system

To measure the delay time in the manufacture of integral kitchens in each of its activities, a work measurement technique called time study was used, which is a technique used to record the times and rhythms of work corresponding to the elements of a defined task, carried out under given conditions, and to analyze the data in order to find out the time required to perform the task.

For the time study, it is not correct to capture the number of observations at random, the idea is to take a number that is actually representative for the study.

Everything consists of obtaining the size of the sample to be taken for each element, to determine this number, the NTC standard (Colombian Technical Standard) was used 2859-1 (28591, n.d.) which establishes a sampling system for attribute inspection based on quality level.

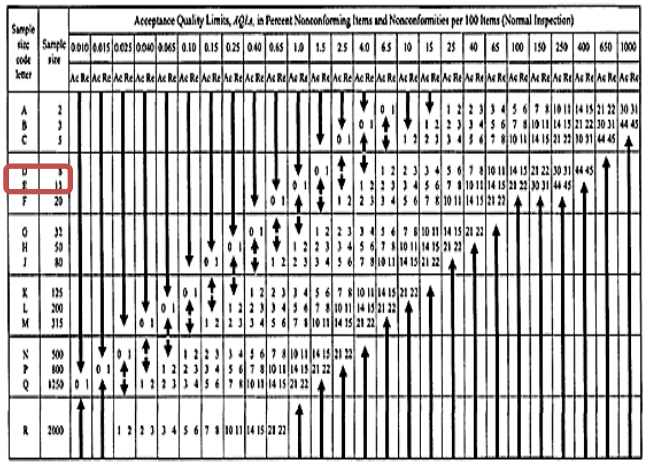
Where it was determined that the level of inspection is II, leaving levels I and III for cases of minor or major discrimination, respectively. It was determined according to NTC-ISO 2859 that for the sample of 35 integral kitchens of 8 linear meters that were carried out from April-August of this year with inspection level II, the result was obtained as letter D. See Table 4.

Table 4. Inspection level

Tamaño del lote	Niveles especiales de inspección				Niveles generales de inspección		
	S-1	S-2	S-3	S-4	I	II	III
2 a 8	A	A	A	A	A	A	B
9 a 15	A	A	A	A	A	B	C
16 a 25	A	A	B	B	B	C	D
26 a 50	A	B	B	C	C	D	E
51 a 90	B	B	C	C	C	E	F
91 a 150	B	B	C	D	D	F	G
151 a 280	B	C	D	E	E	G	H
281 a 500	B	C	D	E	F	H	J
501 a 1 200	C	C	E	F	G	J	K
1201 a 3 200	C	D	E	G	H	K	L
3 200 a 10 000	C	D	F	G	J	L	M
10 001 a 35 000	C	D	F	H	K	M	N
35 001 a 150 000	D	E	G	J	L	N	P
151 000 a 500 000	D	E	G	J	M	P	Q
500 001 y mas	D	E	H	K	N	Q	R

Then, after stablishing the letter D, the sample size was found, through the NTC-ISO 2859 it was stablished that the sample consist of 8 units of 8 linear meters integral kitchens, as it is shown in the red square in Table 5.

Table 5. – Sample size



Once the information has been analyzed and classified, a format was design in which the activities and the manufacturing hours for each sample were registered, in order to perform the relevant calculations, the sample size was determined, which corresponded to 8 kitchens. Because of the previous, 2 weekly samples were developed during the month of september with the support of the staff in charge, whoch consisted in measuring the time for each activity and the distance traveled (receiving raw material, separation of material, cutting, edging, veneer, assembling and installation), it can be seen that the process has a stipulated time for each activity, but the time required for manufacturing is not met.

A format was used to take the times of the production line of 8 linear meters integral kitchens and thus be able to know the current situation, as shown in Table 6 – Taking of times.

Table 6 – Taking of times

Inspection form											
Product	8 linear meters kitchen										
Dates	September 3rd-4th-5th-6th-7th-8th-10th-11th-12th-13th-14th-15th-17th-18th-19th-20th-21st-22nd-24th-25th-26th-27th-28th-29th										
Performed by	Research group										
Sample	**Time h/unit**										
Activities	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Average**	**Stipulated time**	**Delays**
Receiving raw material	0,20	0,18	0,24	0,18	0,18	0,20	0,24	0,2	0,20	0,10	0,10
Separation of material	2,00	1,06	1,18	1,30	1,06	1,12	1,06	1,06	1,23	1,00	0,23
Cutting	4,50	4,50	5,00	5,00	4,40	4,50	4,50	4,40	4,60	2,00	2,60
Edging	4,15	4,00	4,10	4,15	4,00	4,10	4,00	3,50	4,00	2,00	2,00
Veneer	6,40	5,50	6,00	6,10	6,00	6,30	6,20	5,50	6,00	4,00	2,00
Assembling	6,10	6,30	6,30	5,40	6,10	5,50	6,20	6,10	6,00	5,00	1,00
Installation	5,50	6,00	6,10	6,10	6,00	6,10	6,10	6,10	6,00	5,00	1,00
Total (h/unit)	**28,85**	**27,36**	**28,68**	**30,00**	**27,56**	**27,62**	**28,06**	**26,66**	**28,10**	**19,10**	

Once the tool was defined, the corresponding measurements were taken to validate the system and establish whether the data collected were sufficient for the analysis of the system.

After obtaining the data from the time study with the sample of 8 kitchens obtained during the month of September. The X bar control chart in Figure 3.

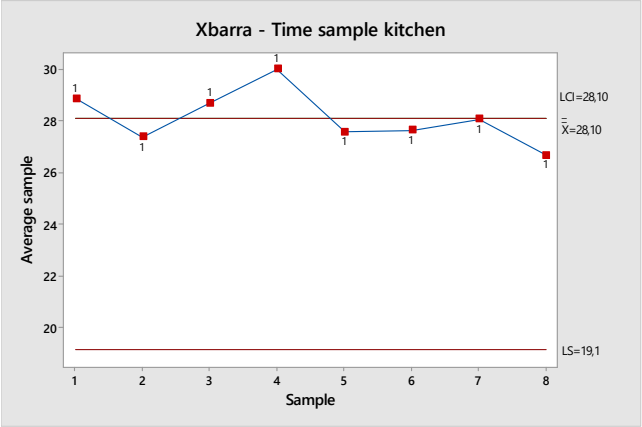


Figure 3. Control X bar chart of collected information
Program: Minitab

Figure 3 shows that all of the samples are above the upper control limit, a clear indicator that the process is out of control and the manufacturing times of 8 linear meter integral kitchens are outside the established standard, so it is possible to affirm that there are assignable causes in the process that should be investigated for correction.

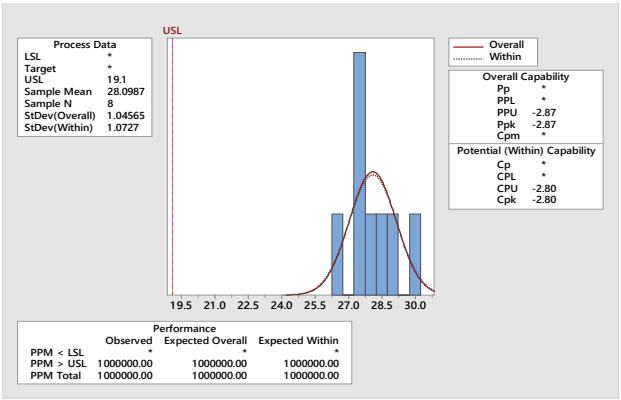


Figure 4. Process capability analysis
Program: Minitab

In Figure 4, it is observed that the sample average is 28.10 hours, the long term standard deviation is 1.04 and the short term deviation is 1.07, also the process has a short term capacity of CPK is -2.80 which indicates that the measurements are outside the specification limits and that the average of the manufacturing process of integral kitchens of 8 linear meters does not comply with the specifications, therefore the data is biased to the right side.

General Analysis of Current Distribution

The company has a type of plant by process: the machines and services are grouped according to the characteristics of each one, that is to say that if it organizes its production by process it must clearly differentiate the steps to which its raw material is subjected to obtain the finished product.

The plant has an area of 213 m² of which 140 m² correspond to the productive area, 73 m² are designated to the materials and tools warehouse.

The plant distribution of CASA MADEIRA has the following opportunities for improvement.
High personnel movement.

- Lack of order and cleanliness.

- Poor utilization of floor space.
- Excessive distances to be traveled in the workflow.

Below is the representation of the current plant layout in Figure 5.

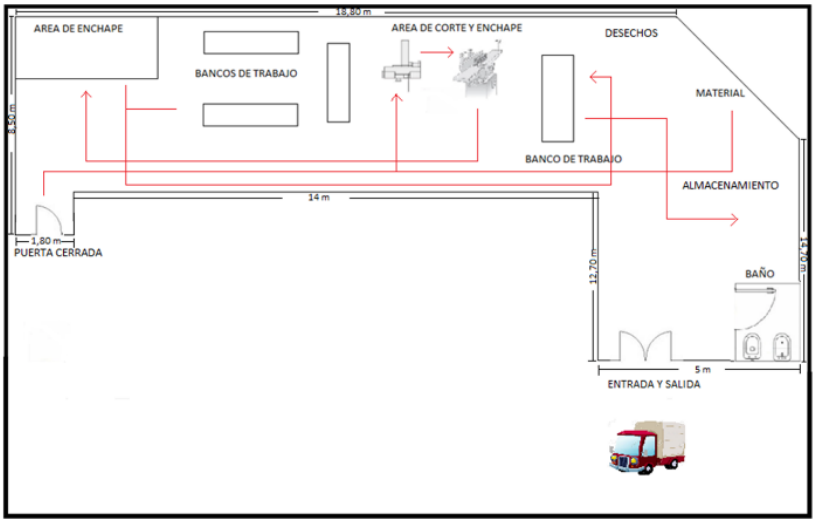


Figure 5 – Current plant distribution

For this reason, an analytical operations diagram of the process for the production of 8 linear meter integral kitchens was created.

The analytical diagram shows in detail the step-by-step process for the production of the current 8-meter linear kitchens, illustrating the five main activities (storage, transport, inspection, operation and waiting). In order to give a convenient and feasible redistribution factor. (CASA MADEIRA COMPANY, s.f.)

The main activities of an analytical diagram are represented in Table 7 as follows:

Table 7. – Símbolos diagrama analítico

Symbol	Name	Description
	Operation	Indicates the main phases of the process.
	Transport	Indicates the movement of materials from one place to another
	Inspection	Verifies the quality or quantity.
	Delays	Indicates delay between two operations or momentary abandonment.
	Storage	Indicates the deposit of an object under surveillance in a storage facility.

The current analytical diagram (Escudero) shows that for the elaboration of the integral kitchen of 8 linear meters, 19 activities are carried out, of which 6 are operation, 8 are transportation, 4 are inspection and 1 is storage with a total distance of 30 meters with a total time of 28.1 h/unit, as shown in Table 8.

Table 8 - Analytical diagram for the manufacture of integral kitchens

Analytical diagram for the manufacture of integral kitchens					
		Current			
		Amount	Time (Hours)		
●	Operations	6	27,16	**Objetive**	Analyze the production process
➡	Transport	8	0,95	**Activity**	Elaboration of 8 linear meter kitchens
■	Inspections	4		**Place**	Productive área
D	Delays	0			
▼	Storage	1			
Total		19	28,1		
Distance (m)		34			

Ítem	Activity description	●	➡	■	D	▼	Distance (m)	Amount	Time (h/unit)	Observations
1	Receive raw material (RM)							6 plates	0,20	
2	Transport RM to the warehouse						4		0,15	
3	RM Separation							6 plates	1,23	
4	Transportr RM to cutting zone						5	6 plates	0,20	
5	Cut material							6 plates	3,92	Cutting of plates according to blueprints
6	Transport RM to edging zone						6	6 plates	0,10	
7	Edging cutted RM							6 plates	4,00	
8	Edging inspection							6 plates		Verify that the material complies with the established parameters
9	Transport RM to veneer zone						5	6 plates	0,20	
10	Veneer RM							6 plates	6,00	
11	Veneer inspection							6 plates		Verify that the material complies with the established parameters
12	Transport RM to assembling zone						6	6 plates		
13	Assemble integral kitchen							6 plates	6,00	Kitchen assembly according to blueprint parameters
14	Assembling inspection							Furniture		
15	Trasport final product to warehouse						8	Furniture	0,10	
16	Storage final product							Furniture		
17	Finished product inspection							Furniture		Verify that the product complies with the established parameters
18	Transport finished product to the client							Furniture		
19	Install integral kitchen to the client							Furniture	6,00	
	Total						34		28,10	

Phase 3 is used to fulfill the second specific objective.

3.3 Phase 3: analyze

In this DMAIC stage (chapter 2. DMAIC methodology), the cause and effect diagram shown in Figure 6 is used to determine the current causes of the CASA MADEIRA company's plant, in which the following was evidenced:

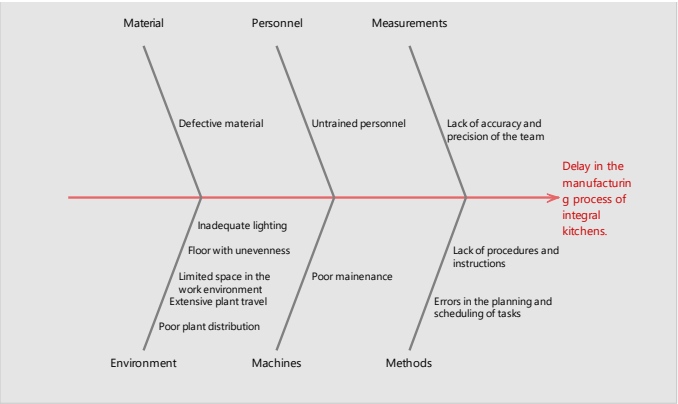


Figure 6 - Fishbone manufacturing process
Program: Minitab

- Lack of accuracy and precision of the team.
- Inadequate plant layout.

- Extensive plant travel.
- Limited space in the work environment.
- Floor with unevenness.
- Inadequate lighting.
- Errors in the planning and scheduling of tasks.
- Lack of procedures and instructions.
- Defective material.
- Untrained personnel.
- Poor maintenance.

Based on the information obtained in the measuring stage, the frequency with which each of the causes occurs in the manufacturing process of 8 linear meter integral kitchens was identified and the Pareto tool was applied for the analysis of the variables that most affect the efficiency of the plant and thus prioritize the few vital ones from the many trivial ones, as shown in Figure 7.

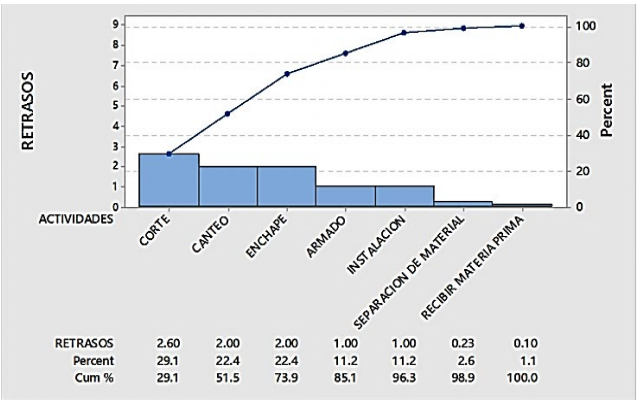


Figure 6. Pareto Diagram Activities
Program: Minitab

In Figure 7. Pareto diagram, it can be observed how three types of incidents comprise 73.9% of the backlog, given the limited resources, technical and financial, the project champion decided to give priority to the processes that accumulate up to 50%, thus the cutting and edging processes will be initially addressed.

Considering Figure 8, the cause and effect analysis tool will be used. In the cutting and edging areas to evaluate each variable involved in these stages. For this, the 6M's were taken into account. (Manpower, materials, machines, method, environment and measurement).

In the cause and effect diagram - Cut, which was developed was the stratification or enumeration of causes which identifies the main causes of the delay in the manufacturing process of integral kitchens of 8 linear meters are as follows:

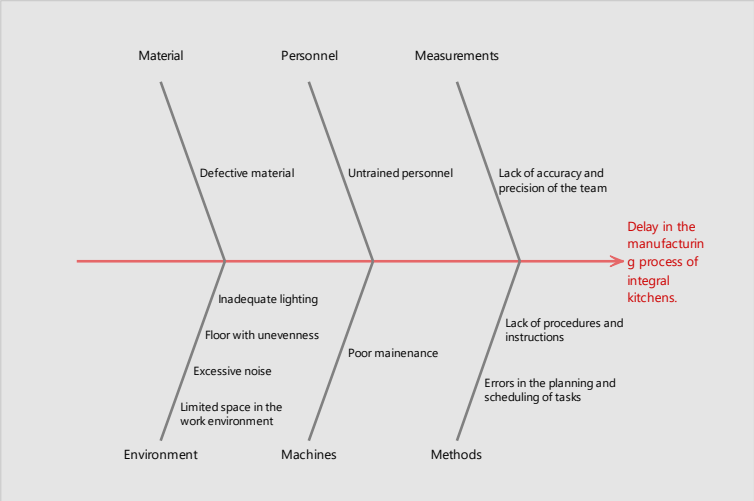


Figure 7 - Fishbone cutting process.
Program: Minitab

- Limited space in the work environment.
- Untrained personnel.
- Defective raw material.
- Inadequate lighting.
- Excessive noise.
- Errors in the planning and scheduling of tasks.
- Lack of procedures and instructions.
- Poor maintenance.
- Floor with unevenness.

Therefore, it is necessary to analyze this problem in greater depth to obtain the major problems that affect the cutting stage in order to make decisions in the manufacturing process of integral kitchens of 8 linear meters.

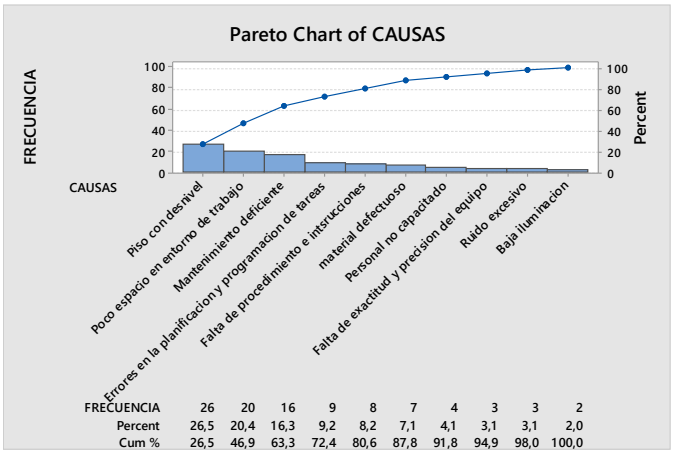


Figure 8. Second level Pareto Diagram in the cutting area.
Program: Minitab

Figure 9, second level Pareto diagram in the cutting area, shows that 63.3% is concentrated in the first 3 causes. That affect the process in the cutting area, so it is necessary to intervene in these causes by optimizing the manufacturing process of integral kitchens of 8 linear meters.

Therefore, it is necessary to further analyze this problem in order to obtain the major problems that affect the edging stage in order to make decisions in the manufacturing process of 8 linear meter integral kitchens.

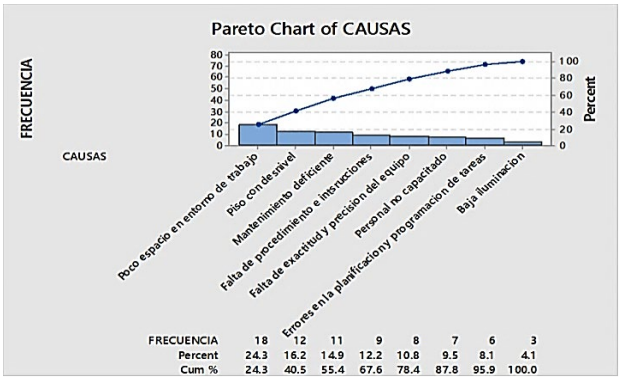


Figure 9. Second Level Pareto Diagram in the edging area
Program: Minitab

Figure 10, second level Pareto diagram, shows that in the edging area, the biggest problem is the lack of space in the work environment represented with 24.3%, followed by the uneven floor representing 16.2% and poor maintenance, obtaining an accumulated 55.4%, therefore these causes should be intervened by carrying out plant distribution in the company CASA MADEIRA.

The following is the prioritized causes of the cause-effect diagram of the defect that will be studied. See Figure 11.

- Limited space in the work environment
- Untrained personnel.
- Inadequate lighting.
- Excessive noise.
- Errors in the planning and scheduling of tasks.
- Lack of procedures and instructions.
- Poor mainenance.
- Floor with unevenness.

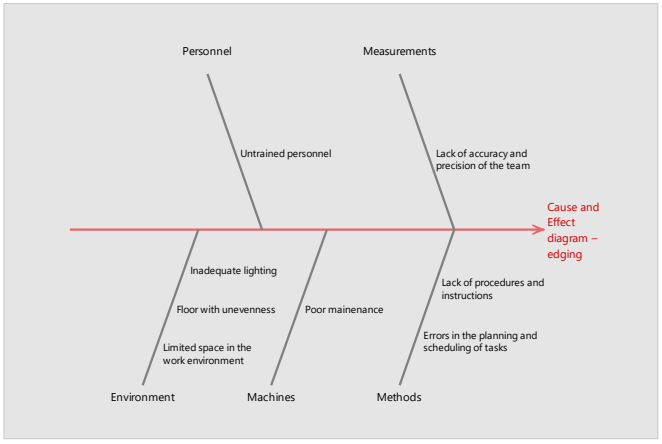


Figure 10 – Prioritized fishbone
Program: Minitab

Phase 4 is used to meet the third specific objective.

3.4 Phase 4: Improve

In this stage of improvement within the manufacturing process of integral kitchens of 8 linear meters, several opportunities for improvement are proposed to be implemented, which are directly related to the cutting and edging stage of the manufacturing process that allow improving the internal operation and description of tasks.

Comparison of the current plant layout vs. proposed plant distribution. See Figure 12 and Figure 13.

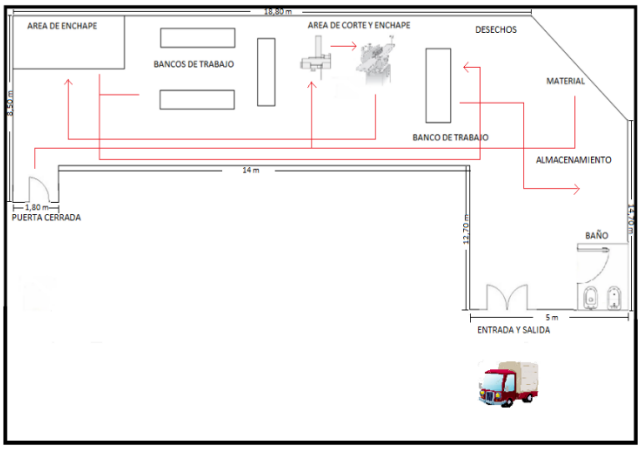


Figure 11 Current plant distribution

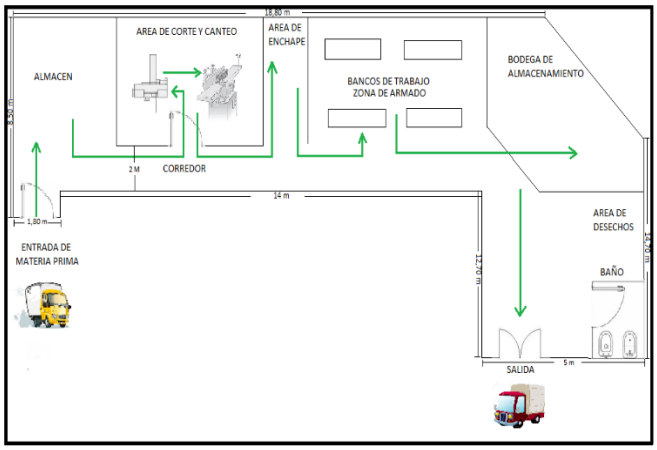


Figure 12 Proposed plant distribution

Proposed plan distribution

The plant distribution of the company CASA MADEIRA is proposed to be carried out as follows. (DELGADO)

With the proposed redistribution of the plant, manufacturing times will be reduced, working conditions will be improved, space will be used efficiently, useless or redundant movements will be eliminated, since the operator will reduce physical effort. It will also achieve a reduction in the duration of the manufacturing cycle of the integral kitchens of 8 linear meters and finally there will be an improvement in the working conditions.

The proposed plant distribution is illustrated in Figure 13, which arises from the need to achieve greater fluidity in the process, avoid unnecessary transportation and adjust manufacturing times to the required standard. The graphic representation shows how in a sequential and orderly manner it will be possible to have a schematic and global way of the production of 8 linear meter integral kitchens and this will result in the exploitation of the activities included in it. The analytical diagram shows in detail the step by step of the product along the manufacturing process of integral kitchens that are object of study, illustrating the five fundamental activities (storage, transport, inspection, operation and waiting), in order to give a convenient and feasible redistribution factor.

The proposed diagram illustrates the proposed route of operators and materials in the plant, focusing primarily on the production area.

Table 9 shows the total times of the transports that would be executed with the proposed model.

Table 9. Summary of total travel time for each of the areas of the manufacturing process of 8 linear meters of integral kitchens.

Summary of proposed new times							
		Current		Proposed		Difference	
		No.	Time h/unit	No.	Time h/unit	No.	Time h/unit
	Operations	6	27,16	5	19,00	1	8,16
	Transport	8	0,95	7	0,40	1	0,55
	Inspections	4		2		2	
	Delays	0		0		0	
	Storage	1		1		0	
Total		19	28,10	15	19,40	3	8,70
Distance (m)		34		20		14	

The times taken for the proposed distribution were determined by means of a pilot test at CASA MADEIRA's plant.

By subtracting the current times with the estimated ones, it is concluded that with this new distribution, we would obtain a decrease in the times of operations and transports. In the manufacturing process of the integral kitchen of 8 linear meters, we obtained a reduction of activities from 19 to 15, of which 5 are operations, 7 are transportation, 2 are inspection and 1 is storage, with a proposed route of 20 meters and a total time of 19.40 h/unit, obtaining an improvement of 8.70 h/unit. See Table 10.

Table 10 – Proposed analytical diagram

Analytical diagram for the manufacture of integral kitchens					
		Proposed			
		Amount	Time (Hours)		
●	Operations	5	19,00	**Objetive**	Analyze the production process
⇨	Transport	7	0,40	**Activity**	Elaboration of 8 linear meter kitchens
▭	Inspections	2		**Place**	Productive área
D	Delays	0			
▼	Storage	1			
Total		15	19,4		
Distance (m)		20			

Ítem	Activity description	●	⇨	▭	D	▼	Distance (m)	Amount	Time (h/unit)	Observations
1	Receive raw material (RM)							6 plates	0,10	
2	Transport RM to the warehouse						4		0,05	
3	RM Separation							6 plates	1,00	
4	Transportr RM to cutting zone						3	6 plates	0,05	Material adequation
5	Material cutting and edging							6 plates	4,00	Cutting of plates according to blueprints
6	Edging inspection							6 plates		Verify that the material complies with the established parameters
7	Transport RM to veneer zone						4	6 plates	0,1	
8	Veneer RM							6 plates	4,00	
9	Transport RM to assembling zone						4	6 plates	0,05	
10	Assemble integral kitchen							Furniture	5,00	
11	Finished product inspection							Furniture		Verify that the material complies with the established parameters
12	Trasport final product to warehouse						5	Furniture	0,05	
13	Storage final product							Furniture		
14	Transport finished product to the client							Furniture		
15	Install integral kitchen to the client							Furniture	5,00	
	Total						20		19,40	

- **Preventive Maintenance Plan:** It is proposed to establish a maintenance schedule by means of which a permanent review of the machines is carried out, to know the condition of the components and to establish the minimum specifications allowed to determine the functionality of the parts, with the objective of intervening in all the components periodically, taking into account the useful life of each one of them, the manufacturer's recommendations and the specific conditions of use given to the machine. The following is a format to record the frequency, the condition of the machine, the type of intervention required and compliance with the maintenance performed. (BENEDETTI, 2004). See Table 11.

Table 11. Preventive maintenance plan

Preventive maintenance plan					
Nomenclature **Frequency:** Annual (A) - Semi-Annual (S) - Quarterly (T) - Monthly (M) - Weekly (W) - Daily (D) **Type of work:** Electrical (Elec) - Mechanical (Mec) - Order and Cleanliness (O&C)					
Machine	Frequency	Type of work	Name of the collaborator	Estimated duration	Observations

Training of operating personnel: Training is an educational process (TORRES, 2011) of a strategic nature applied in an organized and systemic manner, through which personnel acquire or develop specific knowledge and skills related to the job, and modify their attitudes towards aspects of the organization, the work position or the working environment. As a component

of the human talent development process, training implies on the one hand, a defined succession of conditions and stages aimed at achieving the integration of the collaborator to its position in the organization, the increase and maintenance of its efficiency in the manufacturing process of integral kitchens, as well as its personal and labor progress in the company. The following is a format for recording training courses. See Table 12.

Table 12. - Training registration form

Name of the course	Start time	Date	Attendant	End time	Resources

Qualified suppliers: In the process of satisfying the needs of its customers, every organization has a key link formed by the set of suppliers, if they fail to supply products that meet the requirements (technical specifications, delivery times, quantities, etc.) will cause inconveniences that will be reflected in the final performance to the customer, so it is recommended to analyze the following:

- Relevant experience.
- Performance of suppliers in relation to competitors.
- Requirements for product quality, price, delivery and problem response.
- Potential capacity to provide the required products, under the required conditions.
- Financial evaluation to ensure the supplier's viability throughout the supply period.
- Response from the supplier to inquiries, requests for quotations and offers.
- Compliance with relevant legal and regulatory requirements.

To select which are the best suppliers that benefit the company CASA MADEIRA.

Installation of ceiling lights for increased plant lighting: Lighting is one of the most important factors to be taken into account in the workplace because poor lighting can affect the safety and health of the worker because, without being aware of it, low light intensity can cause visual fatigue and a decrease in work performance.

Adequacy of primary floors in the plant: The adequacy of work spaces is vital, so that workers have the necessary conditions and thus fulfill their tasks, to directly achieve productivity and the fulfillment of the objectives of the company.

Provide cup-type earplugs to operators: The use of hearing protection is essential in the workplace because it helps to avoid any injury to the ears. In addition, high-decibel noise can affect the heart rate, causing fatigue and poor work performance.

Planning and scheduling of daily tasks: Planning and scheduling the activities to be performed daily in the manufacturing process of integral kitchens have many benefits which are:

- Achieving objectives and goals.
- Increase revenues.
- Increased time control.
- Increased mental concentration.

In addition, the following improvements are proposed in the cutting stage, which is directly related to the nonconformity of the manufacturing process of 8 linear meter integral kitchens due to the limited space in the work environment. When analyzing the cutting stage, it was determined that by complying with the stipulated work time, the internal operation, description of tasks, location and requirements are known.

Cost analysis of the implementation of the project improvement proposal

A cost-benefit analysis of the proposed improvement plan is performed, based on the problems found in the company. The costs of the proposed plant layout for the company's facilities are detailed below. See Table 13.

Table 13. Summary of costs

Summary of costs	
Detail	**Cost**

Material	$ 17,601,000.00
Manpower	$ 5,760,000.00
Training	$ 150,000.00
Mantenance	$ 2,400,000.00
Total cost	**$ 25,911,000.00**

Taking into account the costs obtained previously, the project will be carried out in the following way, starting with the relocation of the work areas while the proposed activities are being carried out so that the plant does not stop while it is being completed, for this reason it is done in parts, three-meter sections will be taken for the electrical organization, ceiling, lighting and floor, the plant has 35 meters, the estimated time to perform weekly is 6 meters, this would take a period of time of 6 weeks for the complete adequacy of the plant.

There will be 6 trainings of three different topics which are PPE (personal protective equipment), self-care, handling of tools, each training topic will be given twice, the trainings will be directed to all staff in general in order to have knowledge of each of the topics, there will be a weekly training of 30 minutes, which the total time is 6 weeks.

In addition, preventive maintenance of machinery is necessary to maintain the equipment and facilities in adequate condition for the function for which they were created; in addition to improving production by seeking maximum availability and reliability of the equipment and facilities.

With respect to the maintenance of the machines, they will be assigned 2 days to evaluate the equipment, which are: the saw, edger, edge banding machine, padding machine and the router so that it will be done in 2 weeks, also the hand equipment such as the drill, the polisher and the tool in general will be assigned a week where a corresponding distribution will be made so that all the machinery is reviewed by the manufacturer in order to obtain a better performance at the time of using it.

Once employees are well trained and skilled, they are expected to take care of basic repairs, cleaning of the equipment in their charge, daily inspection and abnormal occurrences in the operation of the equipment.

The main maintenance will continue to be performed by specialists, who have the appropriate training and instruments.

In addition, the selection of suppliers will be carried out in three weeks, where the following items will be evaluated:

- Relevant experience.
- Performance of suppliers in relation to competitors.
- Requirements for product quality, price, delivery and problem response.
- Potential capacity to provide the required products, under the required conditions.
- Financial evaluation to ensure the supplier's viability throughout the supply period.
- Response from the supplier to inquiries, requests for quotations and offers.
- Compliance with relevant legal and regulatory requirements.

Where a weekly visit will be made to each supplier which are: Madecentro, Triplex la 11, Aglomerados del cauca obtaining a response in 3 weeks.

Operating personnel will be provided with cup-type earplugs every six months.

Planning and scheduling of tasks each week to obtain greater control of time and compliance with the manufacture of integral kitchens of 8 linear meters.

Short-, medium- and long-term activities and resources must be considered. Table 14 shows a proposed schedule that should be adjusted as soon as the project begins, according to current circumstances.

Table 14. Timeline of implementation activities

Timeline of implementation activities			
		Month 1	Month 2

Activities	Estimated time	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Relocate workplaces	6 weeks	x	x	x	x	x	x		
Construction of infrastructure				x	x	x	x	x	
Installation of electrical wiring					x	x	x	x	x
Personnel training	6 weeks		x	x	x	x	x	x	
Equipment maintenance	2 weeks							x	x

With the implementation of these actions an improvement of 33% is obtained, going from 2 kitchens per week to 3; having a total of 12 kitchens per month obtaining a higher production in less time increasing the sales of the company from $ 24,000,000 to $ 36,000,000 per month, noting a significant improvement from 58% to 91% in the production of integral kitchens of 8 linear meters.

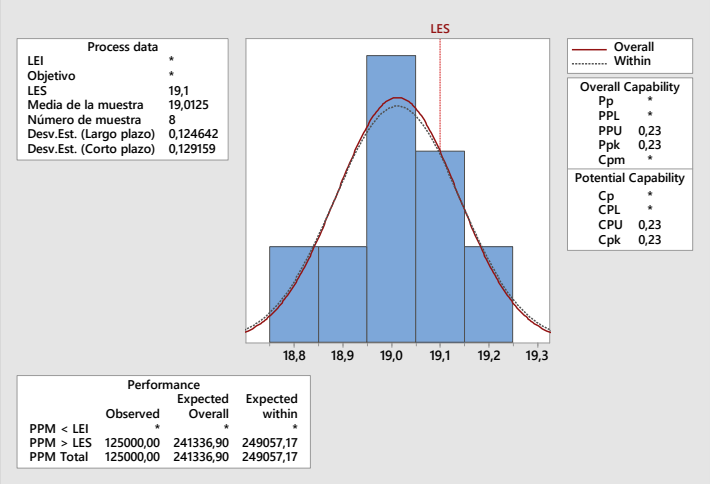


Figure 14 – Process capability analysis
Program: Minitab

4. Conclusions

- Through the study carried out at Casa Madeira in the production line of integral kitchens of 8 linear meters, it was determined that by means of the proposed plant distribution it was possible to increase productivity from 58% to 91%.
- The causes of the delay in the manufacturing process of integral kitchens of 8 linear meters were found in the cutting and edging stage because they do not have the procedures and instructions to operate the machine, likewise they do not have knowledge of the correct sequence for the manufacture of them.
- A plant layout proposal and analytical diagram is established, reducing the number of activities from 19 to 15, of which 5 are for operations, 7 for transportation, 2 for inspection and 1 for storage..
- A total time of 19.40 h/unit is achieved, resulting in a reduction of 8.70 h/unit and 14 meters in transports.
- It is possible to go from 2 kitchens per week to 3; having a total of 12 kitchens per month, obtaining higher production in less time, increasing the company's sales from $ 24,000,000 to $ 36,000,000, which increases the company's sales by 33% per month.

References

Calectec. Metodología DMAIC 6 SIGMA.4 de mayo de 2010. [Online] Disponible en internet: https://www.caletec.com/6sigma/metodologia-dmaic-6-sigma/

Yepes, V. y Pellicer, E. Aplicación de la metodología seis sigma en la mejora de resultados de los proyectos de construcción, s.f. Universidad Politécnica de Valencia. Departamento Ingeniería de la construcción y proyectos de ingeniería civil. [Online] Disponible en internet: personales.upv.es/vyepesp/05ypx01.pdf

Conexionexa. La metodología six sigma. 30 de junio de 2016. [Online] Disponible en internet: https://www.esan.edu.pe/apuntes-empresariales/2016/06/la-metodologia-six-sigma/

Pérez López, E y García Cerdas, M. Implementación de la metodología DMAIC-Seis Sigma en el envasado de licores en Fanal. Vol 27, Num, 3, 2014. [Online] Disponible en internet: http://revistas.tec.ac.cr/index.php/tec_marcha/article/view/2070

Recursos Enprojectmanagement. Plantilla de Project |Charter. Descripción de la plantilla de Project Charter, s,f. [Online] Disponible en internet: https://www.recursosenprojectmanagement.com/project-charter/

Ingenioempresa. Diagrama SIPOC: Qué es, para qué sirve y cómo se hace. A de agosto de 2017. [Online] Disponible en internet: https://ingenioempresa.com/diagrama-sipoc/

Libro de contabilidad del mes de agosto a septiembre del 2018. Datos históricos de la empresa CASA MADEIRA total de páginas 23

NORMA TÉCNICA NTC-ISO COLOMBIANA 2859-2. Procedimientos de muestreo para inspección por atributos. Parte 2: planes de muestreo determinados por la calidad límite (CL) para la inspección de un lote aislado.1994 [Online] Disponible en internet: https://tienda.icontec.org/wp-content/uploads/pdfs/NTC-ISO2859-2.pdf

Ingeniería Industrial Online.com [Online] Disponible en internet: https://www.ingenieriaindustrialonline.com/herramientas-para-el-ingeniero-industrial/estudio-de-tiempos/

Ingeniería Industrial Online.com [Online] Disponible en internet: www.ingenieriaindustrialonline.com/ herramientas-para-el-ingeniero-industrial/gestión-y-control-de-calidad/capacidad-de-proceso/

CASA MADEIRA. Historia. s,f.

Escudero, A. Diagrama de análisis de proceso, s.f. [Online] Disponible en internet: http://www.academia.edu/6886997/DIAGRAMA_DE_AN%C3%81LISIS_DE_PROCESO

Metodología DMAIC. Capítulo 2. [Online] Disponible en internet: tesis.uson.mx/digital/tesis/docs/20189/capitulo2.pdf

Ospina Delgado, J.P. Propuesta de distribución de planta, para aumentar la productividad en una empresa metalmecánica en ate Lima, Perú.2016. Universidad San Ignacio de Loyola. Facultad de Ingeniería. Carrera De Ingeniería Industrial y Comercial. [Online] Disponible en internet: repositorio.usil.edu.pe/.../1/2016_Ospina_ Propuesta_de_distribucion_de_planta.pdf

Benedetti Gómez, M. Plan de mantenimiento para los equipos de la empresa Maderas el Ceibal. Universidad tecnológica Cartagena de Indias. Facultad de ingeniería. Programa de ingeniería mecánica. Noviembre de 2004. [Online] Disponible en internet: biblioteca.unitecnologica.edu.co/notas/tesis/0031697.pdf

Gherardi Torres, V. Capacitación: personal operativo. 17 de marzo de 2011.Gerencia de Edificios. https://www.gerenciadeedificios.com/201103173065/articulos/administracion-hotelera/capacitacion-personal-operativo.html